The Challenge of Climate Change: Towards a New Energy Future

By

Dr. R. K. Pachauri

Director General, TERI and Chairman, IPCC

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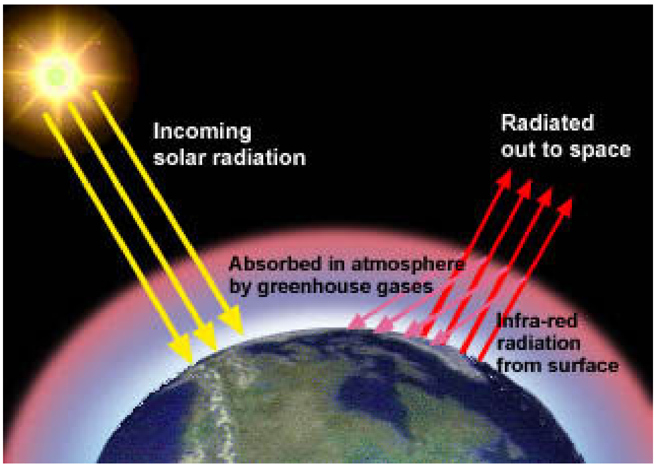
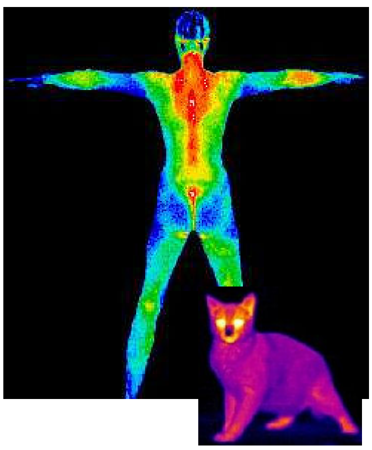
What is the "greenhouse effect"?



Like the sun, the Earth also emits radiation. It is much cooler than the sun, though, so it emits in the infrared, just like a person, or a cat. Some of that energy is absorbed by molecules in the atmosphere, affecting the global energy balance:



Radiated heat = Total absorbed energy

$T_e = [(1\text{-}A)F_s/4s]^{1/4}$

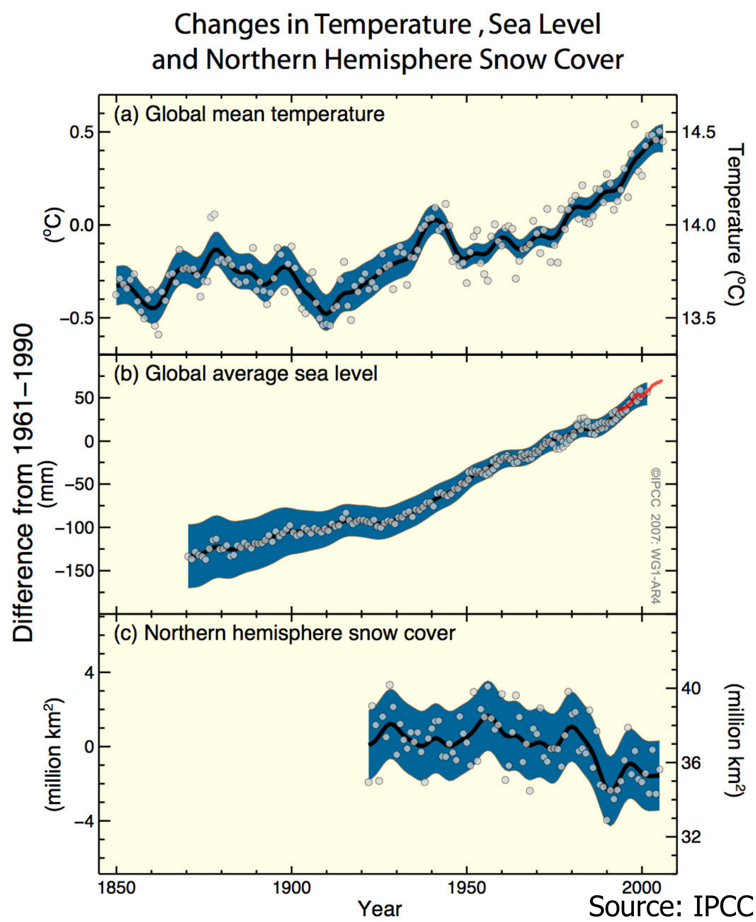
With no greenhouse effect, $T_e \approx -18°C$. We'd be frozen. The real average temperature is +15° C, due to the Earth's natural greenhouse effect. (see IPCC (1990).

Direct observations of recent climate change

Global mean temperature

Global average sea level

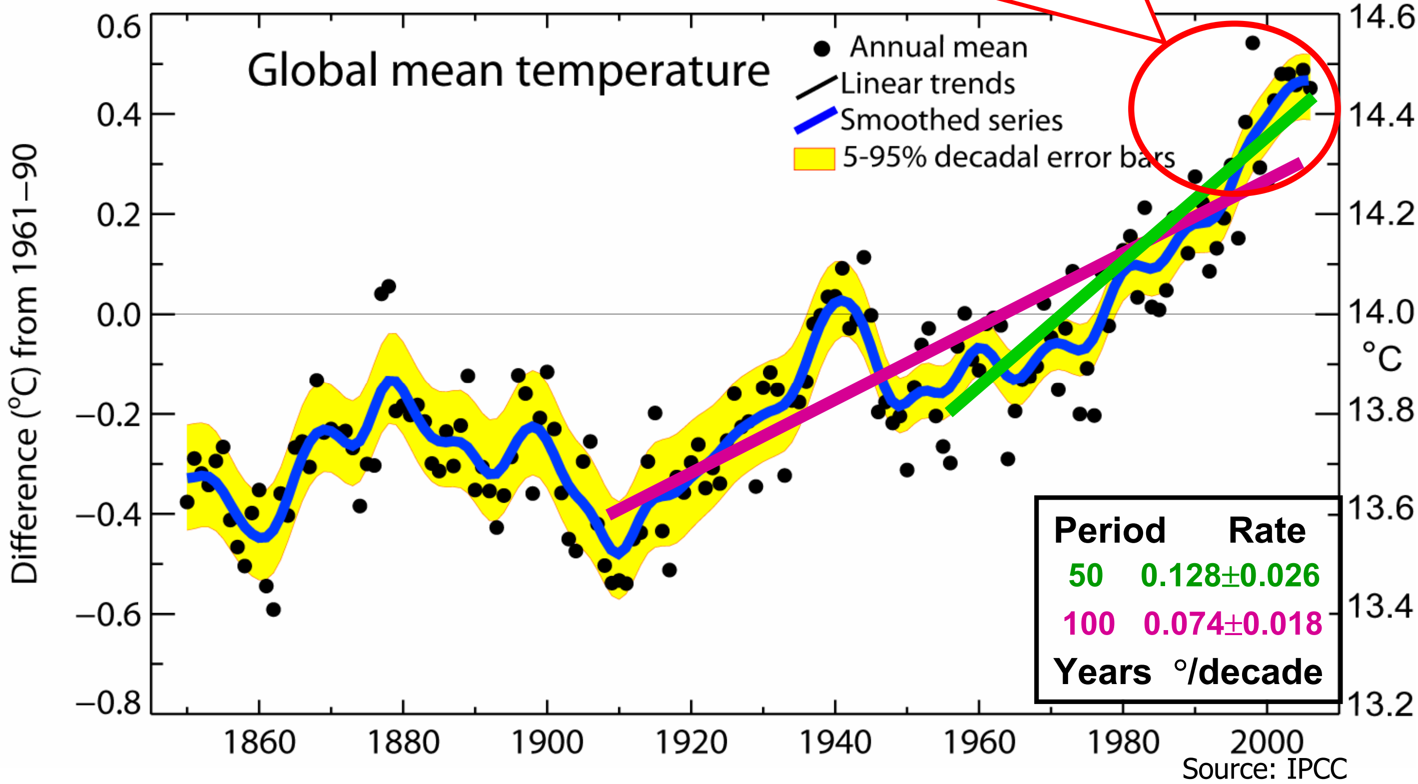
Northern hemisphere Snow cover



Source: IPCC

Global mean temperatures are rising faster with time

Warmest 12 years:
1998,2005,2003,2002,2004,2006,
2001,1997,1995,1999,1990,2000



Source: IPCC

Human and natural drivers of climate change

- Annual fossil CO_2 emissions increased from an average of 6.4 GtCper year in the 1990s, to 7.2 GtC per year in 2000-2005
- CO_2 radiative forcing increased by 20%from 1995 to 2005, the largest in any decade in at least the last 200 years

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- Changes in solar irradiance since 1750 are exstimated to have caused a radiative forcing of +0.12 [+0.06 to +0.30] Wm^{-2}

Source: IPCC

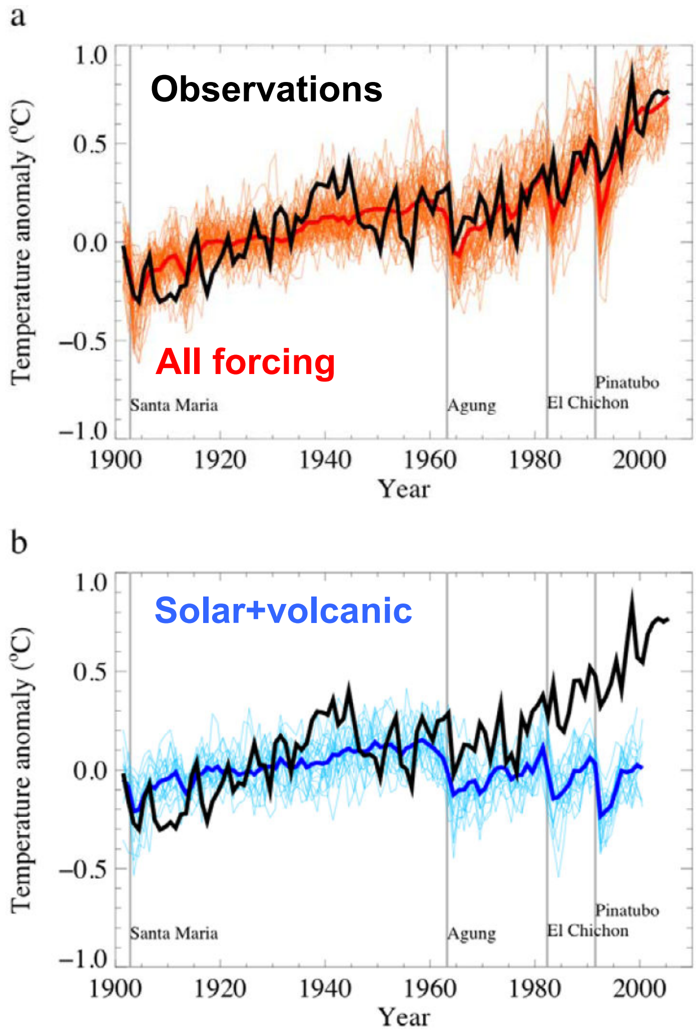
Human and Natural Drivers of Climate Change

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to *very high confidence* that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2}.

Source: IPCC

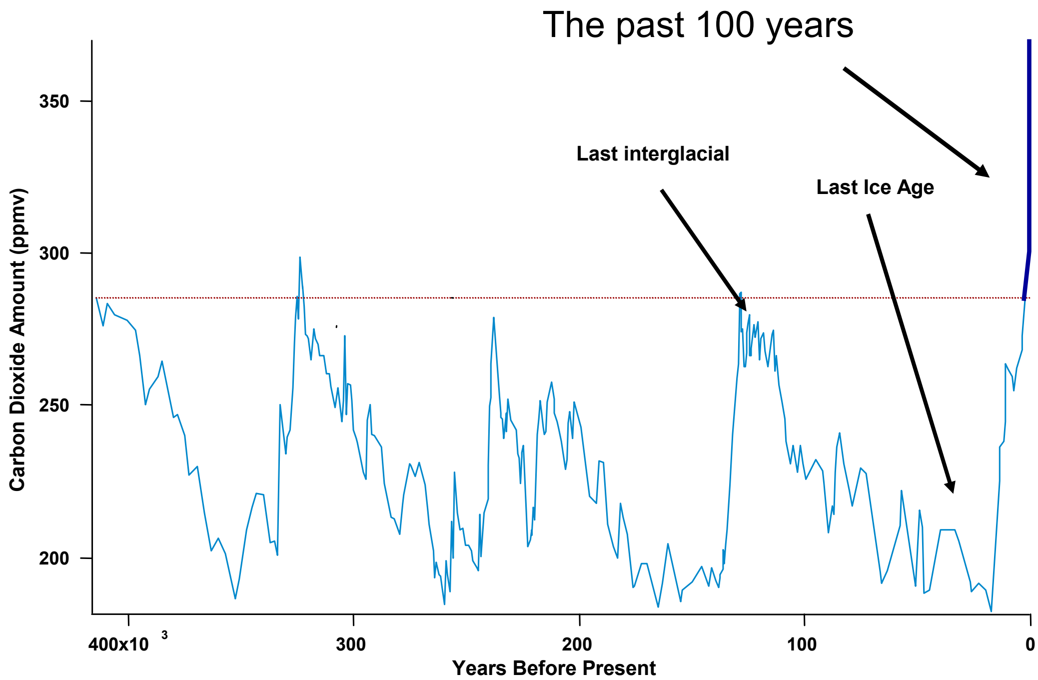
Attribution

- are observed changes consistent with
- ☑ expected responses to forcings
- ☒ inconsistent with alternative explanations



Source: IPCC

Some information about carbon dioxide changes through four past ice ages (from ice cores), and in the modern era (from global data)



Ice ages are 'forced' by earth's orbital clock….

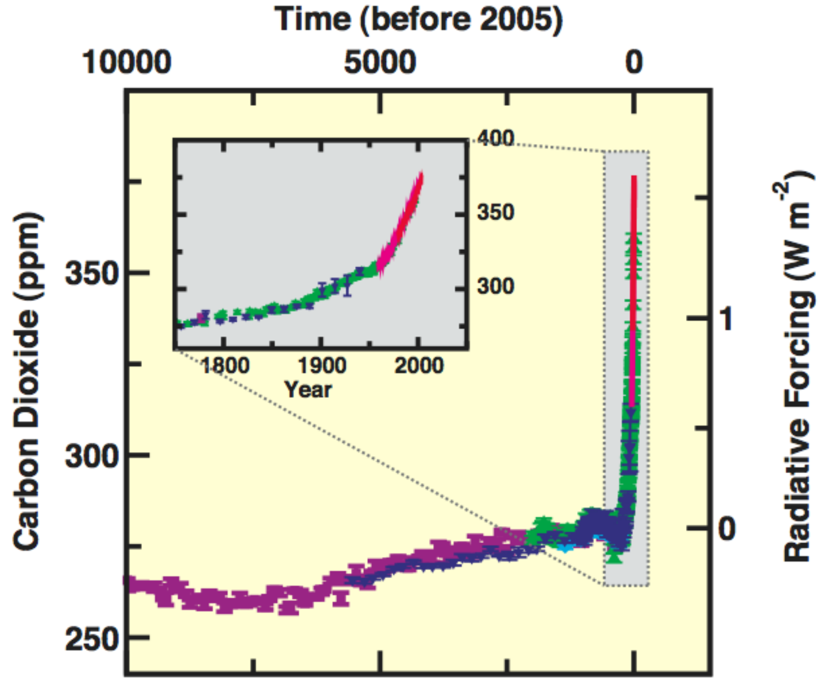
It is well established that there is more carbon dioxide in the atmosphere today than there has been in at least 650,000 years. **(Figure by S. Solomon)**

Human and Natural Drivers of Climate Change: Unprecedented

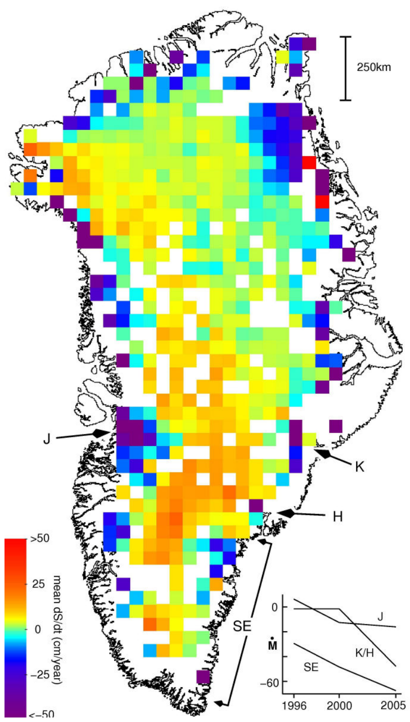
Dramatic rise in the industrial era

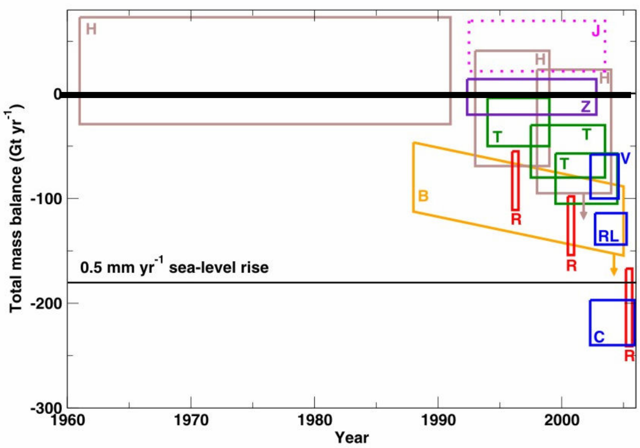
- Largest growth rate of CO2 seen over the last ten years (1995-2005) than in any decade at least since direct measurements began (1960).

Changes in Greenhouse Gases from ice-Core and Modern Data



Greenland and Antarctic ice sheets are shrinking

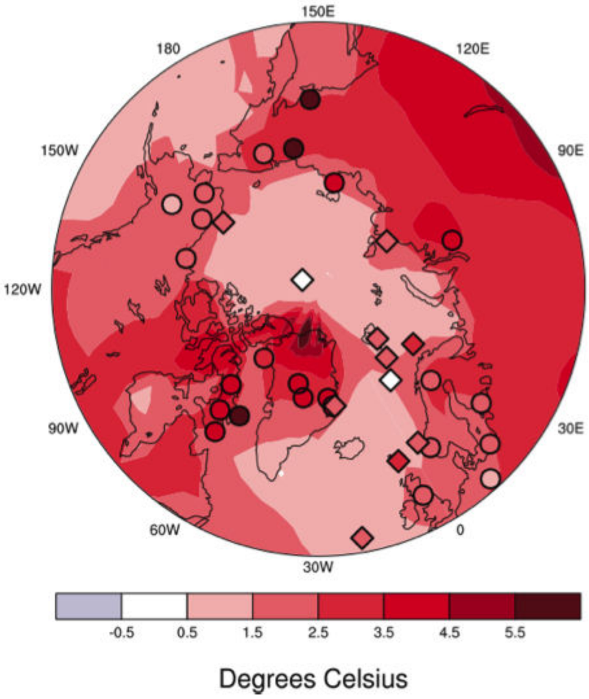




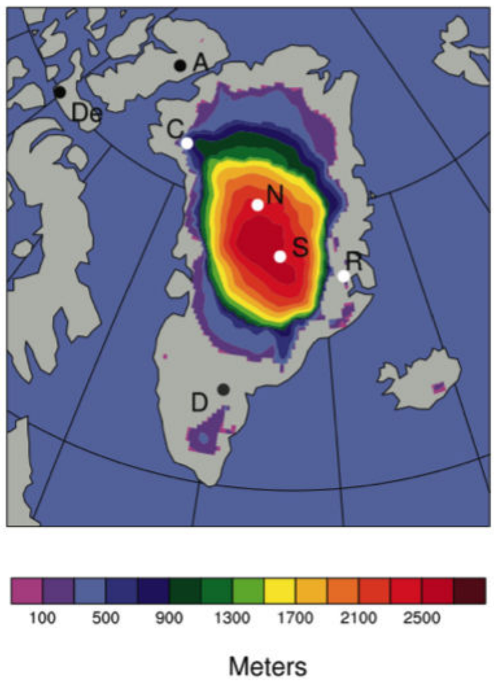
Greenland mass loss is increasing
Loss: glacier discharge, melting

Greenland gains mass in the interior, but loses more at the margins

125,000 years ago, higher polar temperatures <u>due to Earth orbit changes</u> led to sea level 4-6m above present - contributions may have come from both Greenland and Antarctica

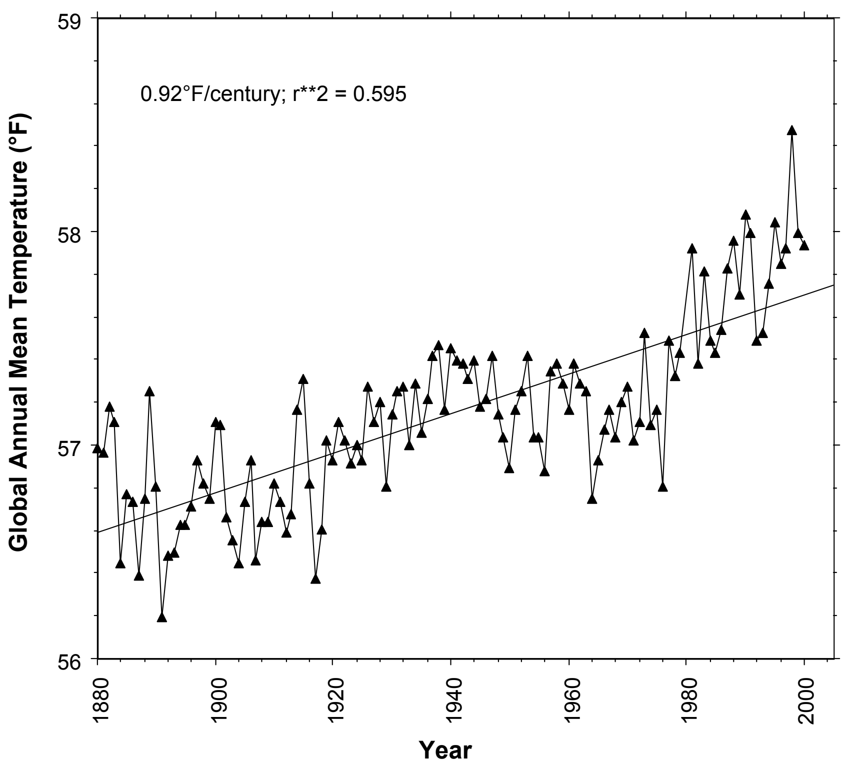


Simulated and observed Arctic warming at 125,000 yr B.P. ≈3-5° C



Estimated reduction in Greenland Ice Sheet Area and Thickness

Global Annual Average Temperatures



QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Figure by S. Solomon

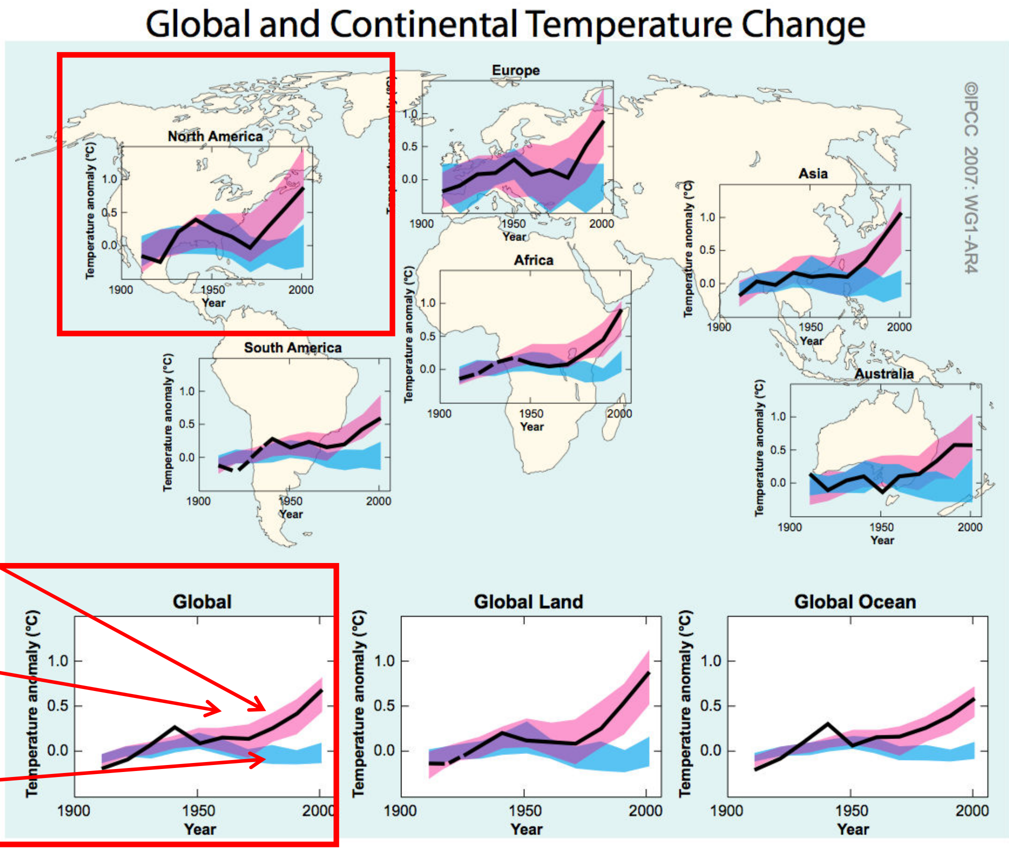
Understanding and Attributing Climate Change

Anthropogenic warming is likely significant averaged over each of the inhabited

Observed

Expected for all forcings

Natural forcing only



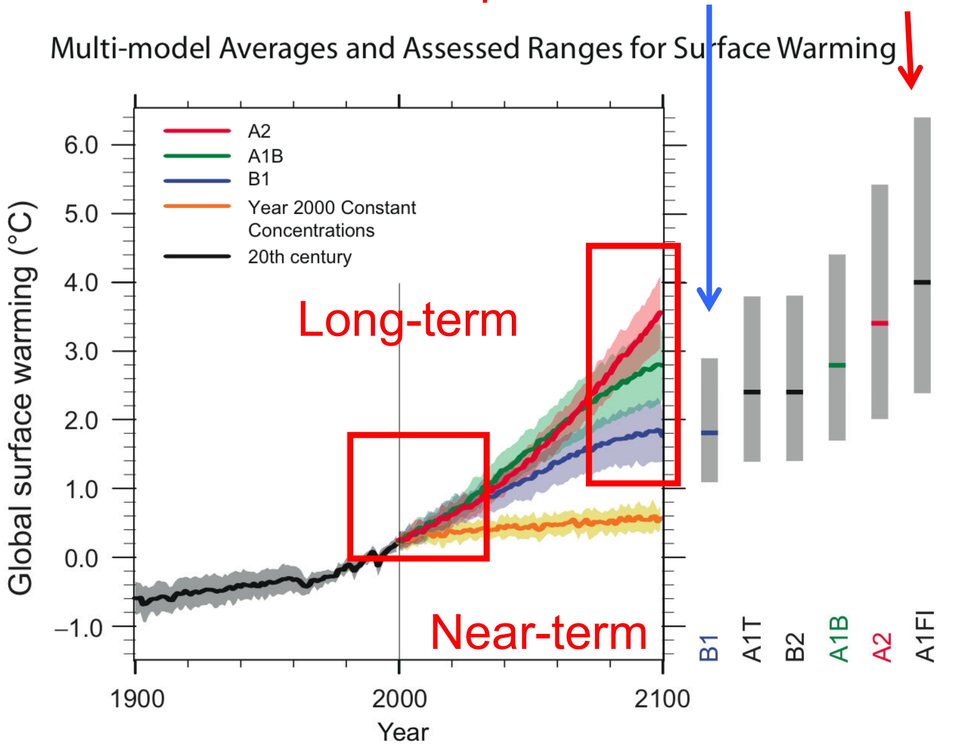
Projections of Future Changes in Climate

The long-term future depends on human choices about emissions. <u>Best estimates and likely ranges given in IPCC for the first time.</u>

In 2100: 600 ppmv CO_2 equiv (B1) Best estimate is +1.8° C by 2100; likely 1.1-2.9° C further warming;

Or 1550 ppmv (A1FI) Best 4° C [likely 2.4-6.4° C]

CO2 equivalent: 600 ->1550



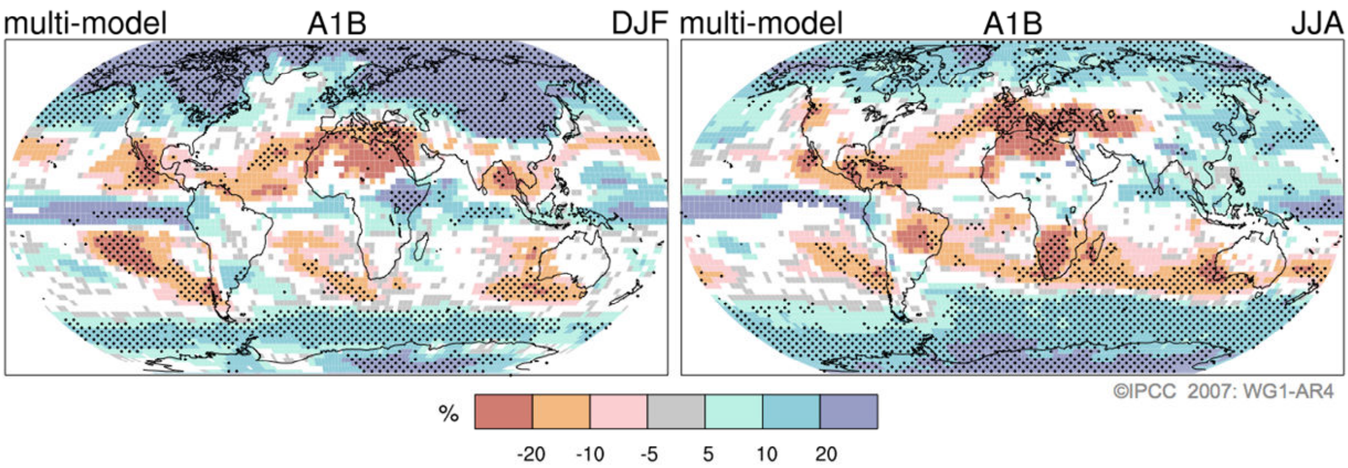
Projections of Future Changes in Climate: Committed Warming is Coming

- **For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios.**

- **Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. {10.3, 10.7}**

Projections of Future Changes in Climate

Projected Patterns of Precipitation Changes



Brand new in AR4: Drying in much of the subtropics, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed.

More heavy precipitation and more droughts….

Projections of Future Changes in Climate

- **Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.**

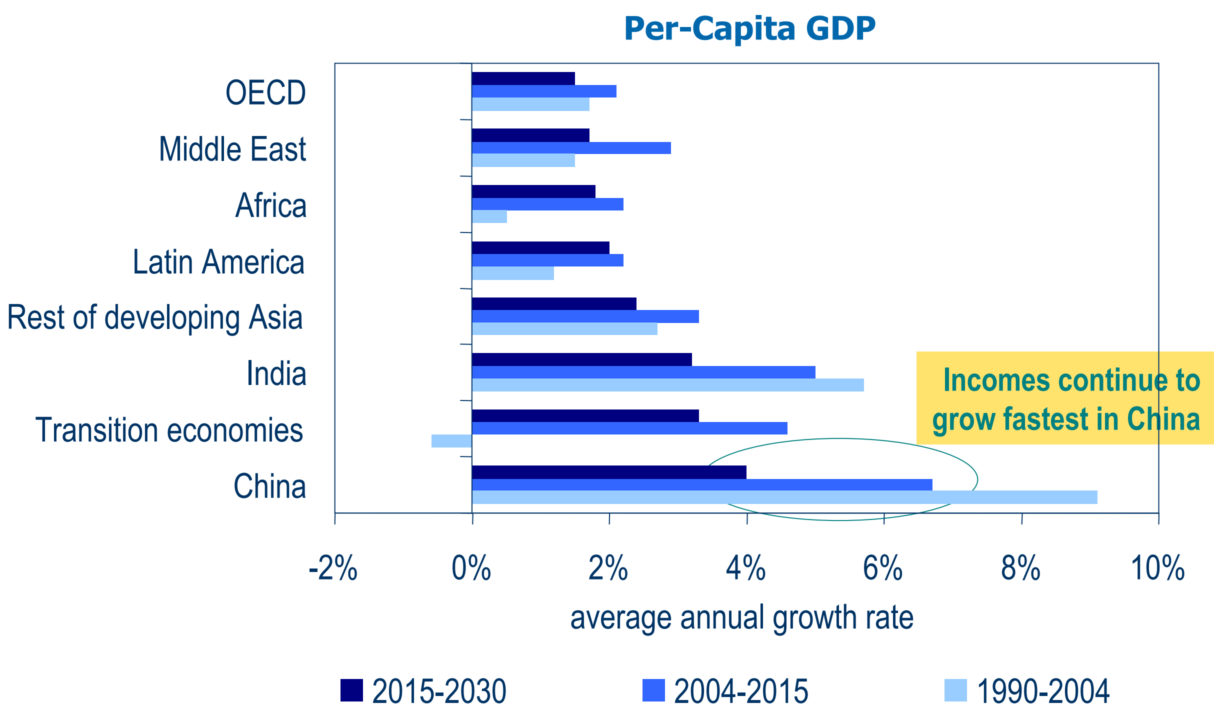
- **Temperatures in excess of 1.9 to 4.6°C warmer than pre-industrial sustained for millennia…eventual melt of the Greenland ice sheet. Would raise sea level by 7 m. Comparable to 125,000 years ago.**

Projections of future changes in climate

- *Very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent
- *Likely* that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation
  - **less confidence in decrease of total number**
- Extra-tropical storm tracks projected to move poleward with consequent changes in wind, precipitation, and temperature patterns

Source: IPCC

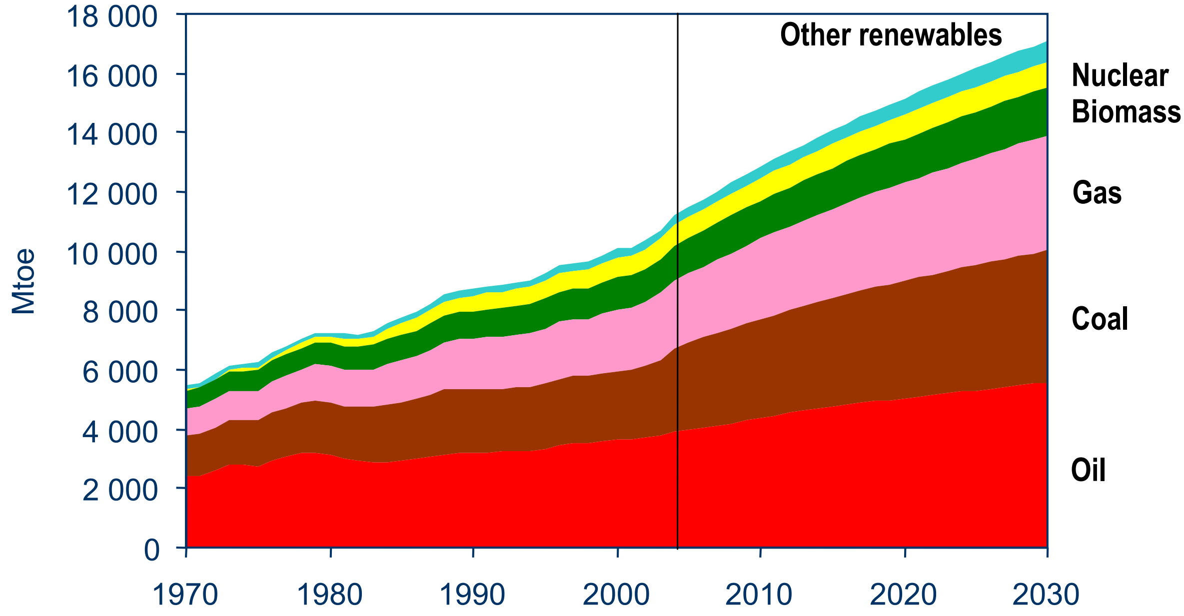
Macroeconomic Assumptions



Incomes in the OECD are still four times higher than in rest of the world in 2030

Source: WEO 2006

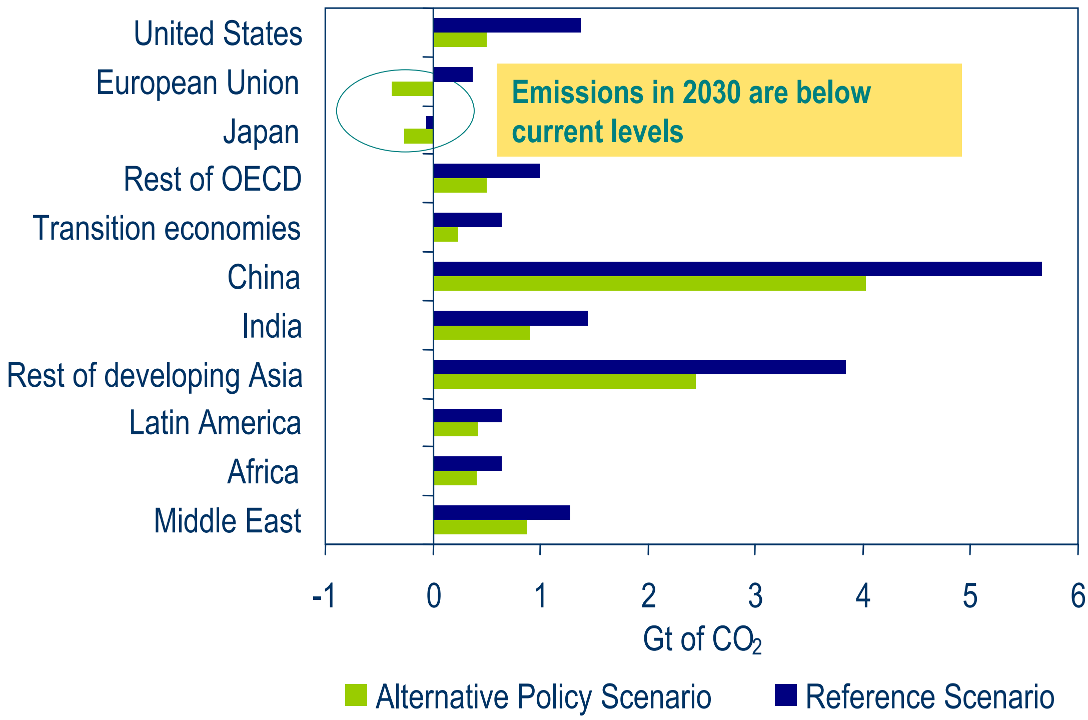
Reference Scenario:
World Primary Energy Demand



Global demand grows by more than half over the next quarter of a century, with coal use rising most in absolute terms

Source: WEO 2006

Alternative Policy Scenario:
Change in Energy-Related CO_2 Emissions, 2004-2030

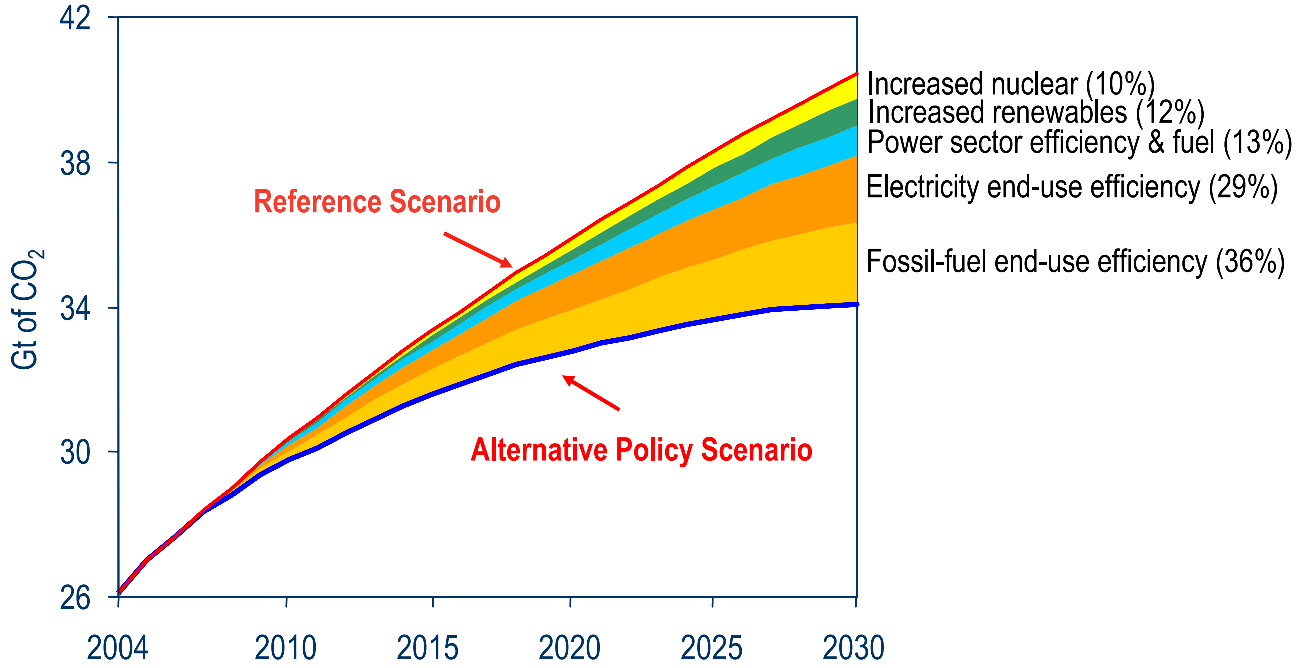


OECD emissions also peak & then decline before 2030, falling below 2004 levels in Europe and Japan

Source: WEO 2006

Alternative Policy Scenario:

Global Savings in Energy-Related CO_2 Emissions

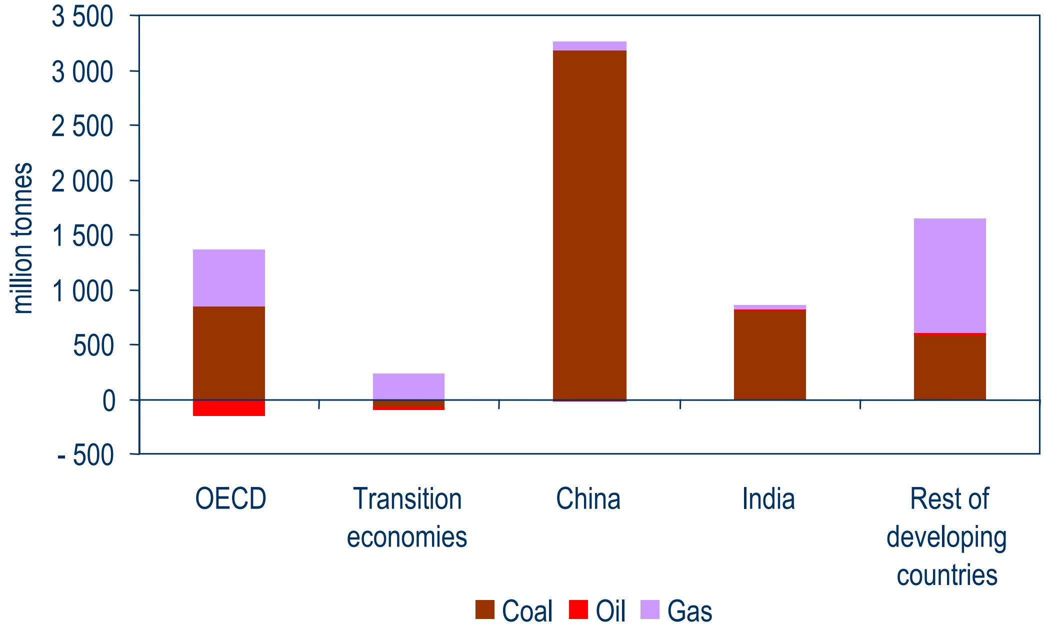


Improved end-use efficiency of electricity & fossil fuels accounts for two-thirds of avoided emissions in 2030

Source: WEO 2006

Reference Scenario:

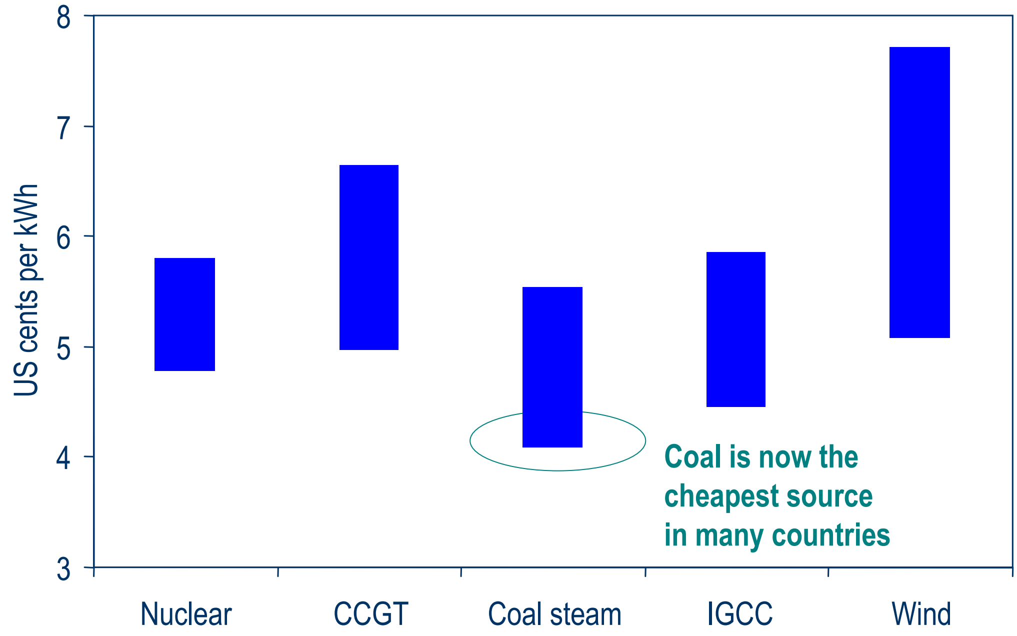
Increase in Power Sector CO_2 Emissions by Fuel, 2004-2030



China and India account for 58% of the increase in power sector CO_2 emissions to 2030

Source: WEO 2006

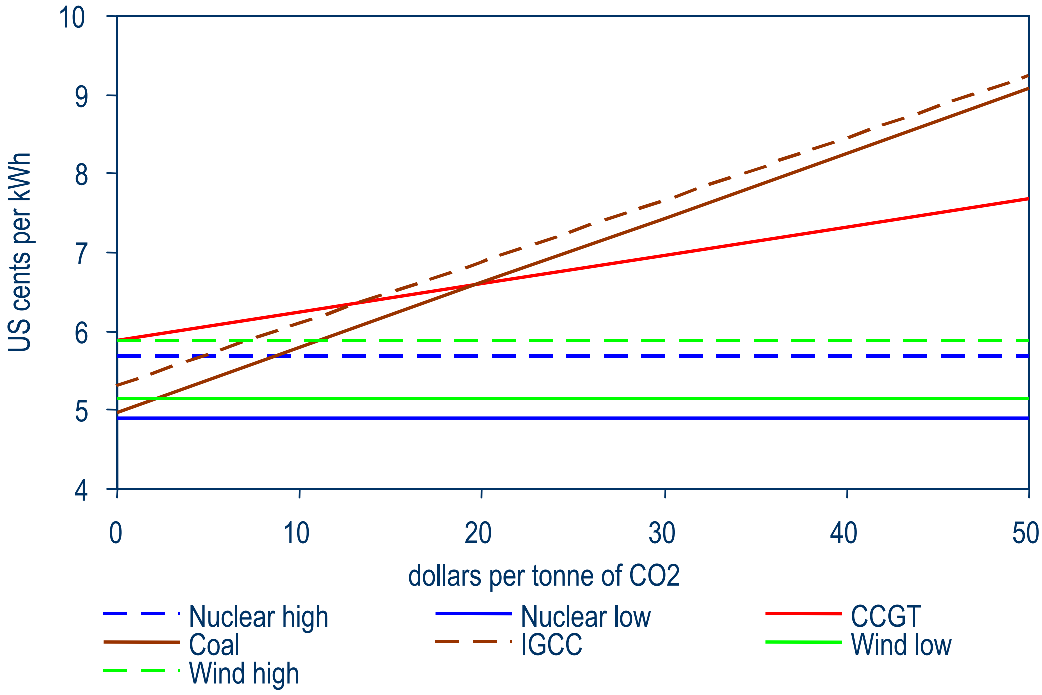
Electricity Generating Cost Ranges of Main Technologies



Gas-fired electricity is no longer the cheapest form of generation; prices assumed to remain between $6 and $7 per MBtu

Source: WEO 2006

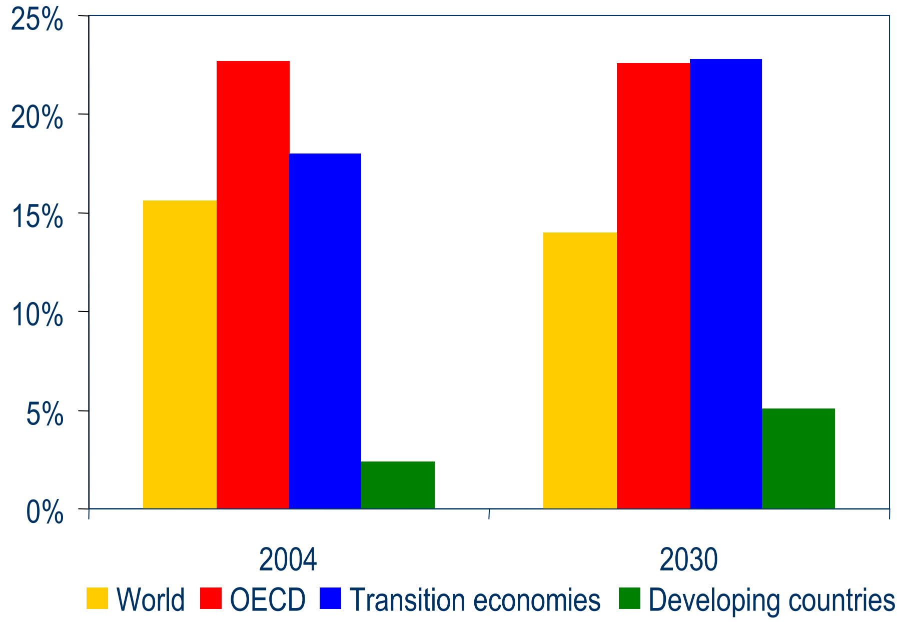
Impact of Carbon Value on Generating Costs



A carbon value would improve the competitive position of gas, wind & nuclear power against coal

Source: WEO 2006

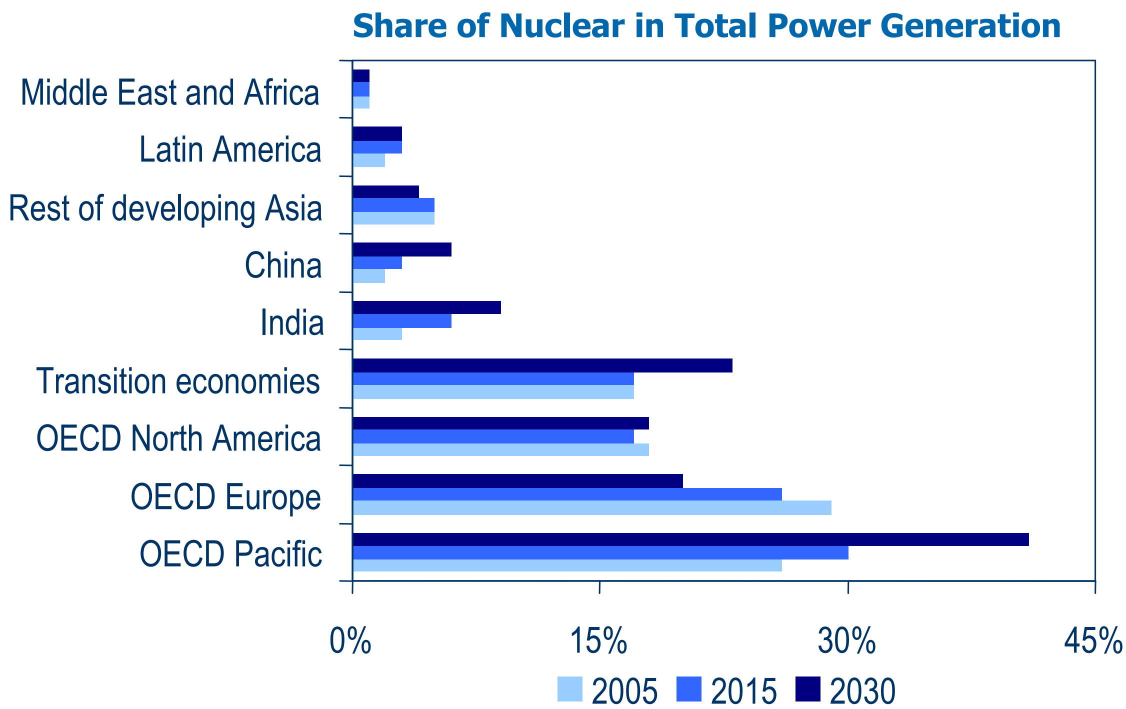
Alternative Policy Scenario:
Share of Nuclear Power in Electricity Generation by Region



The share of nuclear power drops much less than in the Reference Scenario, helping to curb emissions growth

Source: WEO 2006

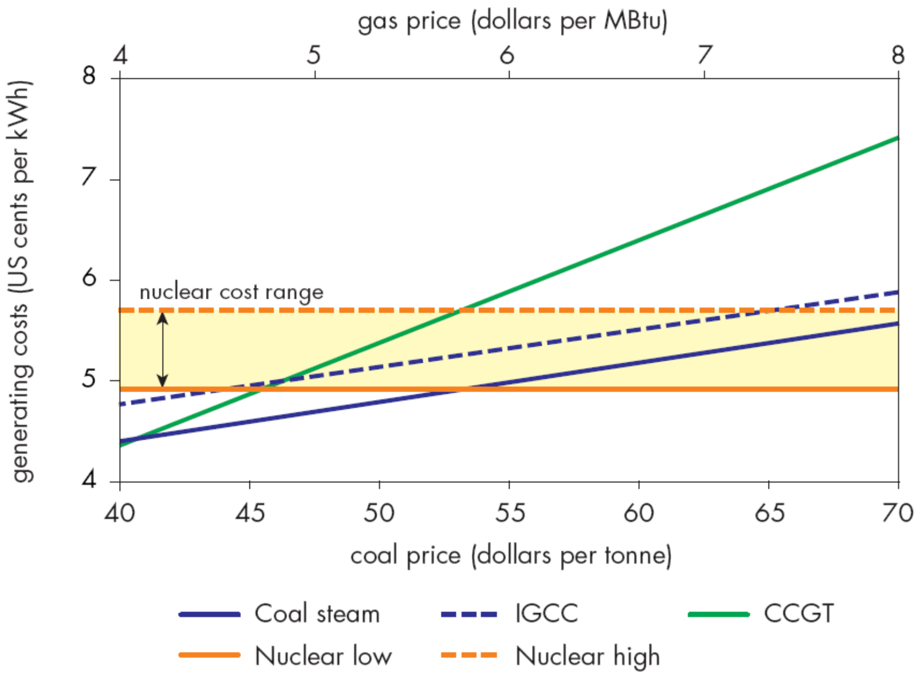
Outlook for Nuclear Power Generation in the Alternative Policy Scenario



Globally, the share of nuclear power drops only slightly, from 15% in 2005 to 14% in 2030, helping reduce emissions

Source: WEO 2006

Sensitivity of generating costs to fossil-fuel prices



Nuclear can compete with gas at a gas price above $5.70/MBtu – corresponding to $40-$45 per barrel of oil

Source: WEO 2006

Approach to climate change: mitigation

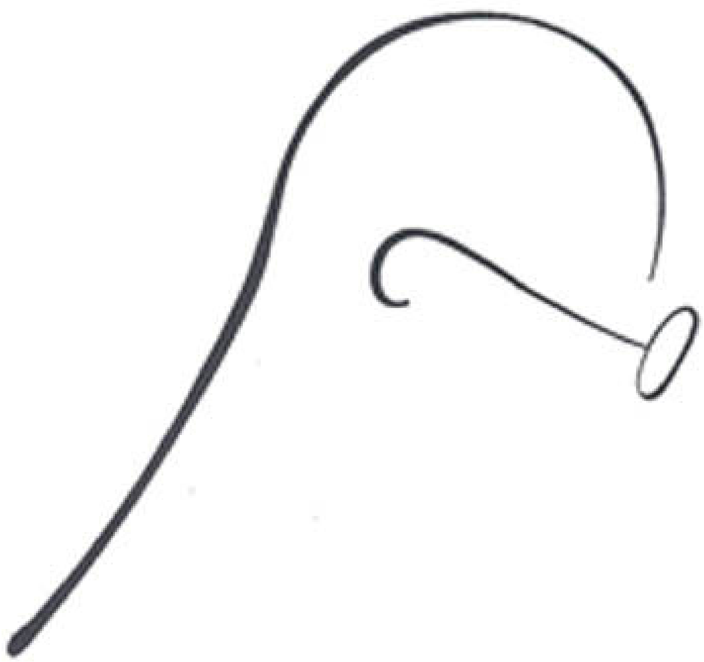
Using the Kaya Identity

CO_2 emissions = GDP * Energy Intensity * Carbon Intensity

Reduction in Energy intensity → Reduced end use demand, increased efficiency (tech change)

Reduction in net CO_2 emissions → Shift towards renewables, away from conventional fuels, C sequestration

Source of figures and data – IPCC Report, Climate Change (2007): The Physical Science Basis, International Energy Agency and Dr. Susan Solomon



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