Global Climate Change-the Mitigation Challenge

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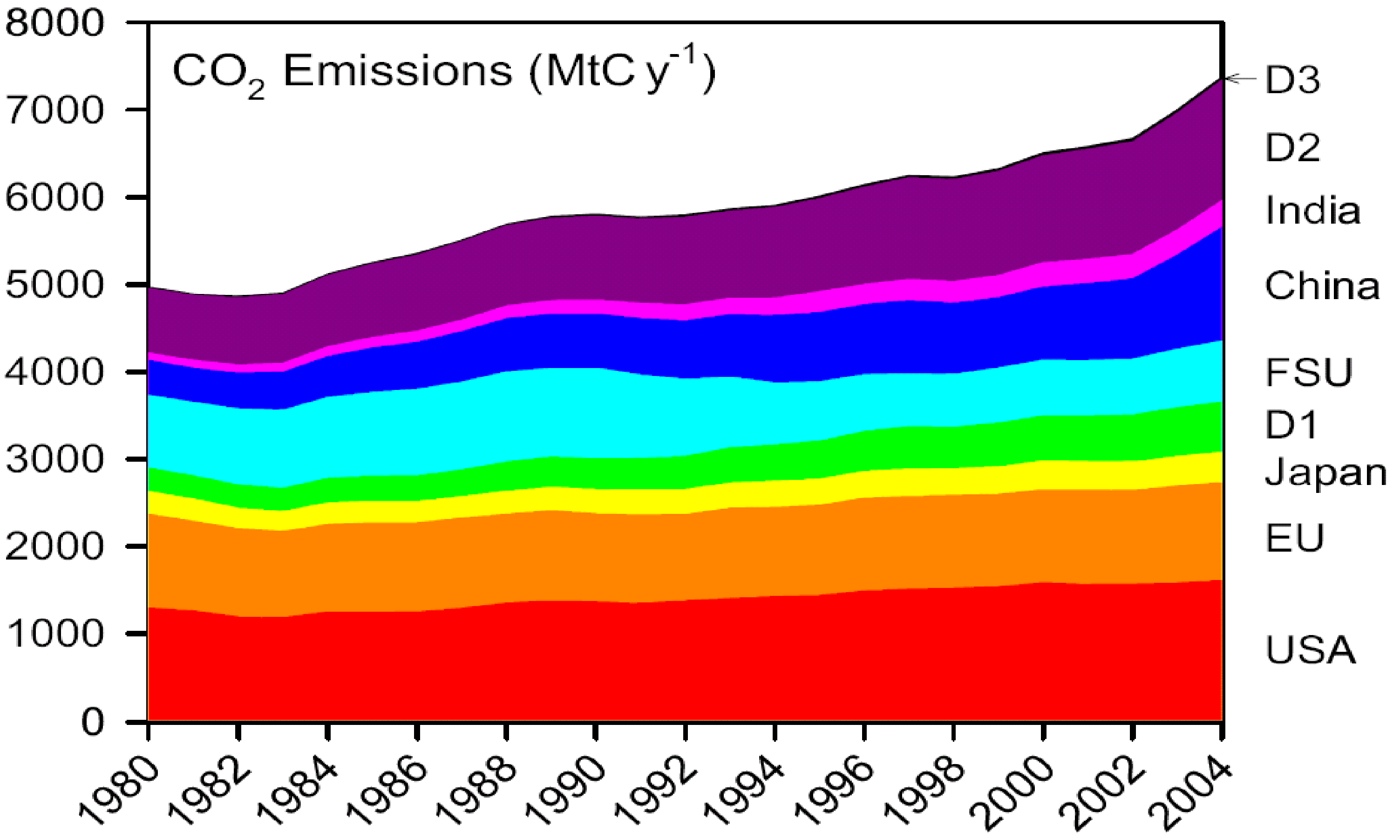
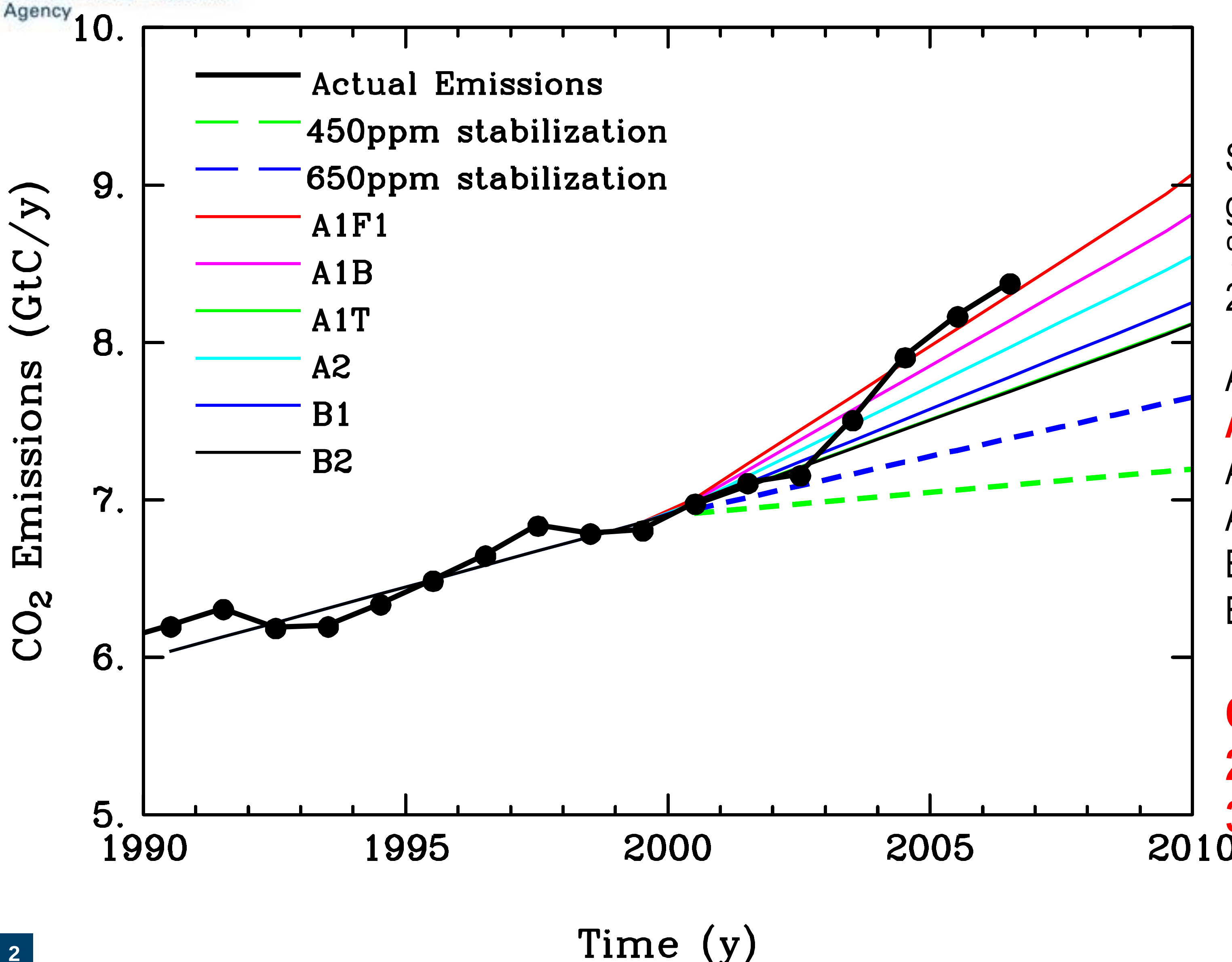
Most Recent CO_2 Emission Data by Countries and Sectors



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.

Trajectory of Global Fossil Fuel Emissions



SRES (2000) growth rates in % y^{-1} for 2000-2010:

A1B: 2.42

A1FI: 2.71

A1T: 1.63

A2: 2.13

B1: 1.79

B2: 1.61

Observed 2000-2006 3.3%

Raupach et al. 2007, PNAS

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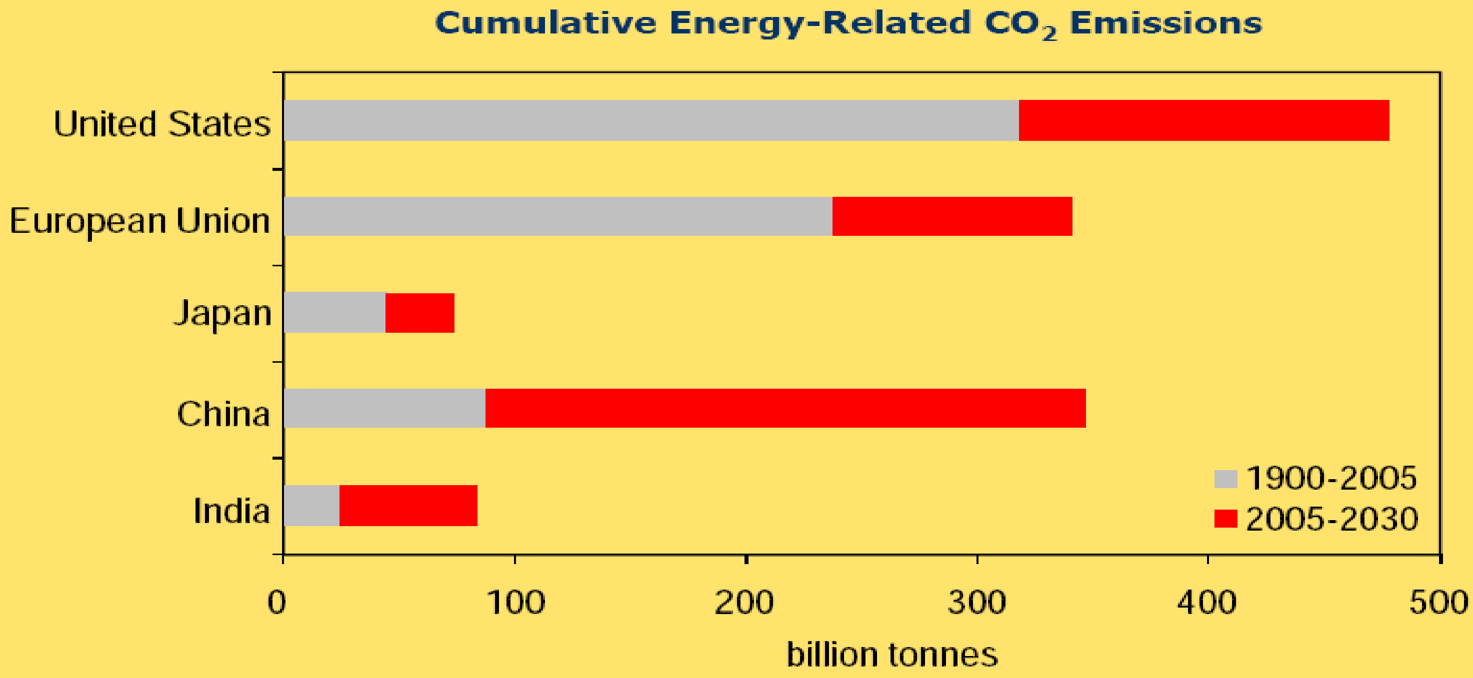
China & India in Global CO_2 Emissions WEO2007 Reference Scenario



Around 60% of the global increase in emissions in 2005-2030 comes from China & India

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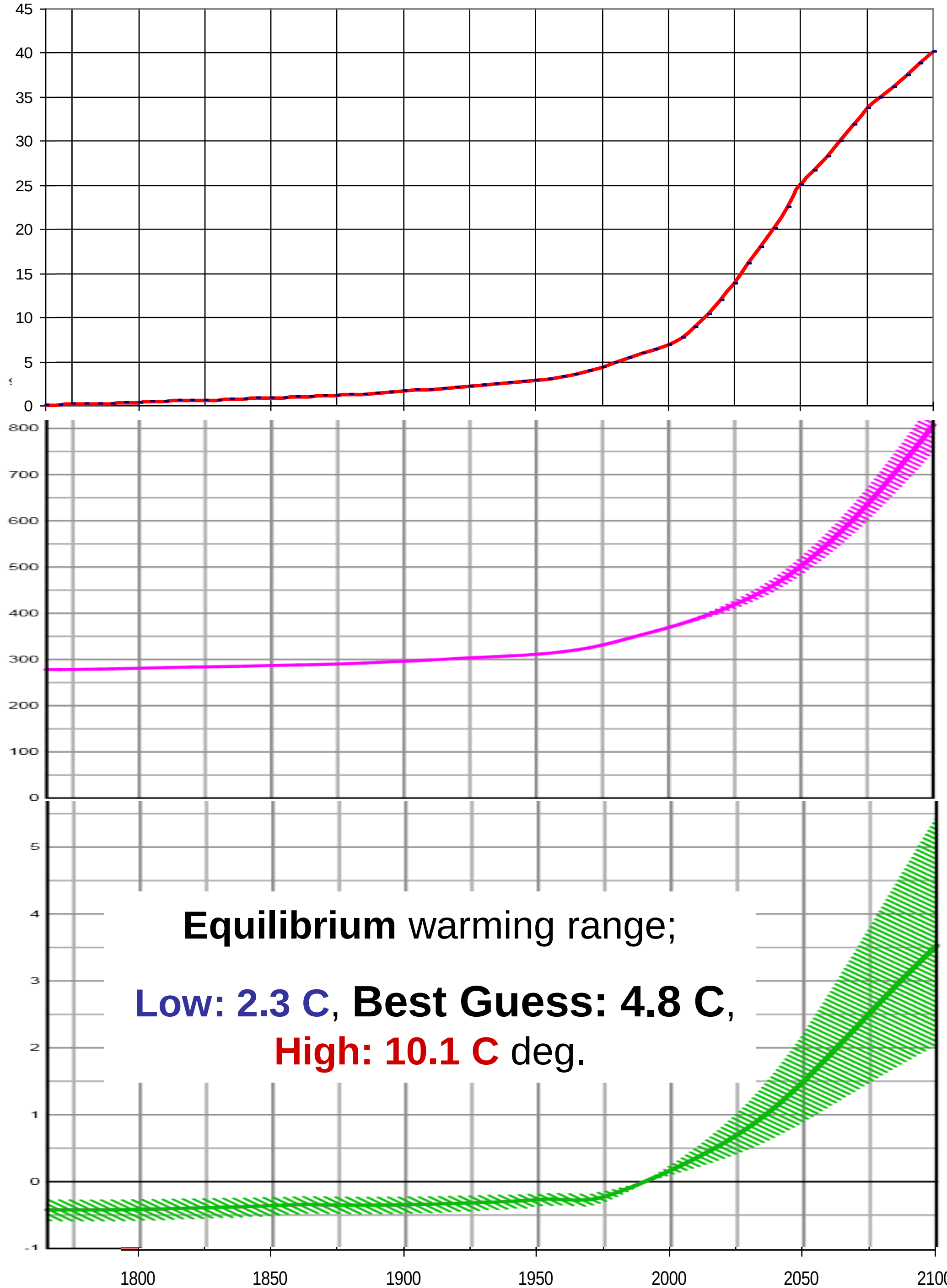
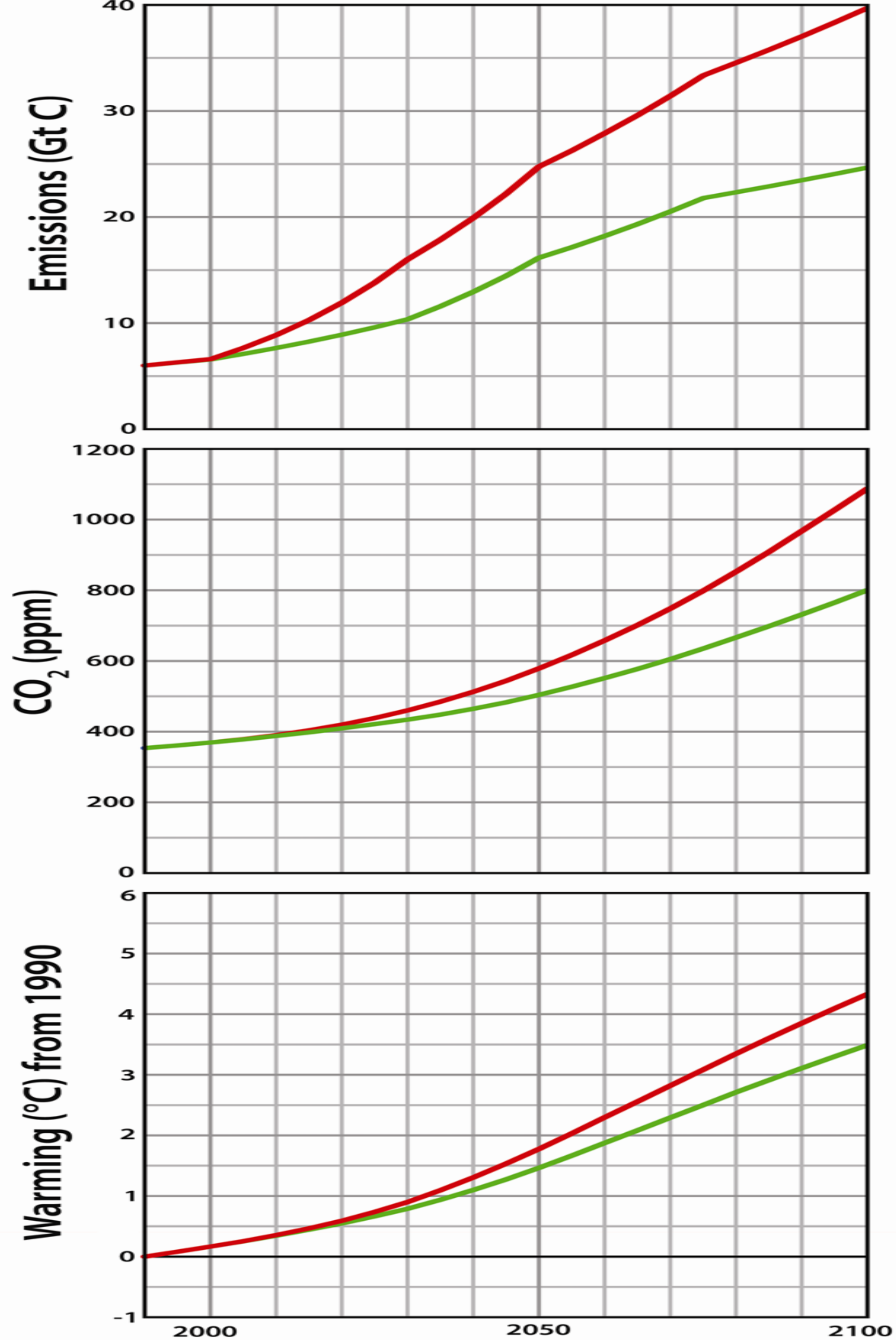
Assumed Business as Usual emission scenario per IEA (to 2050) extended to 2100 by author, concentration and warming calculations via MAGICC 5.3



CO_2 Emissions Gt C per Year

CO_2 ppm

Warming from 1990, C degree



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%

Atm. Sensitivity =3.0 C

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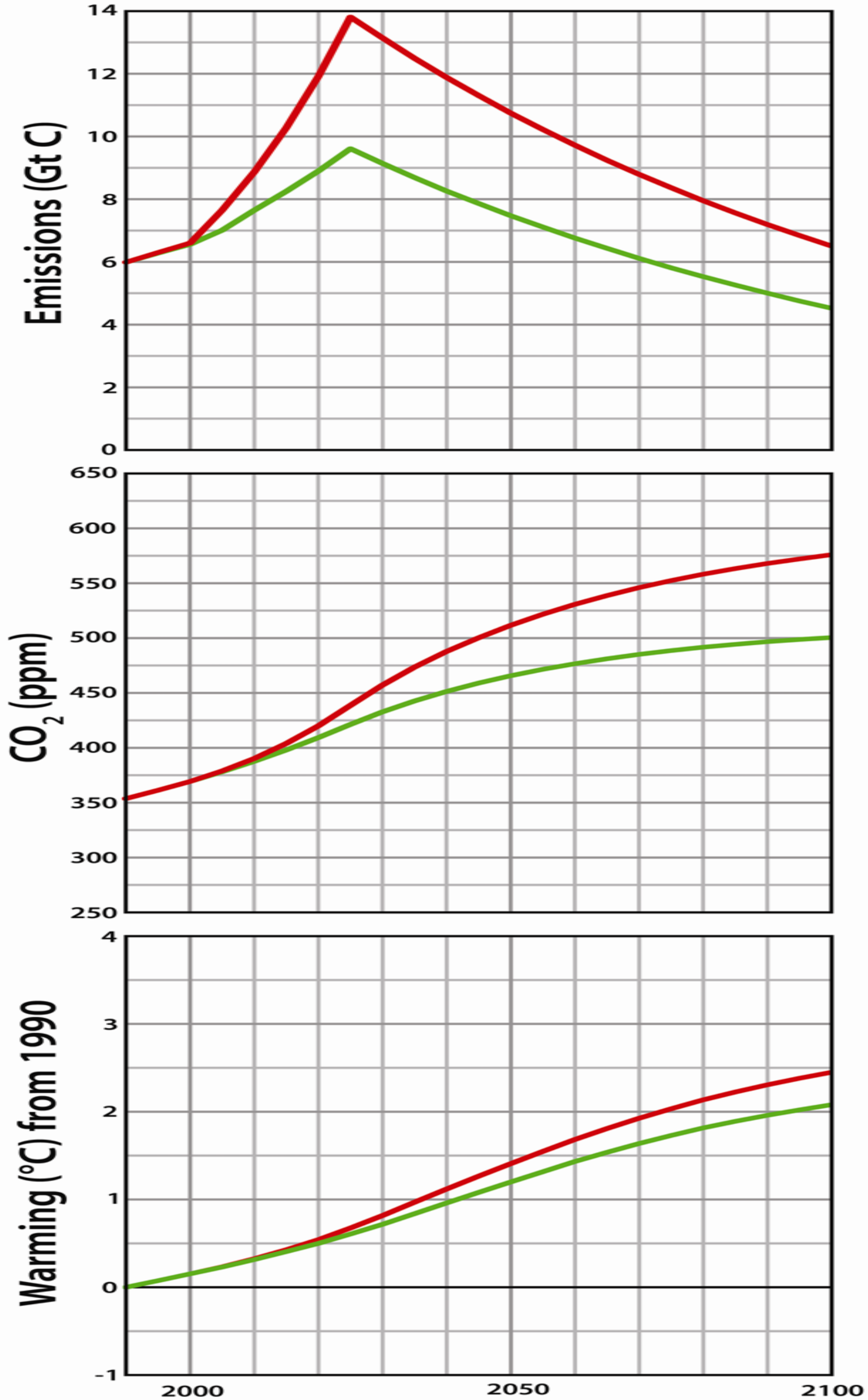

Two Mitigation Scenarios: Original assumed emission 2000 to 2025 growth rate of 1.6%, then a 1% annual reduction; Revised 2000 to 2025 growth rate of 3.0%, then an annual 1% reduction

Atm. Sensitivity =3.0 C

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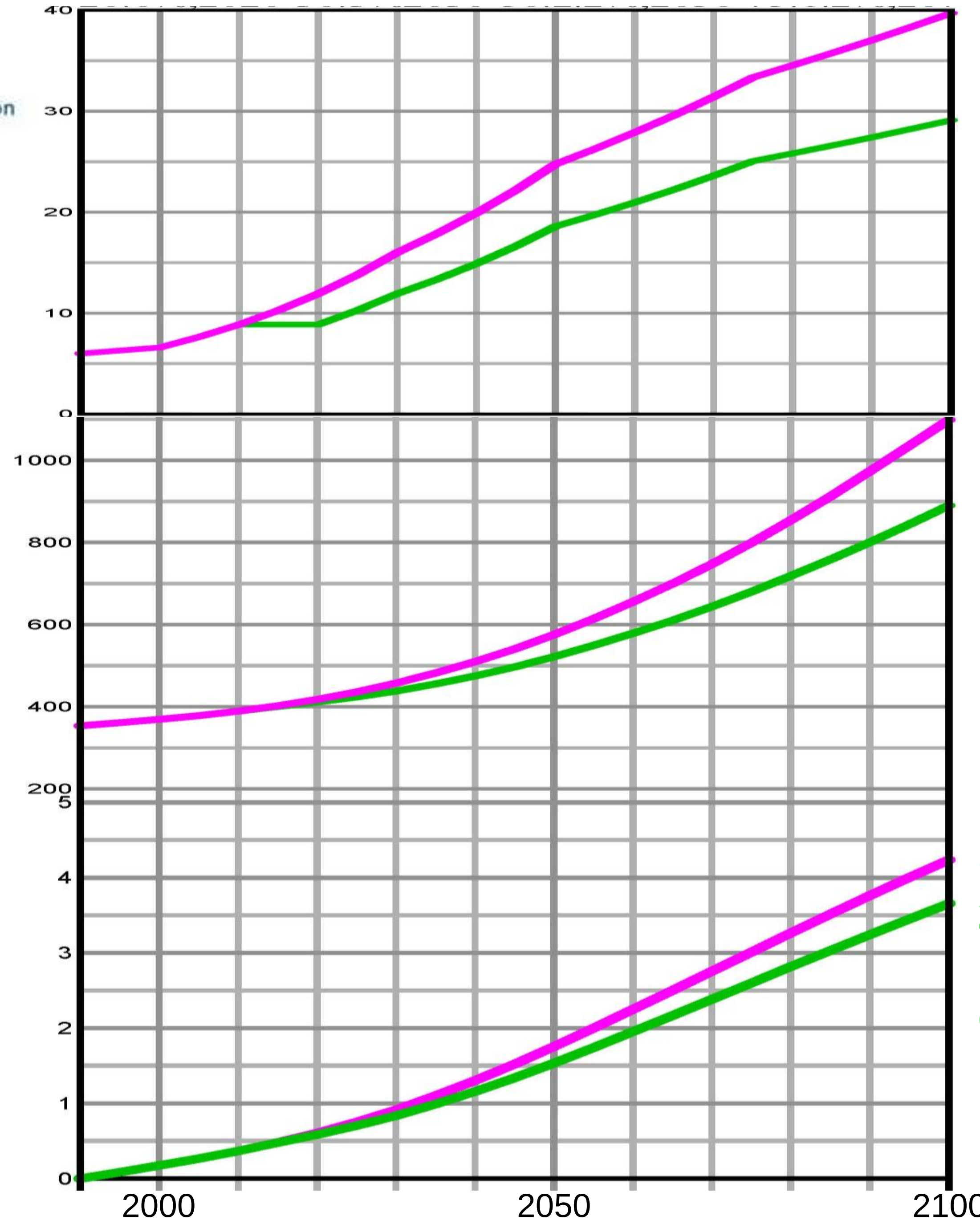
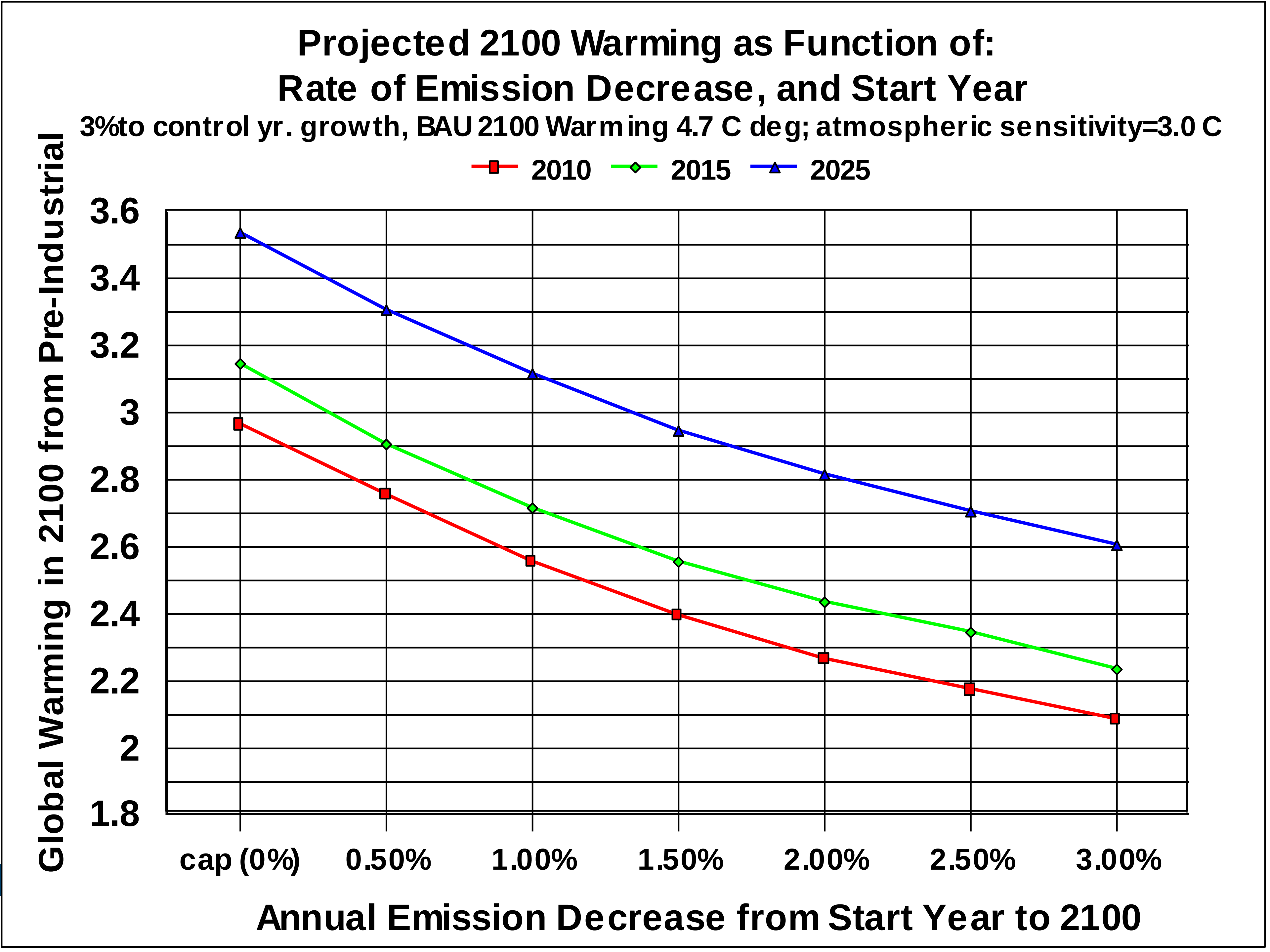


What are potential warming impacts for prolonged, 2010 to 2020, *Global Recession* (0% emission growth)?

Growth rate from 2000 to 2030 of 3.0% then lower growth rates:
2030 to 2050: 2.2%,
2050 to 2075: 1.2%,
2075 to 2100: 0.7%

***Global recession* 2010 to 2020 then 10 years of 3% growth, then same reduced growth rates**


Projected 2100 Warming as Function of:
Rate of Emission Decrease, and Start Year
3%to control yr. growth, BAU 2100 Warming 4.7 C deg; atmospheric sensitivity=3.0 C
2010
2015
2025
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
Global Warming in 2100 from Pre-Industrial
cap (0%)
0.50%
1.00%
1.50%
2.00%
2.50%
3.00%
Annual Emission Decrease from Start Year to 2100

In June 2008 IEA Released the 2008 version of Energy Technology Perspectives

- Mandate by G-8 Leaders and Energy Ministers
- in 2006 their *ACT* scenario (2050 =2005 emissions) still yielded ~3.1 C warming
- In light of IPCC (2007), they analyzed new *Blue* scenario to limit warming to ~ 2.4 C; this requires 2050 emissions to be 1/2 of 2005 values (1.5% annual reduction for 45+ years)
- They concluded:

"We are facing serious challenges in energy sector"

"The situation is getting worse"

"A global revolution is needed in ways that energy is supplied and used"

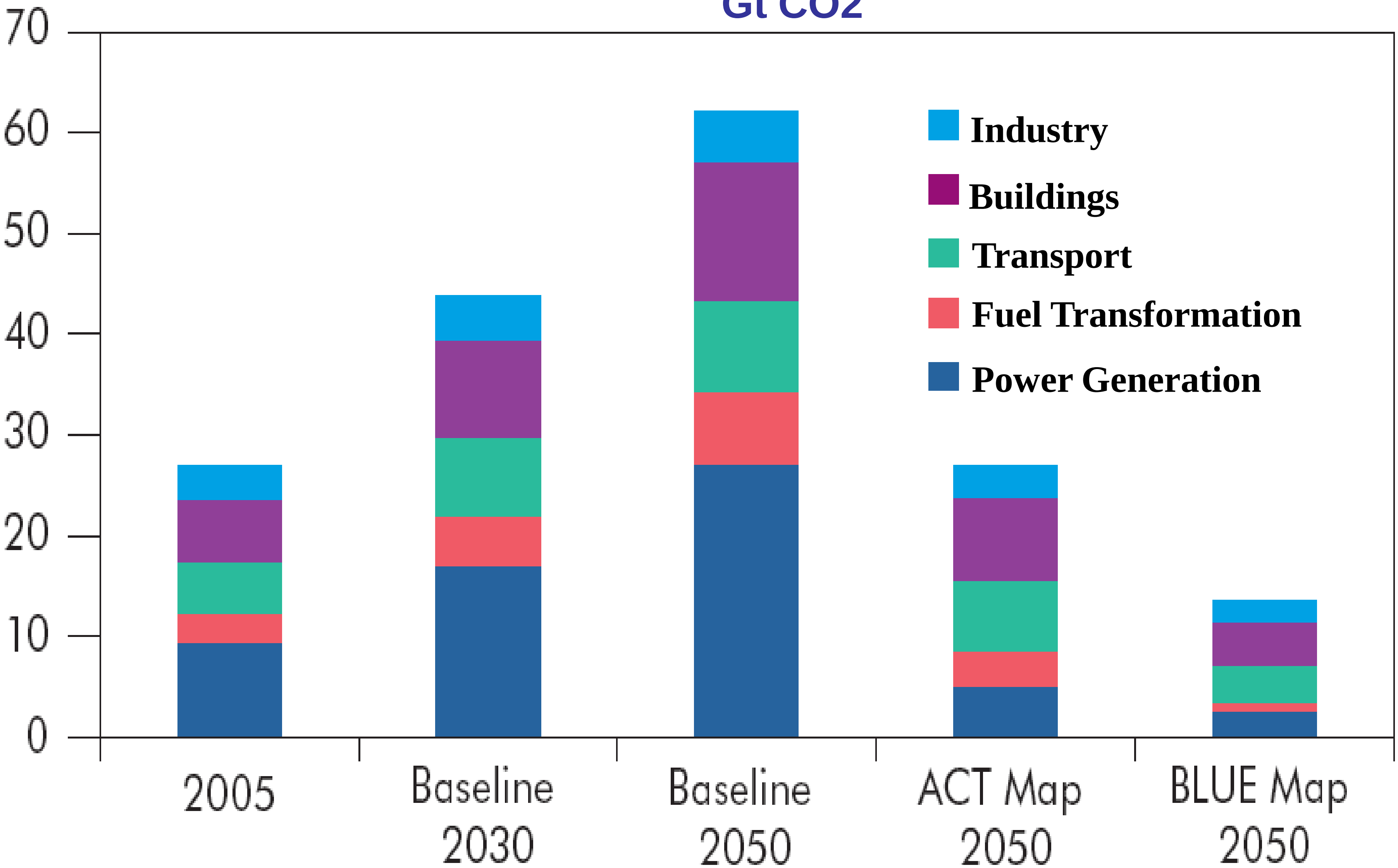
"The Blue scenarios require urgent implementation of unprecedented and far reaching new policies in the energy sector"

In June 2008 **IEA Released the 2008 version of Energy Technology Perspectives (Continued)**

- Key technologies not available: “a huge effort of RD&D will … be needed”
- “Critical technologies: solar PV, advanced coal and biomass, CCS, batteries, fuel cells and H_2”
- “There is an urgent need for full scale CCS demonstration”
- Blue scenario requires ***$13 to $16*** trillion for Research, Development Demonstration & Deployment (RDD&D)
- Blue scenario requires marginal costs up to **200 to 500 $/ton**; the more modest ACT scenario (2050 emissions=2005 emissions) *revised* from **$25 to 50$/ton**
- Additional *investment* needs in the Blue scenario is ***$45*** trillion; about ***$43*** in energy cost savings

IEA CO2 Projections: Base, ACT and Blue Scenarios

Gt CO2



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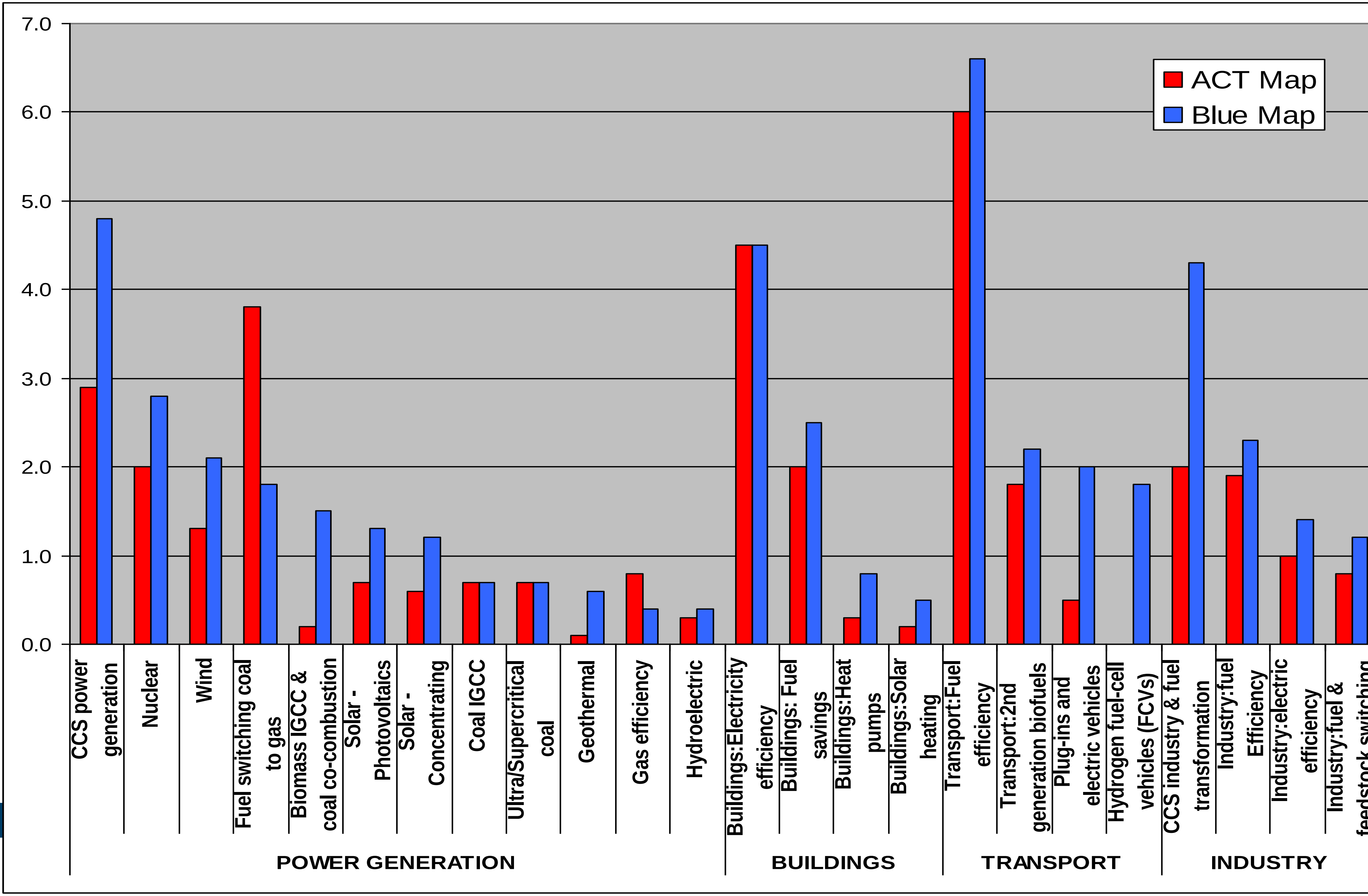
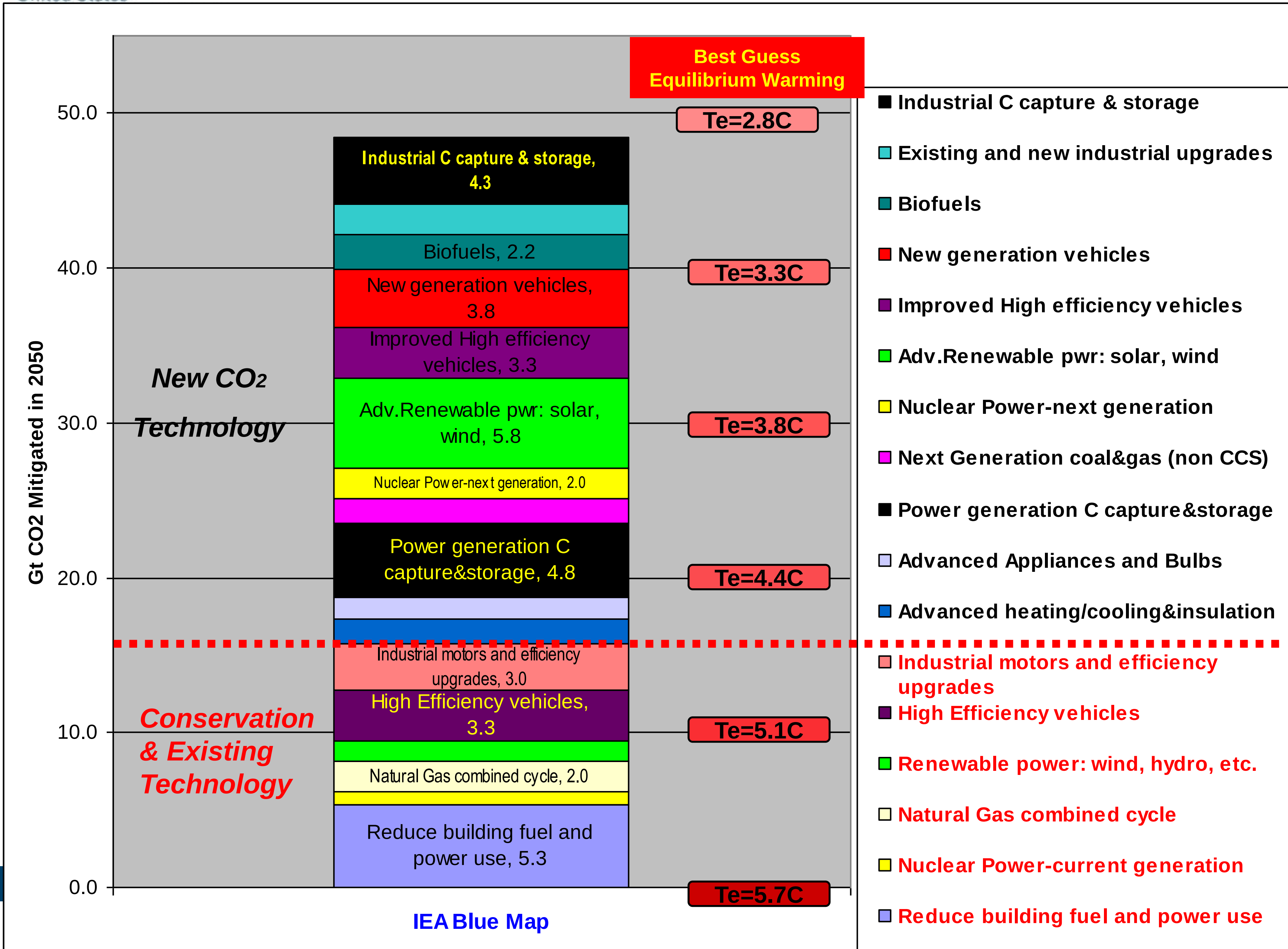
Summary Of IEA Technology Scenarios;

Total: 35 Gt in 2050 for ACT, 48 Gt for Blue



Energy Technologies: potential to mitigate global Gt CO_2 in 2050 & impact on next century equilibrium warming, $T_{e(Grouped)}$



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Power Generation Sector-Key Technologies

Impact in 2050 Gt CO_2 per IEA

Technology	Current State of the Art	Blue 2050 Impact	Issues	Technology R,D&D Needs
Solar-Photovoltaic and concentrating (renewable)	First generation commercial, but very high costs	2.5	Costs unacceptably high, solar resource intermittent	**High**, breakthrough R,D&D needed to develop & demo cells with higher efficiency and lower capital costs
Wind Power (renewable)	Commercial	2.1	Costs very dependent on strength of wind source, large turbines visually obtrusive, intermittent power source	**Medium**, higher efficiencies, off-shore demonstrations
Fuel Switching coal to gas	Commercial	1.8	Key issue is availability and affordability of natural gas	**Medium**, higher efficiencies with new materials desirable
Nuclear Power-next generation	Developmental, Generation III+ and IV: e.g. Pebble Bed Modular Reactor and Supercritical Water Cooled Reactor	1.8	Deployment targeted by 2030 with a focus on lower cost, minimal waste, enhanced safety and resistance to proliferation	**High**, Demonstrations of key technologies with complimentary research on important issues

Power Generation Sector-Key Technologies, Continued

Technology	Current State of the Art	Blue 2050 Impact	Issues	Technology R,D&D Needs
Coal IGCC with CO2 Capture and Storage	*IGCC* : early commercialization, Underground storage *(US)* : early development.	1.6	*IGCC* :High capital costs, retrofittability, viability for low rank coals, complexity and potential reliability concerns; *US* : Cost, safety, efficacy	**High**, *IGCC* : Demos on a variety of coals, hot gas cleanup research; *US* : major program with long term demos evaluating large number of geological formations to evaluate environmental impact, efficacy, cost
Pulverized Coal/Oxygen combustion with CO2 Capture and Storage	Developmental: *US* early development	1.6	Oxygen combustion allows lower cost CO2 removal, but oxygen production cost is high, retrofittabilty concerns; *US* : Cost, safety and permanency	**High**, large pilot followed by full scale demos needed, low cost O_2 production needed, *US* requires major program (see write-up above)
Pulverized Coal with CO2 Capture and Storage	CO_2 scrubbing with MEA near commercial but expensive; *US* early development	1.6	*US* : Cost, safety and efficacy issues, CO_2 scrubbing energy intensive: yielding high costs and energy penalties, also retrofittability issues	**High,** *US* requires major program (see write-up above); affordable CO_2 removal technologies need to be developed and demonstrated
Biomass as fuel gasified or co-fired with coal (renewable)	Commercial, steam cycles	1.5	Biomass dispersed source, limited to 20% when co-fired with coal	**Medium,** biomass/IGCC would enhance efficiency and CO_2 benefit; also genetic engineering to enhance biomass plantations
Nuclear Power-current generation	Commercial, Pressurized Water Reactors and Boiling Water Reactors	1.0	Plant siting, high capital costs, levelized cost 10 to 40% higher than coal or gas plants, potential U	**Medium,** Waste disposal research

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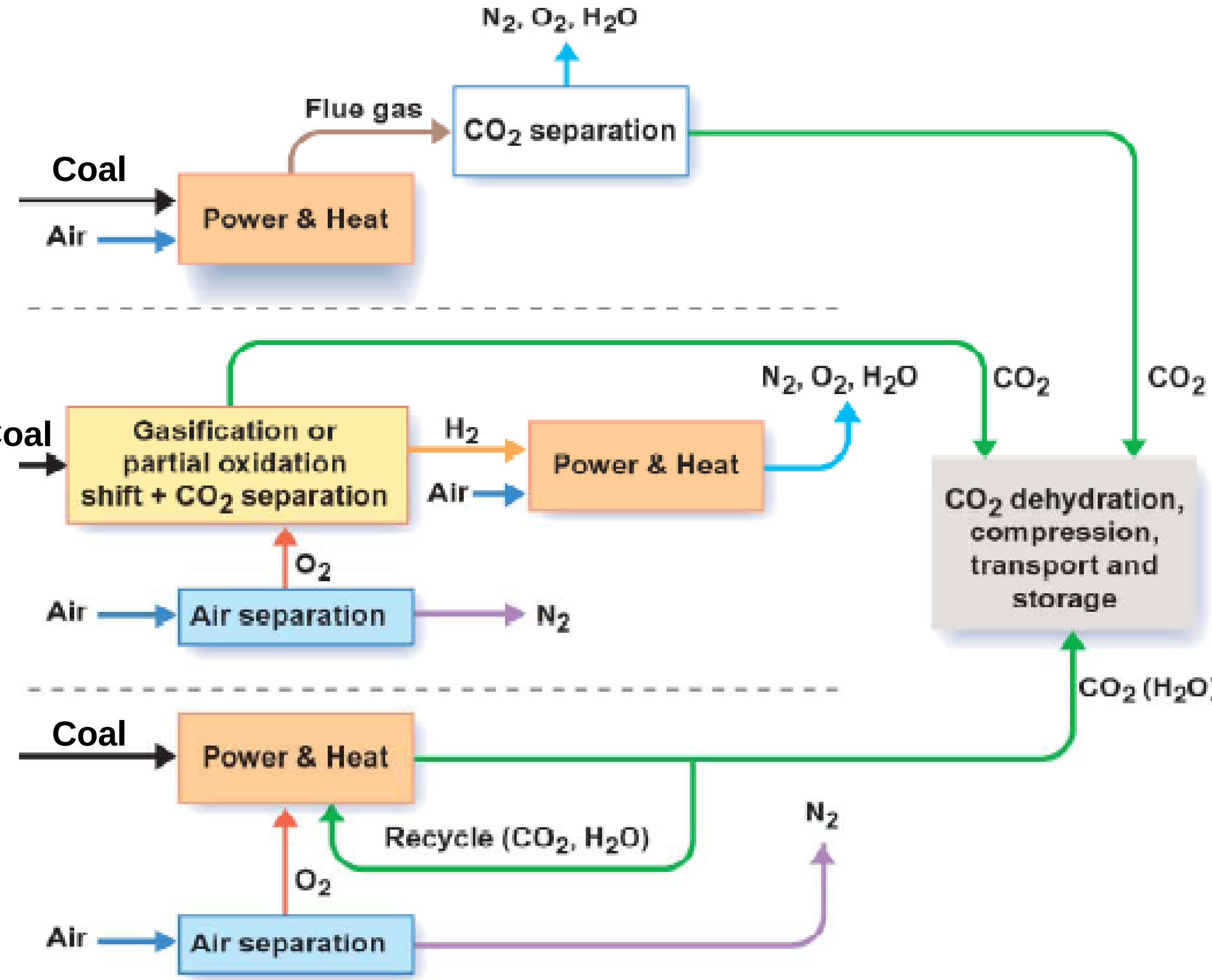
Three Options for CO_2 Capture from Coal Power Generation Plants

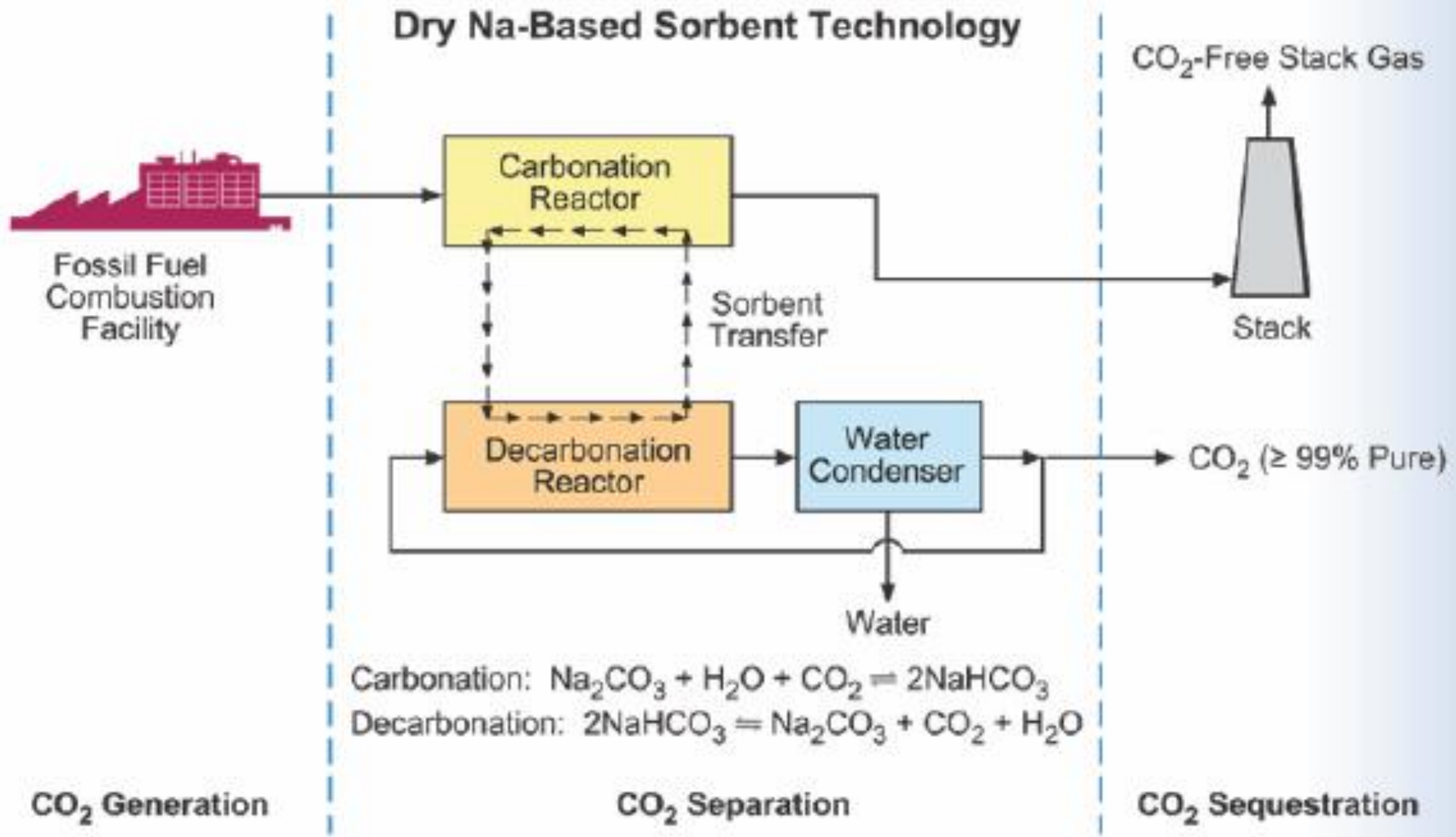
Post Combustion CO_2 Separation

IGCC: Pre-combustion CO_2 removal

Post Oxy-fuel Combustion CO_2 Removal



RTI's "Dry Carbonate Process" for CO2 Capture from Power Plants



The Climate Change Technology Challenge

- **Man is pumping CO_2 in the atmosphere at unprecedented rates; 30 billion tons last year, and growing at 3% annually from 2000 to 2006. Although US is large emitter, much of recent growth is due to China; key drivers: economic and population growth**
- **It is too late to avoid substantial warming and significant impacts; at least 2 C inevitable, the challenge remaining: avoid catastrophic warming**
- **Limiting warming to below 2.5 C will be a monumental challenge; growth rate of 3% must change to -1 to -2%; sooner control starts, the better**
- **Available technology if aggressively utilized, will only avoid about 40%% of required CO_2 by 2050; *next generation low emission/high efficiency technologies need to be developed and utilized ASAP***

The Climate Change Technology Challenge-continued

- **Major technology advances necessary, especially in critical power generation and mobile source sectors; *carbon capture and storage, nuclear reactors, and low emission vehicles are critical technologies***
- **No "silver bullets", all promising technologies should be pursued**
- **Research funding is grossly inadequate; "too few eggs in too few baskets"**
- **Focused fundamental research aiming at breakthrough technologies important**
- **Technology necessary but not sufficient; utilization requires incentives/regulations**
- ***"A global revolution is needed in ways that energy is supplied and used"***
- **Given the monumental challenge of mitigating substantial climate change via energy technology restructuring, geoengineering options should be seriously studied**

Current Status of GHG Mitigation Policy in Obama Administration

- President Obama: “The issue of climate change is one that we ignore at our own peril. … what we can be scientifically certain of is that our continued use of fossil fuels is pushing us to a point of no return. And unless we free ourselves from a dependence on these fossil fuels and chart a new course on energy in this country, we are condemning future generations to global catastrophe.”
- President Obama has put in place strong leaders who have stated global climate change mitigation a high priority: Carol Browner, White House Advisor, John Holdren, Science Advisor, Steve Chu, DOE Secretary, Lisa Jackson,EPA Administrator
- In April 2007,Supreme Court: GHGs meet Clean Air Act definition of “air pollutant,” authorizes regulation of GHGs subject to EPA determination that GHG emissions cause or contribute to air pollution that may reasonably be anticipated to ***endanger*** *public health or welfare.* A positive EPA endangerment determination is likely, allowing potential CAA regulation of both mobile and stationary sources; an NSPS for CO_2 from power generators is possible.

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Current Status of GHG Mitigation Policy in Obama Administration, continued

- Administration committed to signing legislation to implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions by 14% below 2005 levels by 2020 and 83 below 2005 levels by 2050. Proposal involves ***auctioning*** of allowances raising $646 billion over 10 years.
- Obama announced $1.2 billion in basic research for DOE's national laboratories; also money to upgrade facilities at national labs, for research in renewable energy, such as solar power and biofuels, as well as in nuclear energy, underground storage of carbon dioxide, and hydrogen.
- Through the stimulus package, the federal government has set aside $59 billion in direct spending and in tax incentives to promote clean energy and energy efficiency; primary focus: green buildings

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Our Stakeholders Count on Us;
They will reap from seeds we sow