The Role of Technology in Mitigating Global Climate Change

Frank Princiotta,
Director Air Pollution Prevention and Control Division

AWMA RTP Chapter

Dinner Presentation

December 4, 2007

Office of Research and Development
National Risk Management Research Laboratory

Presentation Objectives

- What is a credible warming scenario given current and projected emission trends? What factors and sectors drive emissions?
- What level of emission reductions will constrain warming to acceptable levels? What technologies will be needed to constrain emissions to acceptable levels?
- Are such technologies available and if not is R,D,D&D adequate?
- What strategies would encourage availability and utilization of low emission technologies?

Earth's Thin and Delicate Atmosphere

It sustains life:

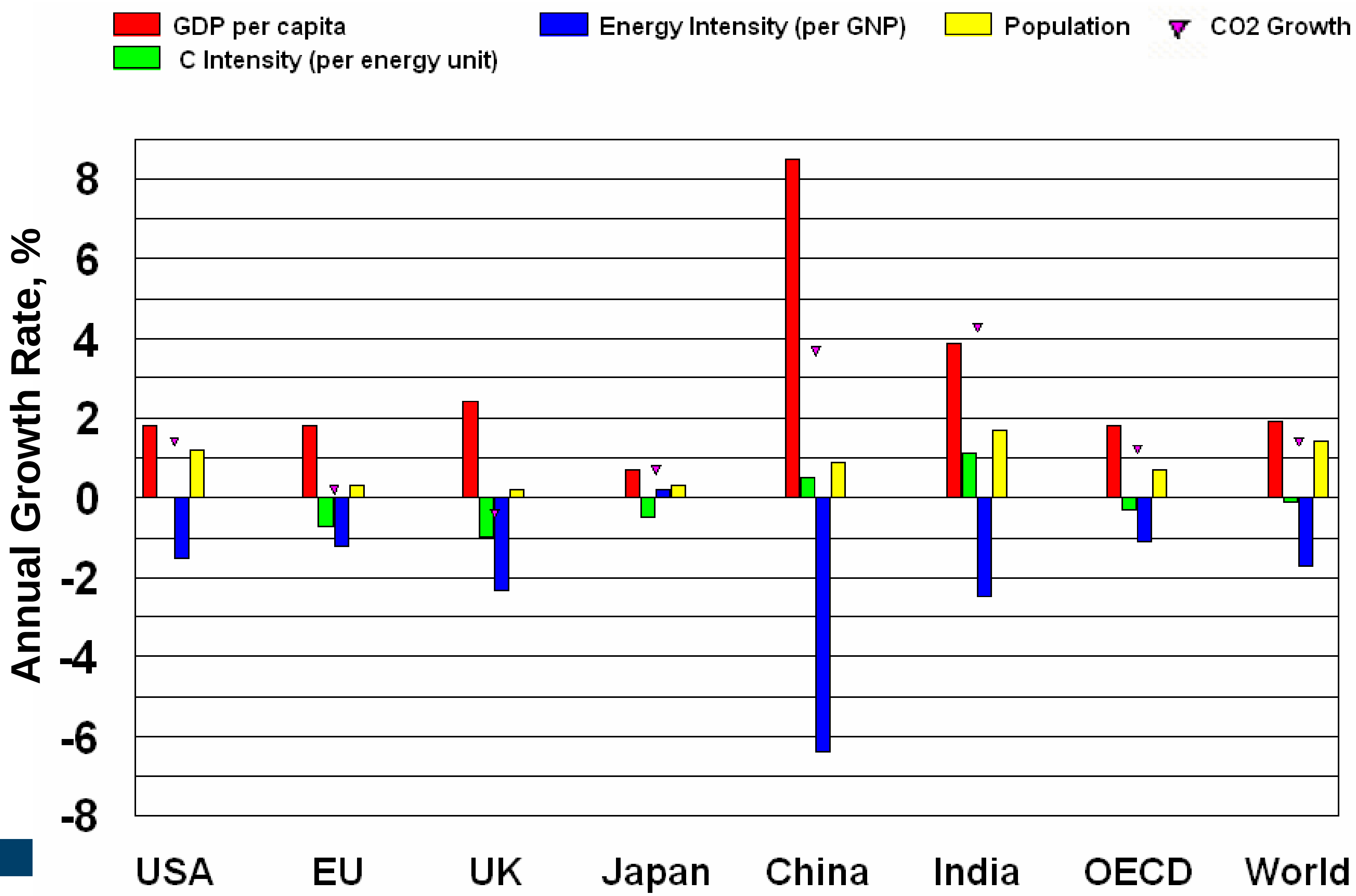
-provides oxygen,

-protects against harmful radiation

-moderates temperature

20/02/01962
John Glenn's images made with an Ansco Autoset 35mm Minolta
© NASA

Factors Driving CO_2 Annual Growth (1992-2002)



CO_2 Emissions
Gt C per Year

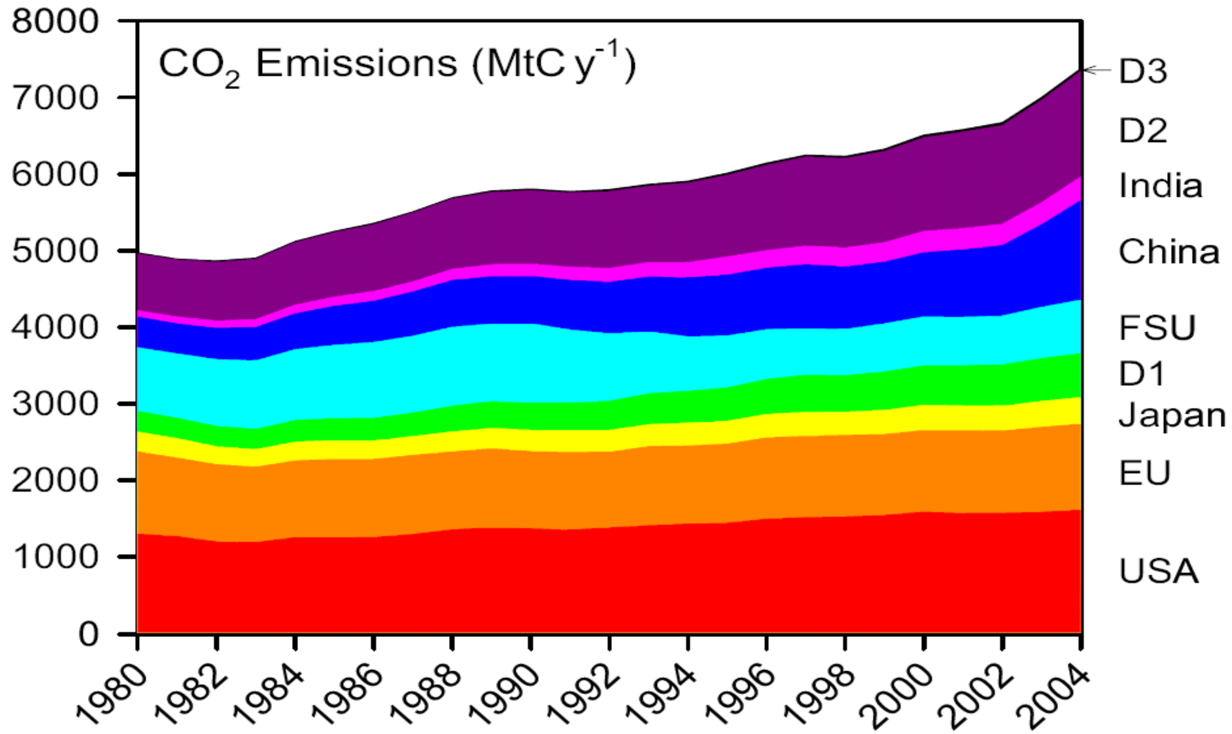
CO_2 ppm

Warming
from 1990, C
degree

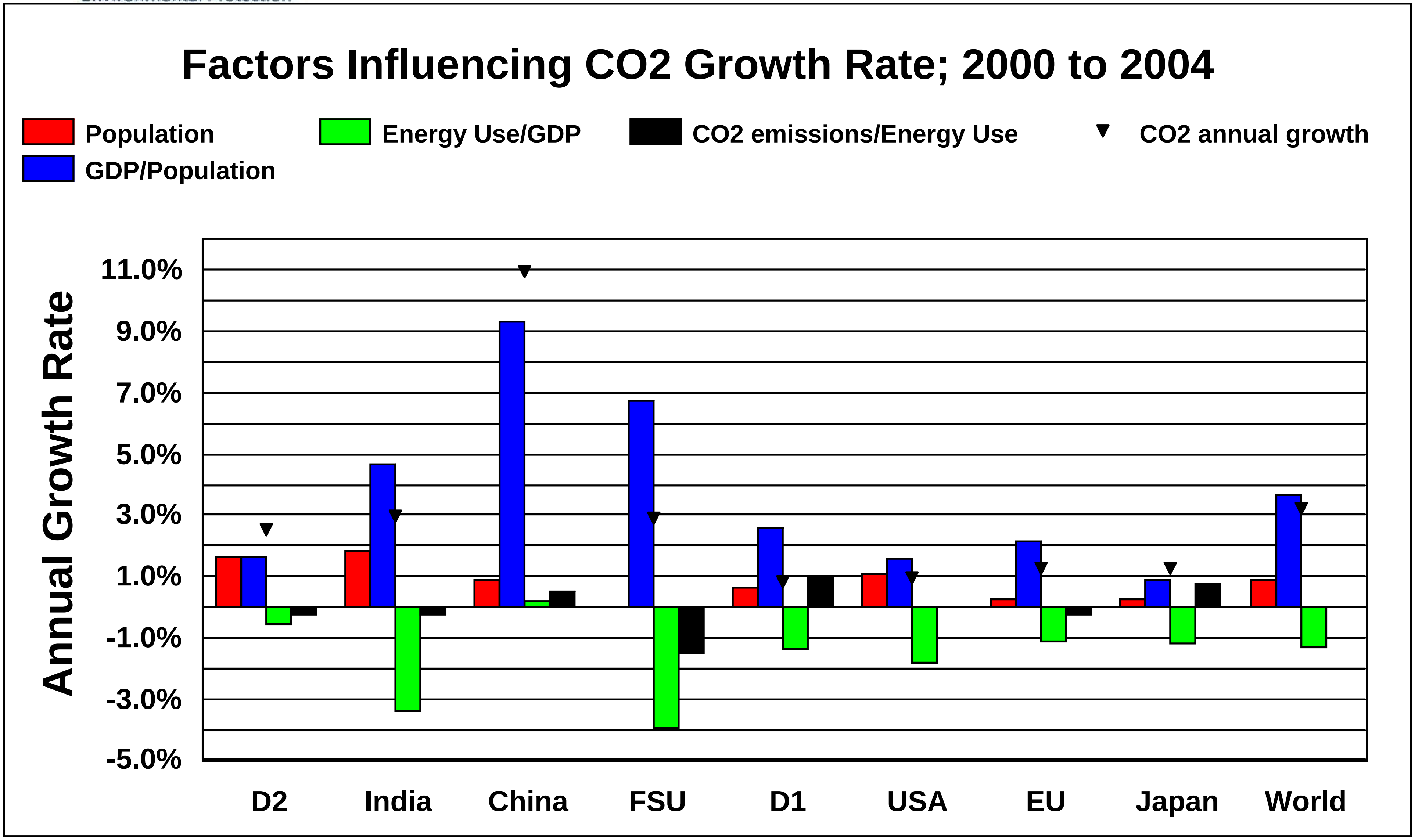
Assumed Business as Usual emission scenario per IEA (to 2050) extended to 2100 by author, concentration and warming calculations via MAGICC 4.1

Equilibrium warming range from pre-industrial; **Low: 2.9 C**, **Best Guess: 4.9 C**, **High: 8.2 C** deg.

Most Recent CO_2 Emission Data by Countries and Sectors

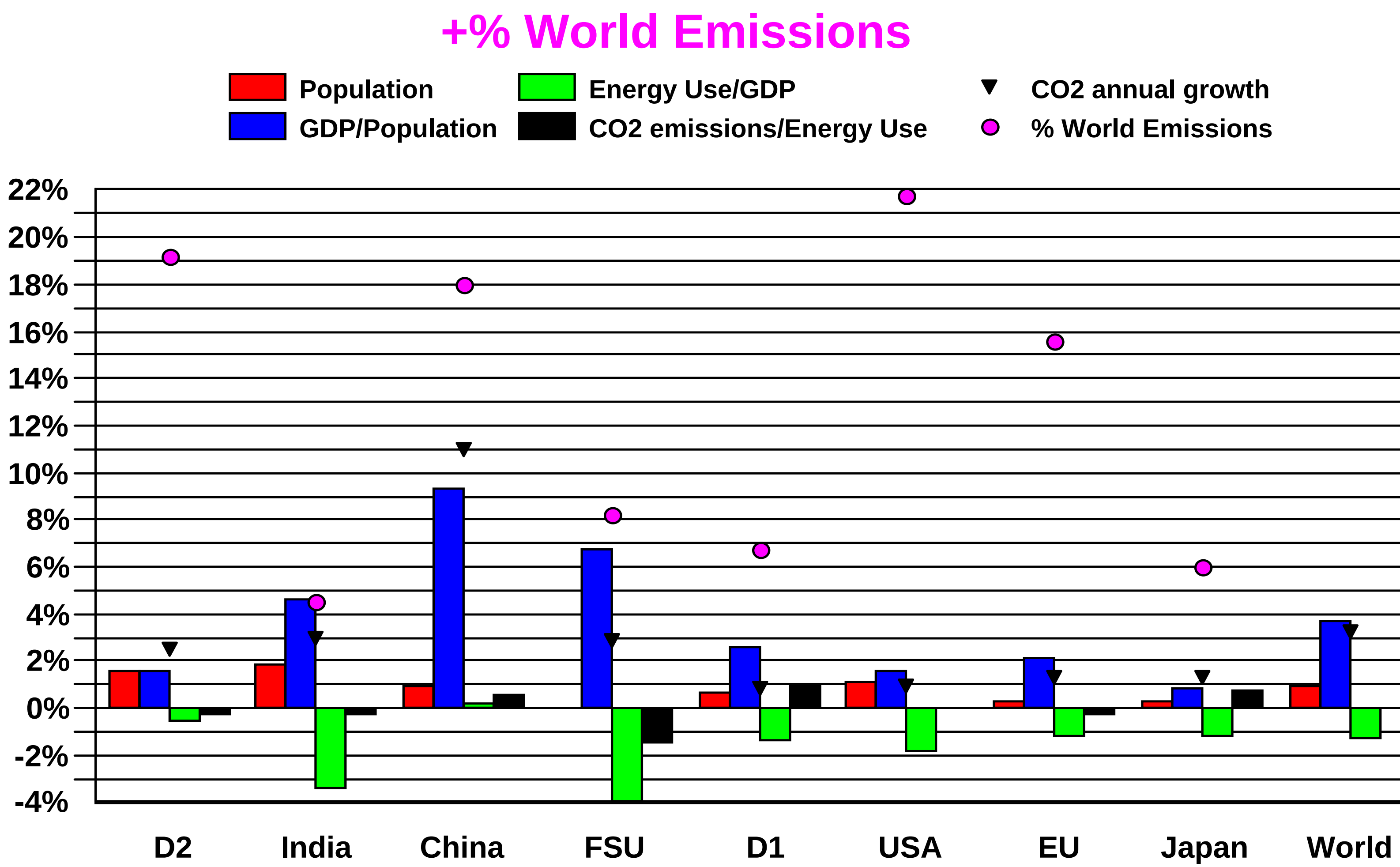


FSU=republics of the former Soviet Union,
D1=15 other developed nations, including Australia, Canada, S. Korea and Taiwan,
D2=102 actively developing countries, from Albania to Zimbabwe and
D3= 52 least developed countries, from Afghanistan to Zambia.



FSU=republics of the former Soviet Union, D1=15 other developed nations, including Australia, Canada, S. Korea and Taiwan, D2=102 actively developing countries, from Albania to Zimbabwe and D3= 52 least developed countries, from Afghanistan to Zambia.

Factors Influencing CO2 Growth Rate; 2000 to 2004

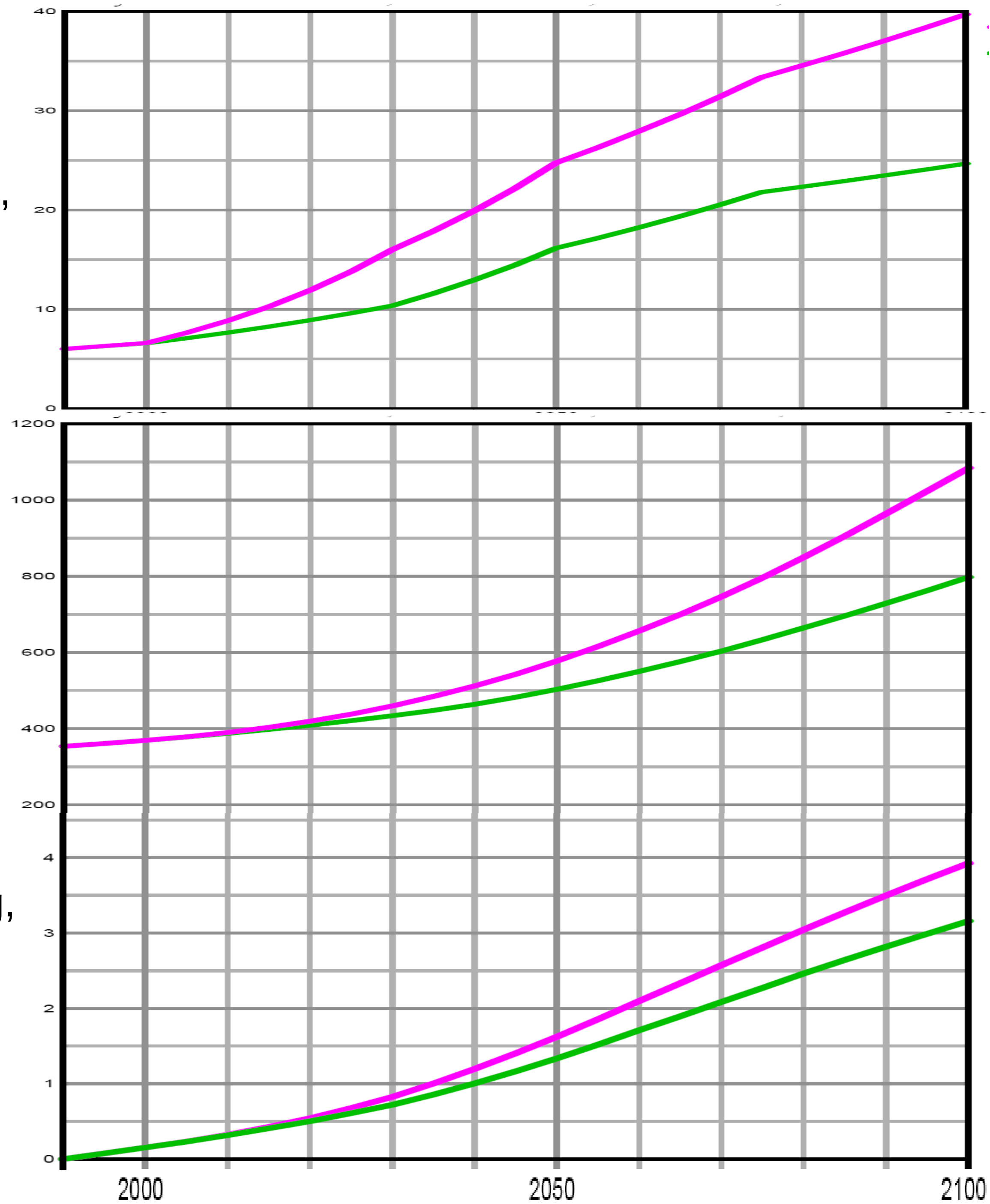


FSU=republics of the former Soviet Union, D1=15 other developed nations, including Australia, Canada, S. Korea and Taiwan, D2=102 actively developing countries, from Albania to Zimbabwe and D3= 52 least developed countries, from Afghanistan to Zambia.

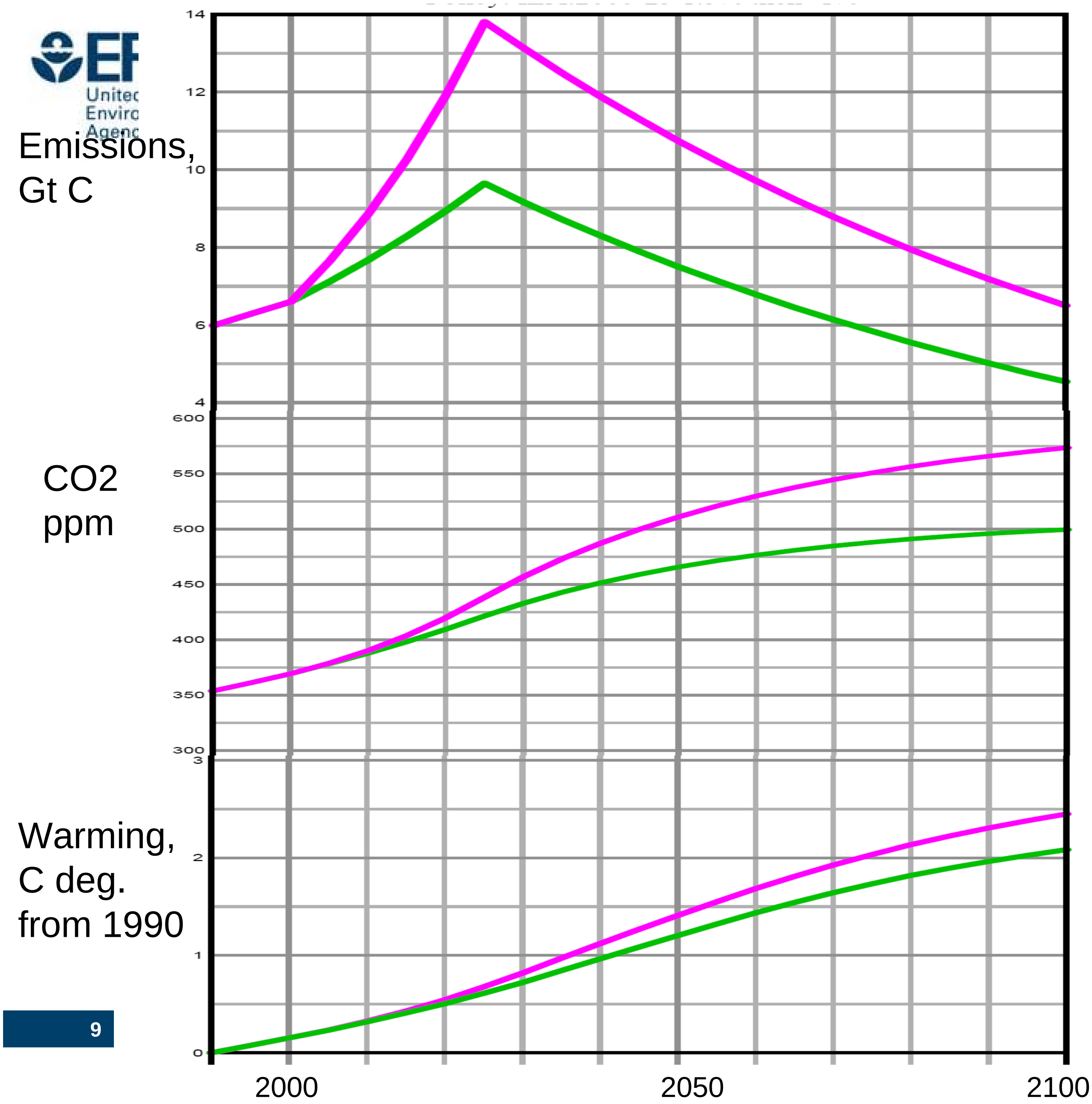
Emissions, Gt C

CO2 ppm

Warming, C deg. from 1990

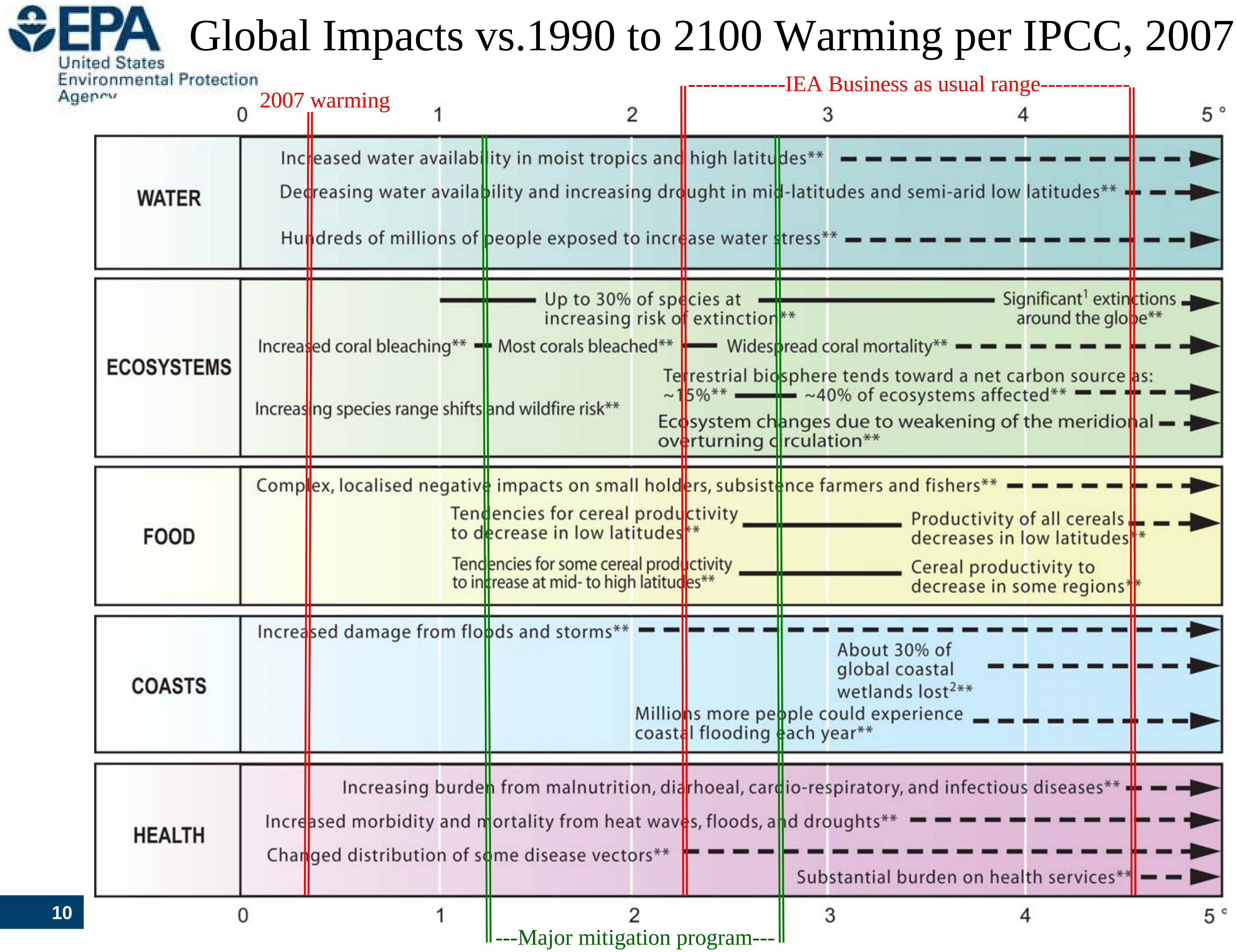


Two Emission Scenarios: IEA base: Original assumed growth rate from 2000 to 2030 of 1.6%; Revised growth rate from 2000 to 2030 of 3.0%



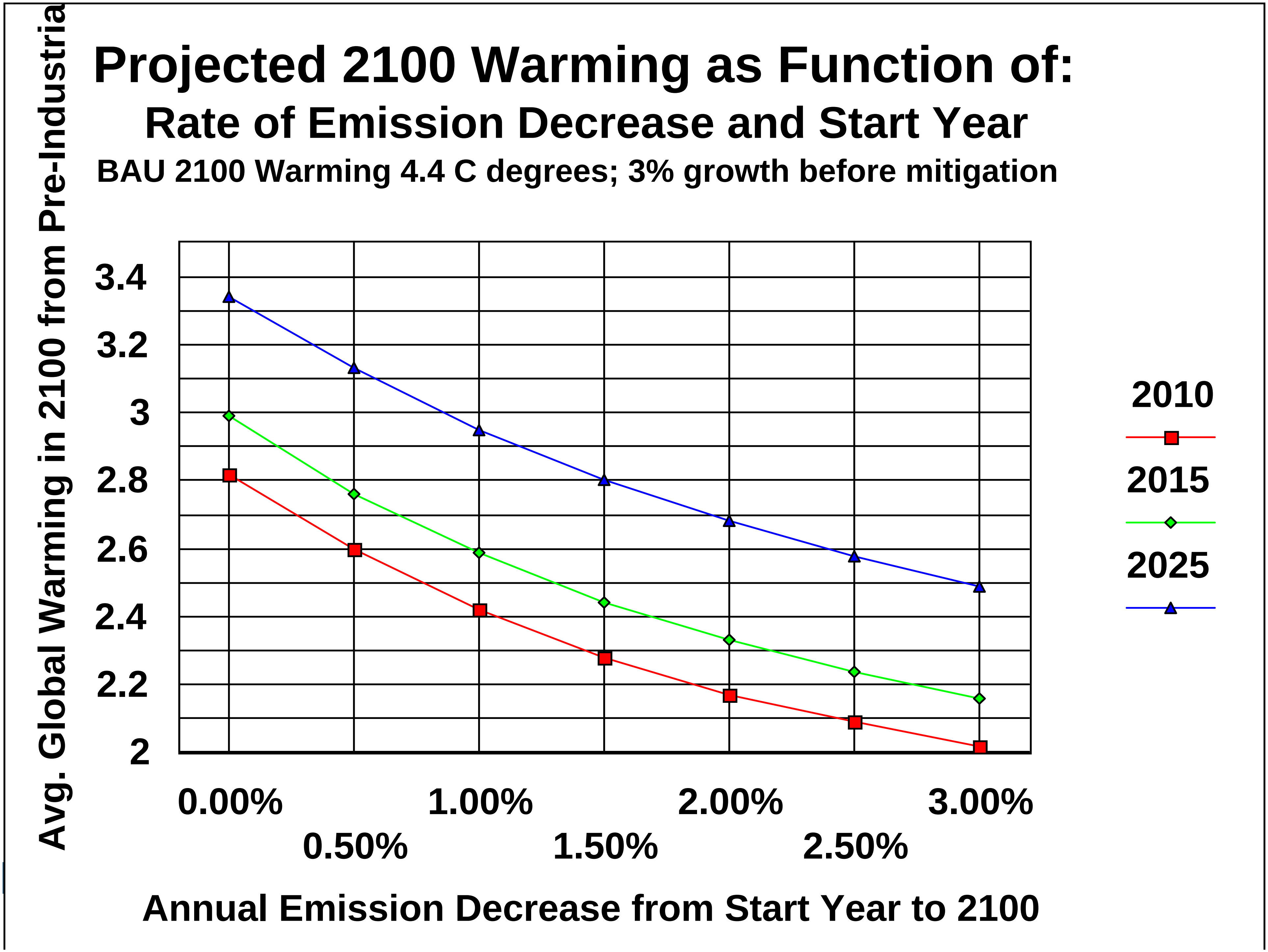
Two Mitigation Scenarios: Original assumed emission 2000 to 2025 growth rate of 1.6%, then a 1% annual reduction; Revised 2000 to 2025 growth rate of 3.0%, then an annual 1% reduction

Global Impacts vs.1990 to 2100 Warming per IPCC, 2007

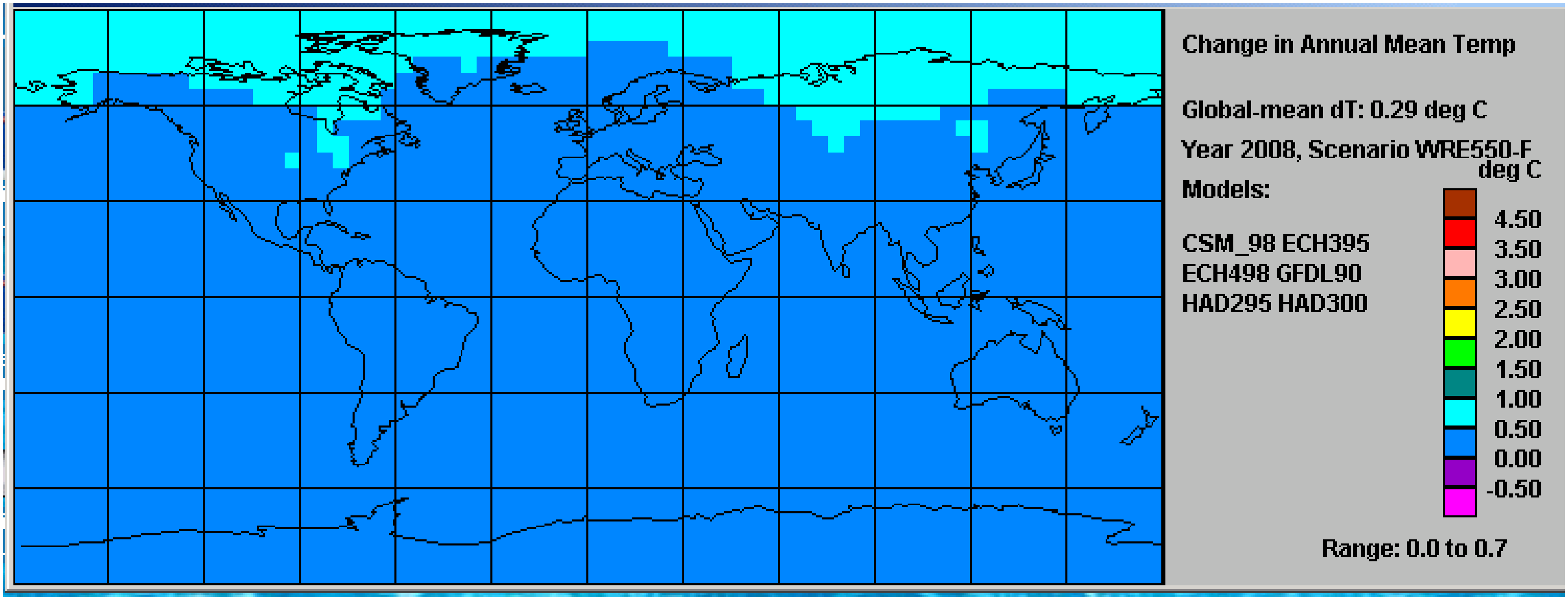


IPCC Fourth Assessment Report Impacts

- **Water:** Water supplies stored in glaciers and snow coverage projected to decline, reducing water availability in regions supplied by melting water from major mountain ranges, where more than one-sixth of the world population currently lives.
- **Ecosystems:**~20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if warming exceeds1.5-2.5 oC.
- **Food:** At lower latitudes, crop productivity is projected to decrease for even small local temperature increases (1-2°C). At higher latitudes crop productivity is projected to increase for increases of 1-3°C, then decrease beyond that.
- **Coasts:** Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s.
- **Human Health:** Projected climate change-related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity.
- **Air:** Declining air quality, > 99% certainty, in cities due to warmer/more frequent hot days and nights over most land areas, including US. Increases in regional ozone, with risks in respiratory infection, asthma, and premature death in people with heart and lung disease.

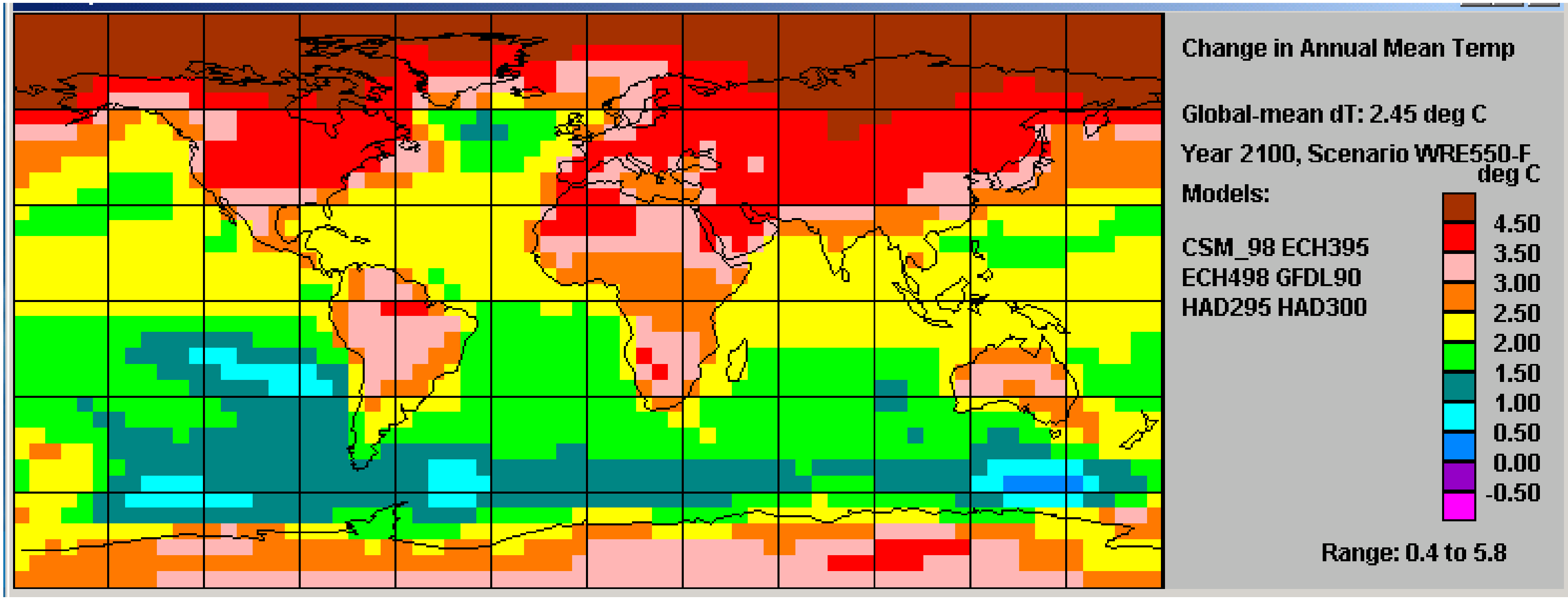

Projected 2100 Warming as Function of:
Rate of Emission Decrease and Start Year
BAU 2100 Warming 4.4 C degrees; 3% growth before mitigation
Avg. Global Warming in 2100 from Pre-Industria
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0.00%
0.50%
1.00%
1.50%
2.00%
2.50%
3.00%
Annual Emission Decrease from Start Year to 2100
2010
2015
2025

Best Guess Annual Mean Temperature Change in 2008 from 1990



Best Guess Annual Mean Temperature Change in 2100 assuming Major Mitigation Program:

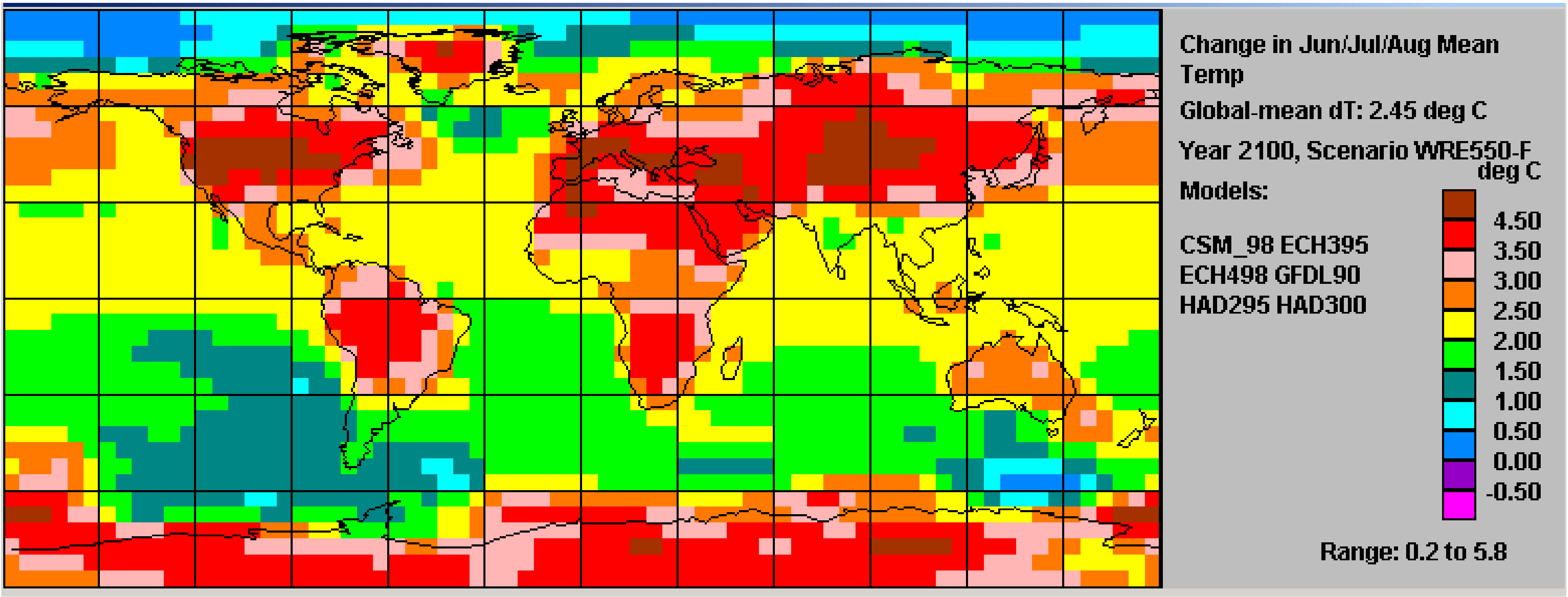
Minus 1% per year starting 2025 for 75 Years



Location Warming: Miami 2.3 C, Raleigh 3.6 C, New York 4.1 C, Chicago 4.3 C, Los Angeles 3.5 C, Alaska 4.6 C

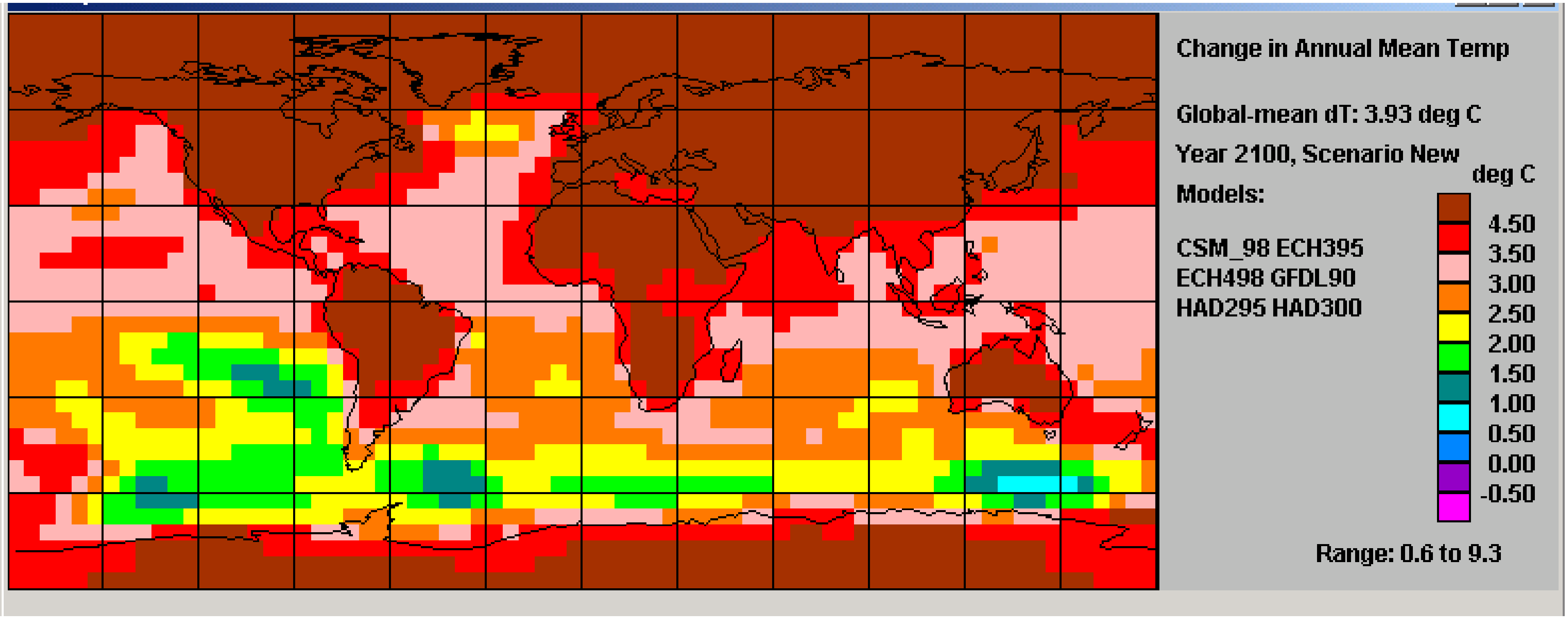
Best Guess Summer Mean Temperature Change in 2100 Assuming Major Mitigation Program:

Minus 1% per year starting 2025 for 75 Years



Location Warming: Miami 2.5 C, Raleigh 4.7 C, New York 4.5 C, Chicago 3.8 C, Los Angeles 4.6 C, Alaska 2.6 C

Best Guess Annual Warming in 2100 assuming 3% CO2 Growth to 2025 Business as Usual Case

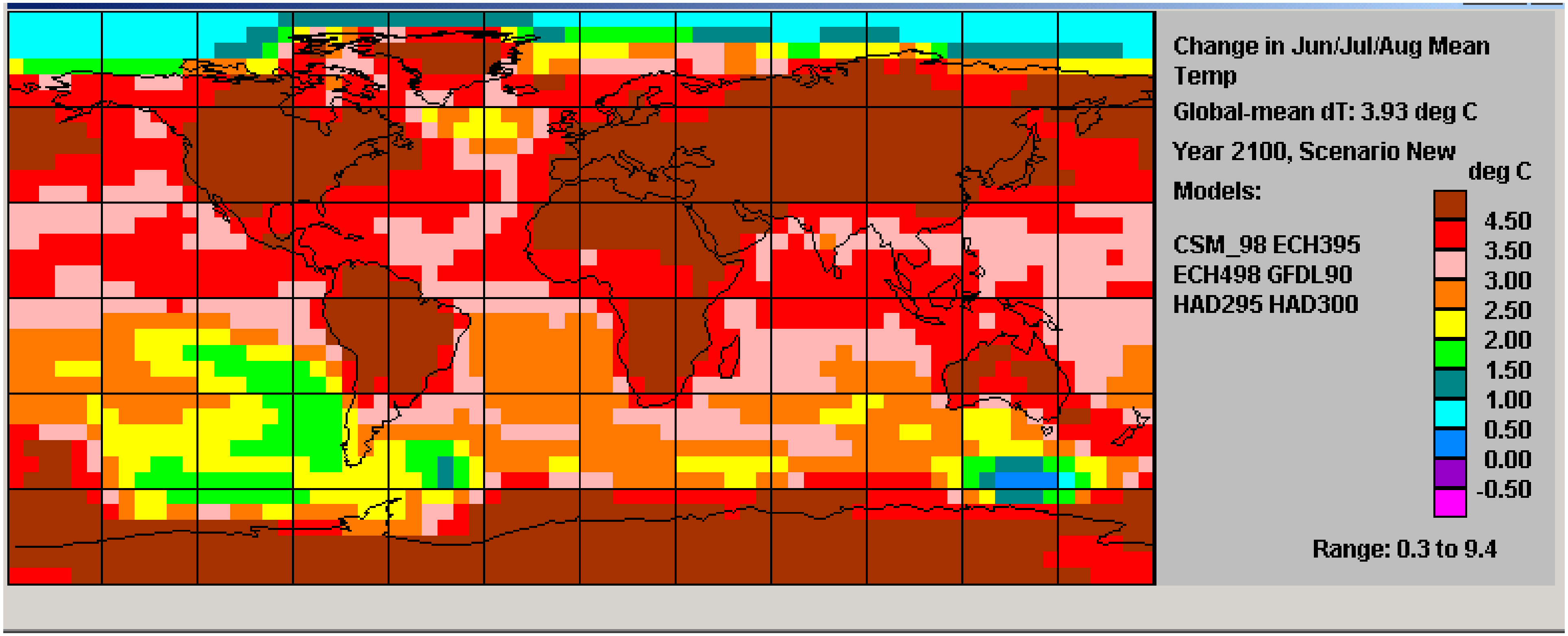


Location Warming: Miami 3.8 C, Raleigh 5.9 C, New York 6.9 C, Chicago 6.8 C, Los Angeles 5.7 C, Alaska 7.4 C

United States Environmental Protection Agency

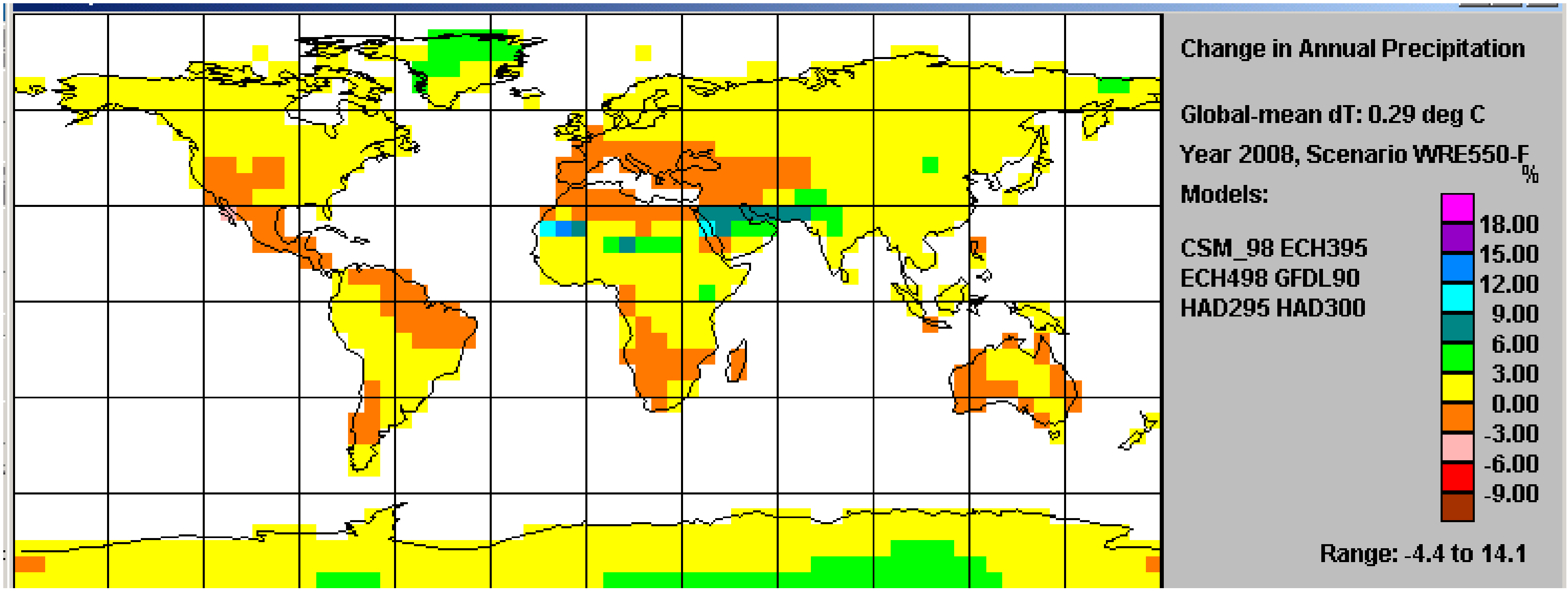
Best Guess Summer Warming in 2100 assuming 3% CO2 Growth to 2025

Business as Usual Case

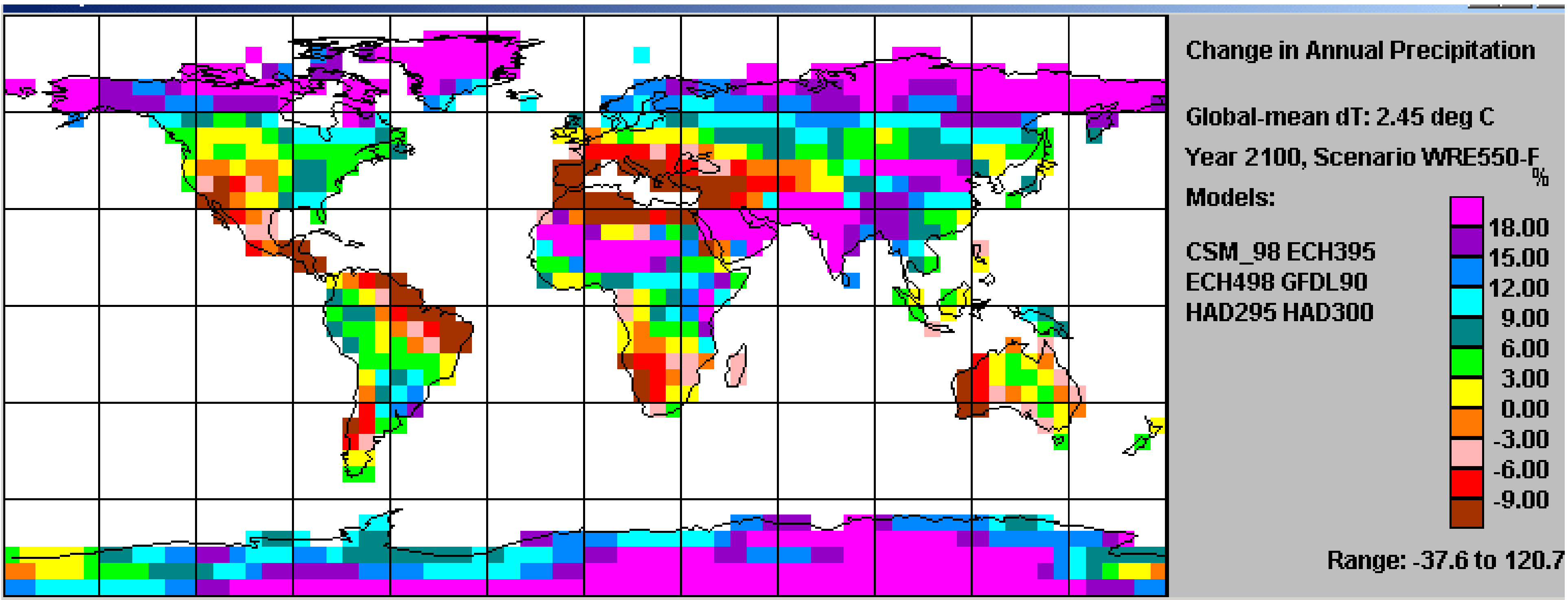


Location Warming: Miami 3.9 C, Raleigh 6.1 C, New York 7.2 C, Chicago 6.0 C, Los Angeles 4.7 C, Alaska 3.6 C

Best Guess Annual Precipitation Change in 2008

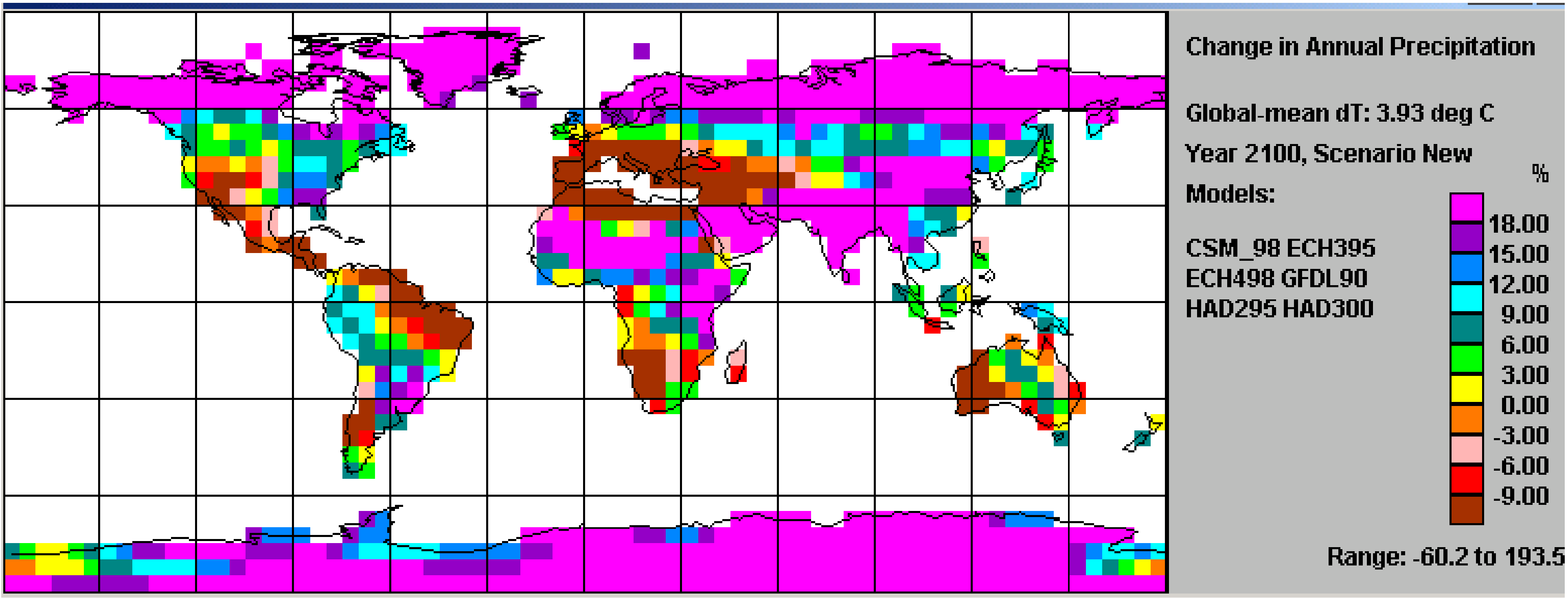


Best Guess Annual Precipitation Change in 2100 assuming Major Mitigation Program: Minus 1% per year starting 2025 for 75 Years



United States Environmental Protection Agency

Best Guess Annual Precipitation Change in 2100 assuming 3% CO2 Growth to 2025



IEA Accelerated Technology (ACT) Scenarios

- Mandate by G-8 Leaders and Energy Ministers
- Assumes aggressive R,D&D Program
- Major mitigation starts in 2030
- Assumes policies in place to encourage technology use in accelerated time frame
  - CO_2 reduction incentives of up to $25 per ton
  - Policies include regulation, tax breaks, subsidies and trading schemes

Reference: International Energy Agency, Energy Technology Perspectives 2006, OECD-IEA, 2006

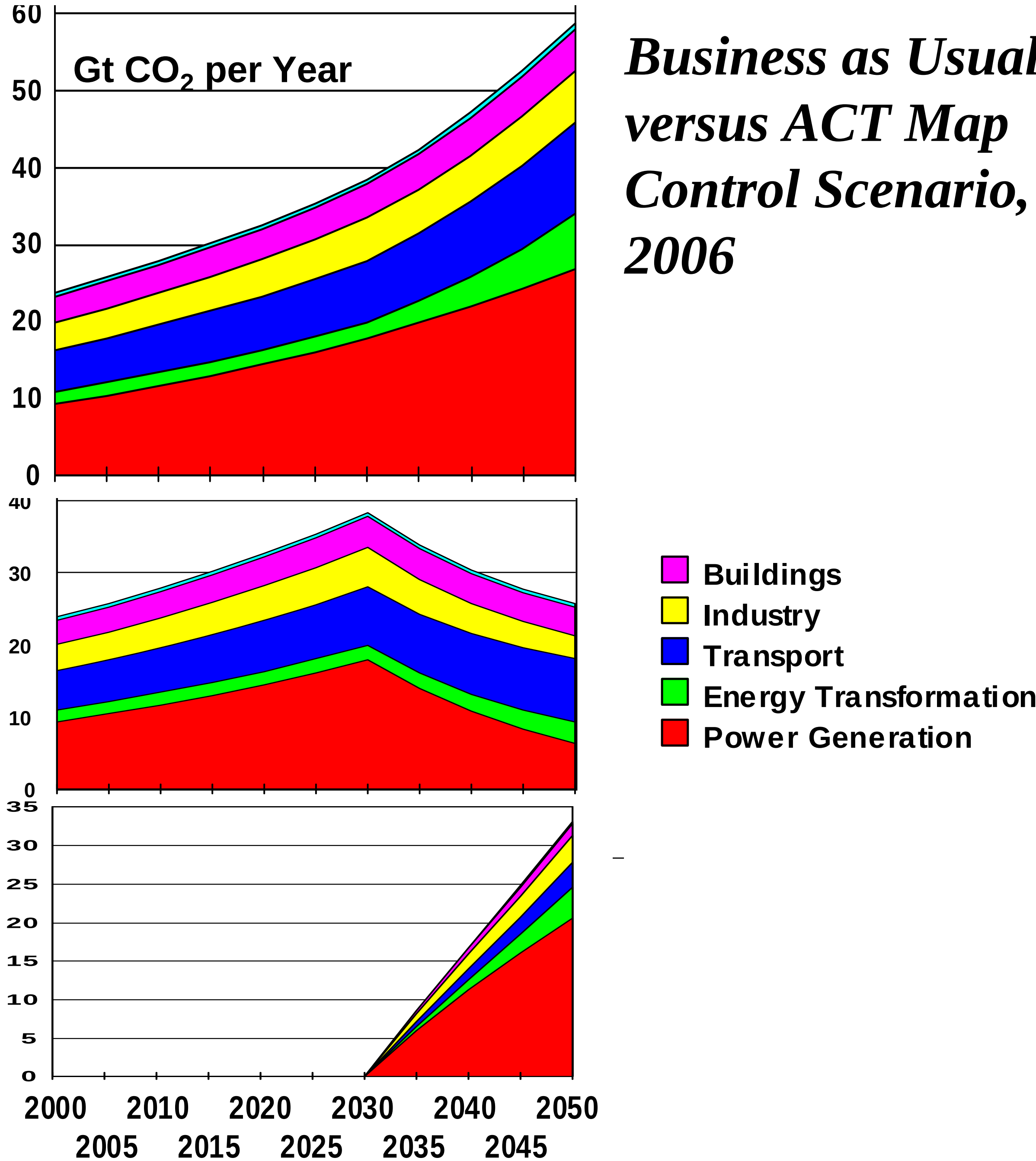
United States Environmental Protection Agency

Business as Usual, versus ACT Map Control Scenario, IEA 2006

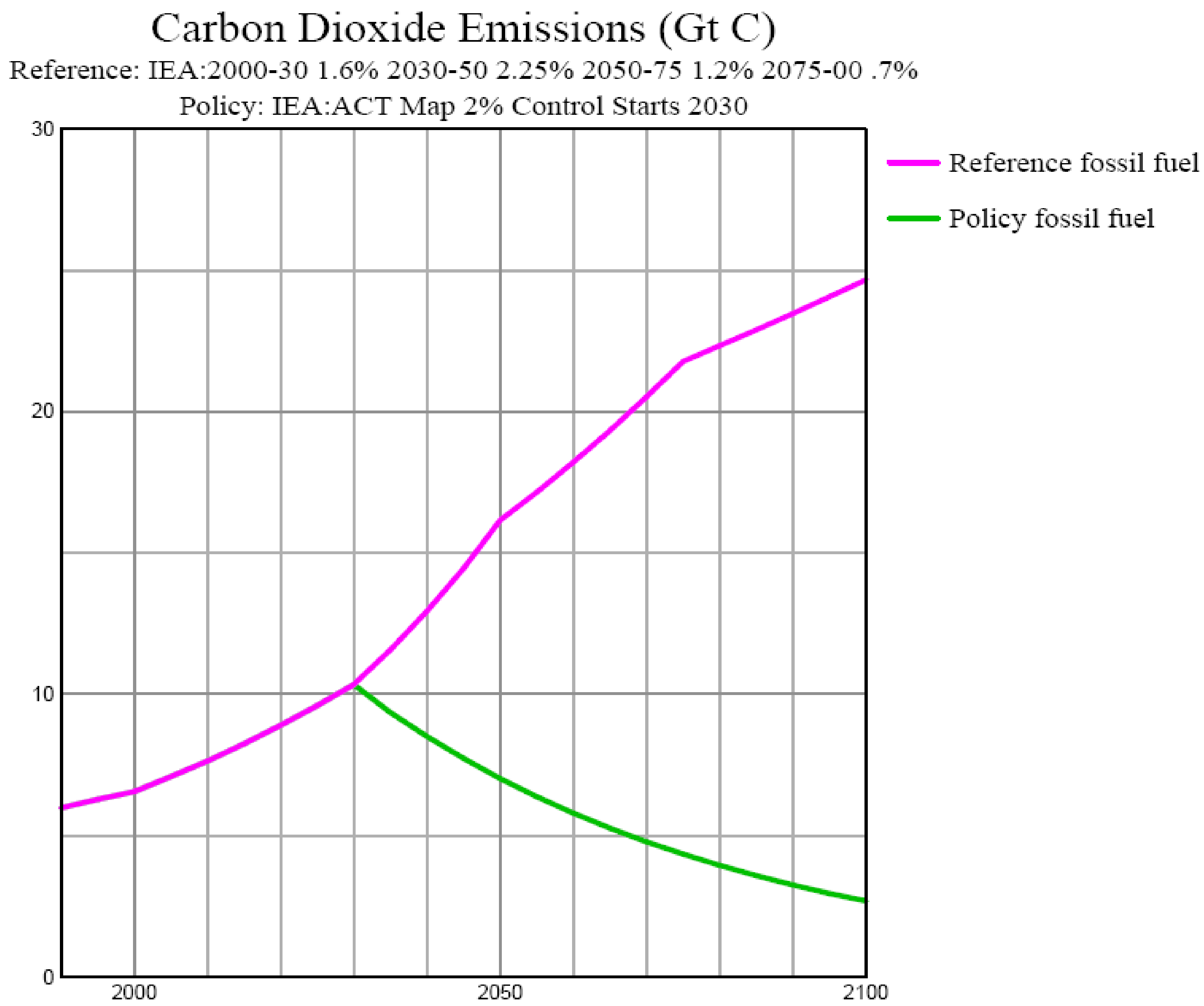
World Projection of CO_2 Emissions by Sector (IEA, 2006)

IEA Baseline ACT Map Scenario

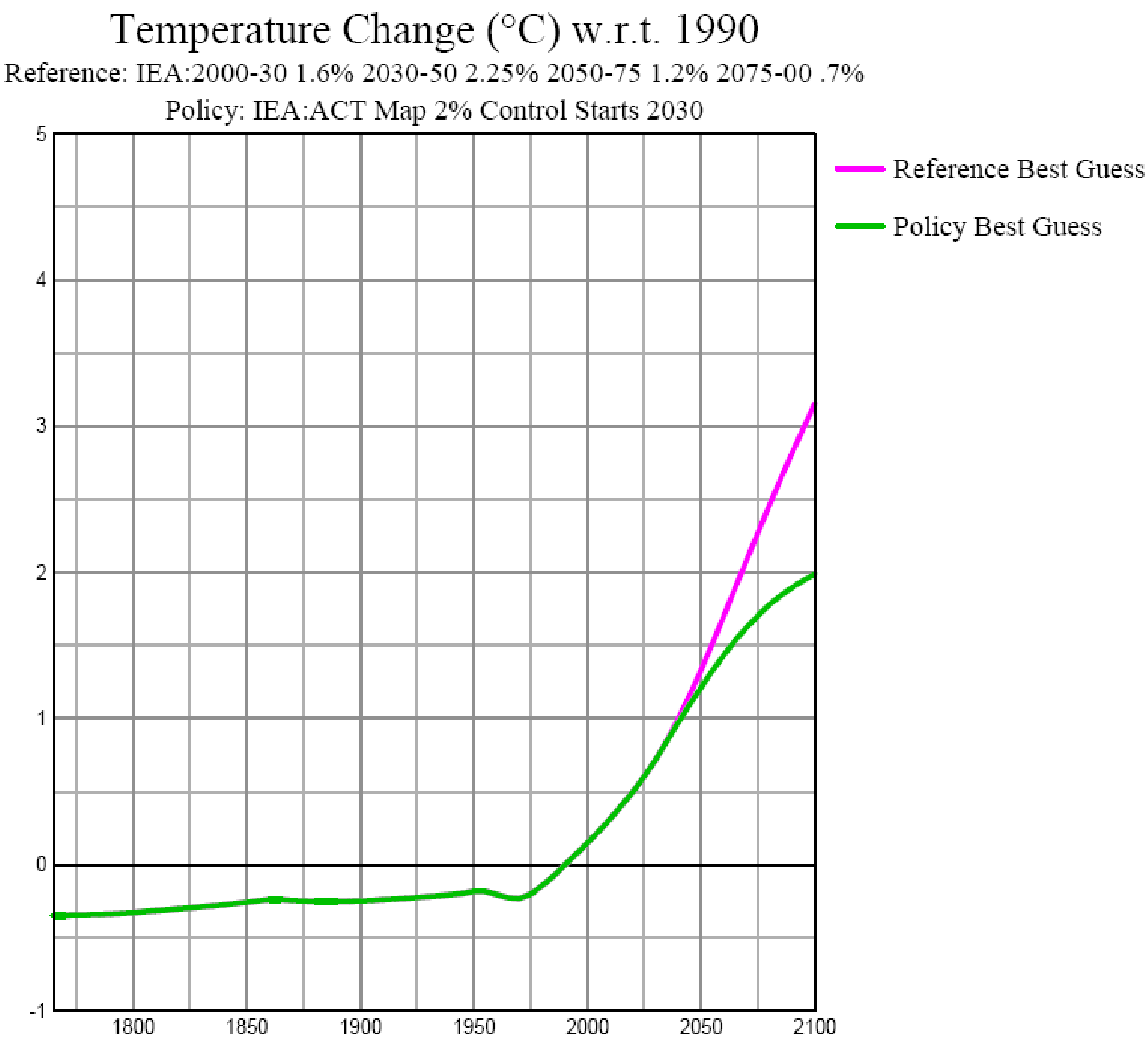
IEA ACT Map Scenario, CO2 Reductions by Sector



CO_2 Emissions for IEA Base Case and ACT Map Scenario



Projected Warming for IEA Base Case & ACT Map Scenario

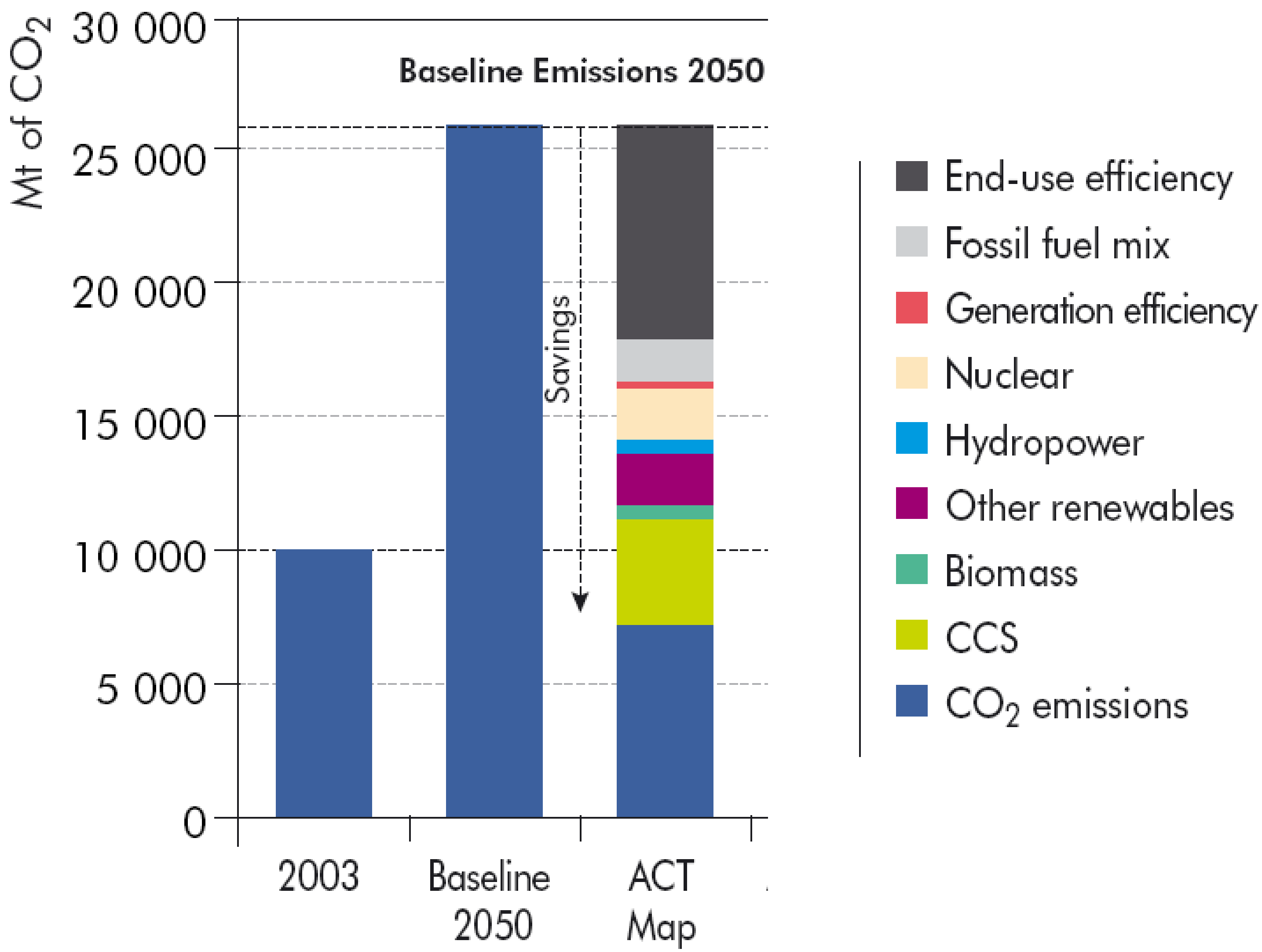


Power Generation Sector

- Projected to grow from large base at 2% annually, China and India critical; offers greatest opportunity for reductions; 38% of US CO_2
- Coal combustion key source, important to develop CO_2 CCS technologies and alternatives to coal-based systems.
- 3 major candidates for CO_2 capture: PC boilers/advanced CO_2 scrubbing, IGCC/carbon capture and oxygen-fed PC combustors. Only IGCC funded at significant levels
- Underground storage in deep geological formations an unproven technology at scale needed for coal-fired boilers, with serious cost, efficacy, & safety issues.
- Nuclear power plants; accelerated R, D and D program is important for advanced reactors, given high mitigation potential, yet serious safety, proliferation and waste disposal concerns.
- Natural gas/combined cycle plants, wind turbines also have potential to decrease dependence on coal

United States Environmental Protection Agency

CO_2 Avoidance in Power Generation Sector for IEA ACT Map Scenario by Energy Category



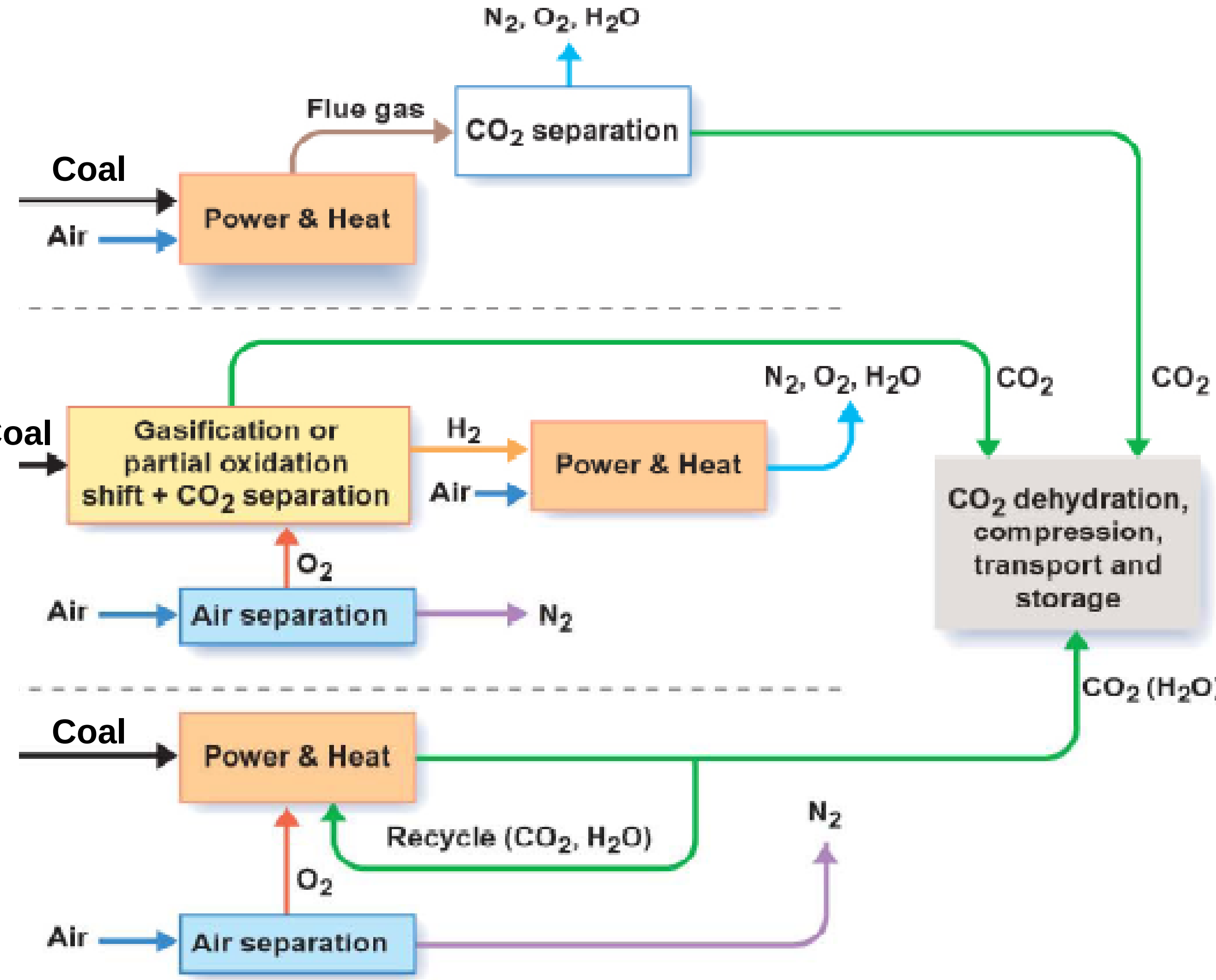
EPA United States Environmental Protection Agency

Three Options for CO_2 Capture from Coal Power Generation Plants

Post Combustion CO_2 Separation

IGCC: Pre-combustion CO_2 removal

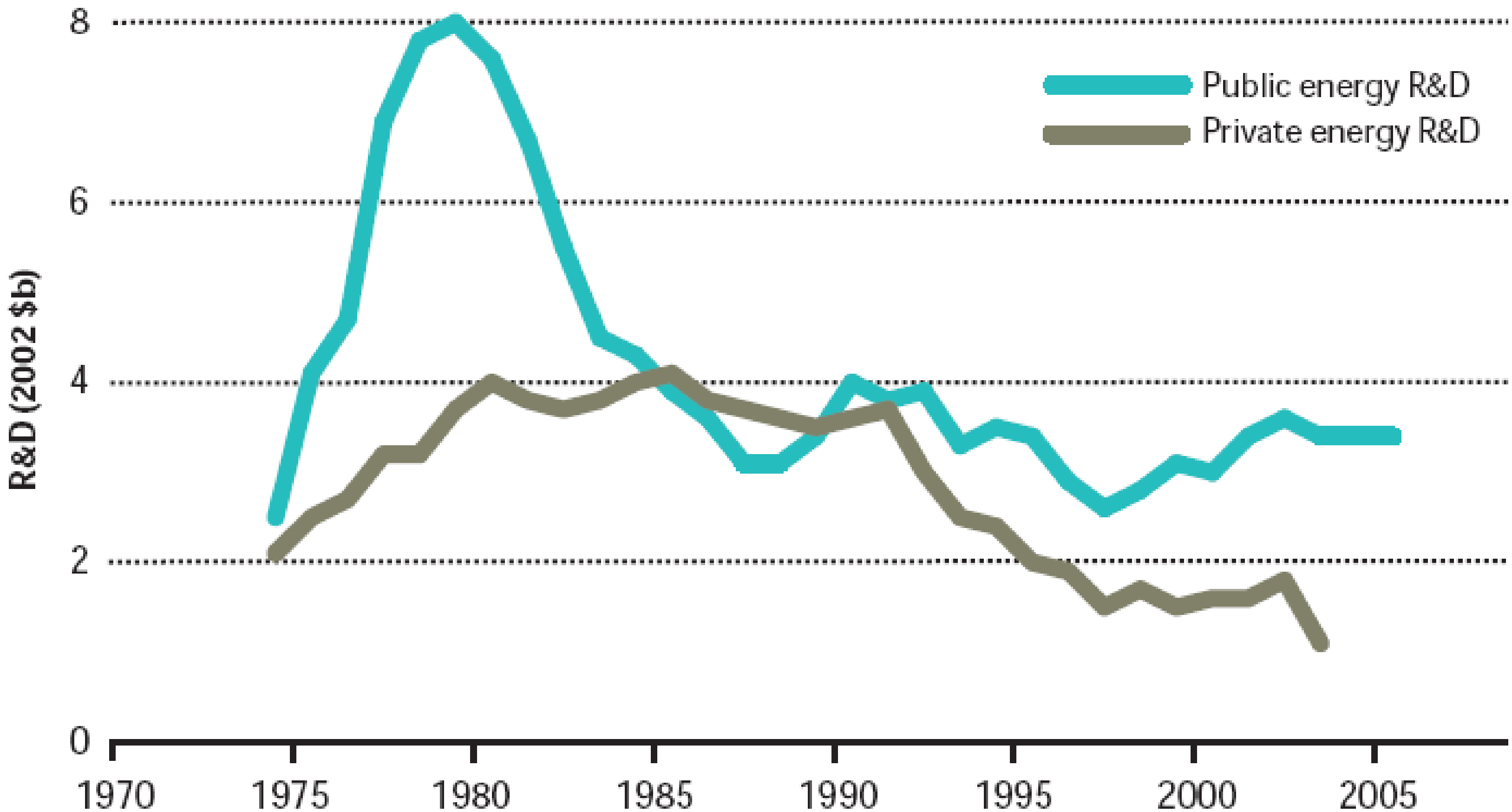
Post Oxy-fuel Combustion CO_2 Removal



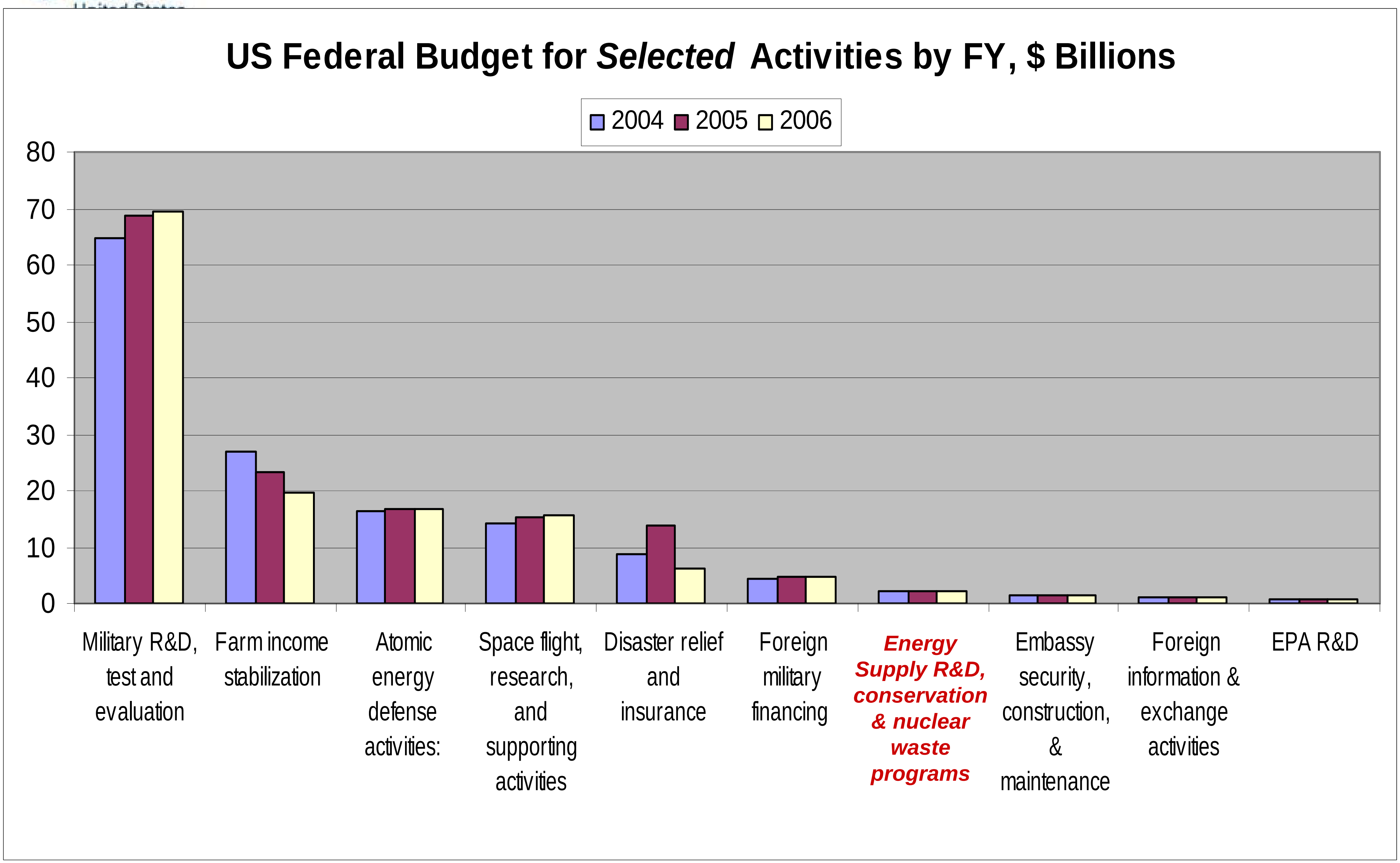
Transportation Sector

- Growing at 2% per year, most difficult sector. 32% of US CO_2
- The first challenge: current propulsion systems all depend on fossil fuels with associated CO_2 emissions, suggesting renewable sources such as biomass, important; but resource limited
- The second challenge: the automobile industry, driven by consumer preferences (especially in North America), have offered heavy, high emitting vehicles such as SUVs.
- A review of evolving technologies suggests hybrids & biomass-to-diesel fuel via thermochemical processing are most promising.
- However, cellulosic biomass-to-ethanol and hydrogen/fuel cell vehicles offer longer term potential, if key technical issues are resolved and, for hydrogen, renewable sources are developed.
- Ethanol from grain, e.g. corn, not an effective avoidance approach

U.S. Federal Funding in Key Energy Areas per IEA in 2004 $



Sources: R. M. Wolfe, Resea rch and Development in Industry" (National Science Foundation, Division of Science Resources Statistics, 2004); M. Jefferson, *et al.*, "Energy Technologies for the 21st Century" (World Energy Council, 2001); R. L. Meeks, "Federal R&D Funding by Budget Function: Fiscal Years 2003-05" NSF 05-303 (National Science Foundation, Division of Science Resources Statistics, 20040; R. Margolis, and D. M. Kammen "Underinvestment: The energy technology and R&D policy challenge", *Science*, 285, 690-692 (1999).


US Federal Budget for *Selected* Activities by FY, $ Billions
2004
2005
2006
80
70
60
50
40
30
20
10
0
Military R&D, test and evaluation
Farm income stabilization
Atomic energy defense activities:
Space flight, research, and supporting activities
Disaster relief and insurance
Foreign military financing
Energy Supply R&D, conservation & nuclear waste programs
Embassy security, construction, & maintenance
Foreign information & exchange activities
EPA R&D

EPA United States Environmental Protection Agency

Major Increase in R,D,D &D Essential

- If mitigation of one trillion tons of carbon is deemed a serious goal, a major increase in R,D,D&D needed. The Stern Report : "…support for energy R&D should at least double, and support for the deployment of new low-carbon technologies should increase up to five-fold."
- Currently world spends $1trillion on military, $10 billion on all energy technologies, $1.5 billion on coal technologies
- Current CO_2 mitigation research funding in US and globally relatively flat in recent years, US spending on mitigation 70% lower than that in response to oil shortages in mid-1970's.
- R,D&D particularly important for coal generation technologies: IGCC, oxy-coal combustion, and CO_2 capture technology for PC boilers; all need to be integrated with underground storage, a key technology, but need numerous demos
- Also important; next generation nuclear power plants

United States Environmental Protection Agency

Conclusions

- Limiting warming to below 2.5 C will be a monumental challenge; growth rate of 1.5% to **3%** must change to -1 to -2%; sooner control starts, less drastic are controls
- Warming of at least 2 C inevitable, adaptation strategies needed
- Power production and mobile sources key sectors
- Required technology is not available; major advances necessary in underground storage, PC CO_2 capture, IGCC, oxygen combustion, advanced nuclear, mobile source fuels/propulsion systems and renewables
- No “silver bullets”, all promising technologies should be pursued
- Research funding is grossly inadequate; “too few eggs in too few baskets”
- Technology necessary but not sufficient; utilization requires incentives/regulations

What Global Program Strategies Would Encourage Availability and Utilization of Low Emission Technologies?

- *Adequate* R,D&D program on key technologies; dramatically increase funding, carefully set priorities and select a broad portfolio for key sectors
- *Focused* fundamental research with potential for breakthroughs: batteries, renewables, fuel cells, air separation, hot gas cleanup, high temperature metals
- *Incentives* to encourage deployment of key technologies:
  - Low emission technologies will often be more expensive; policies that provide in the order of \$20 to \$30/ton CO_2 cost incentive, will likely be needed
  - Since such technologies can be more complex, with greater financial, deployment and safety risks; streamlining of siting and regulatory approval processes and government indemnification could be important

United States Environmental Protection Agency

Our Stakeholders Count on Us