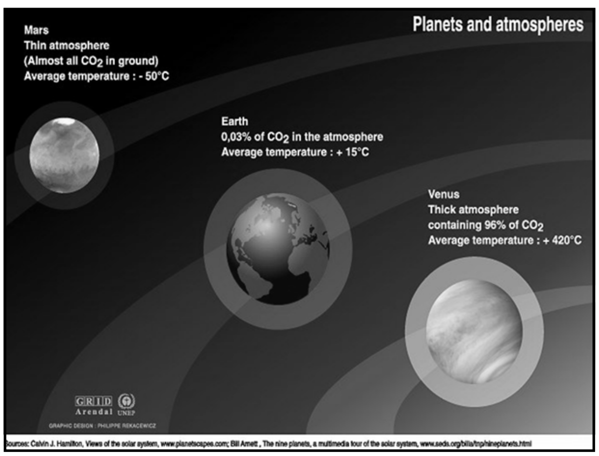
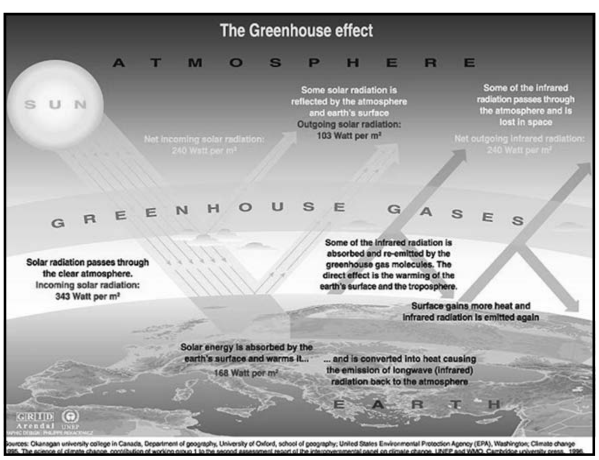
10

Case Study VI
Climate Change

Technik & Umwelt

Arnulf Grübler





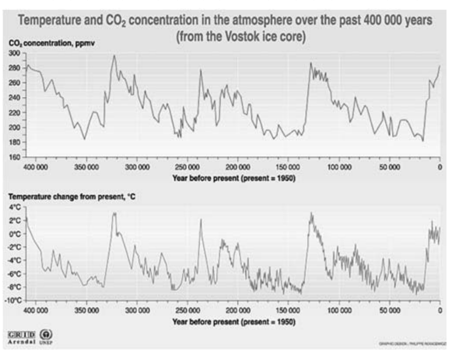
The Greenhouse Effect

E. Boeker, *Environmental Physics*

#updated for 2005 ann.average CO2 conc. CDIAC

Gas	conc. ppm	GWP factor	**G. Warming (ºK)**
H_2O	5000	0.2	20.6
CO_2	380#	1	7.2
O_3	0.03	3900	2.4
N_2O	0.3	310	0.8
CH_4	1.7	21	0.8
HFC-134	~ 0.03	1000	0.6
		Total	**32.4**

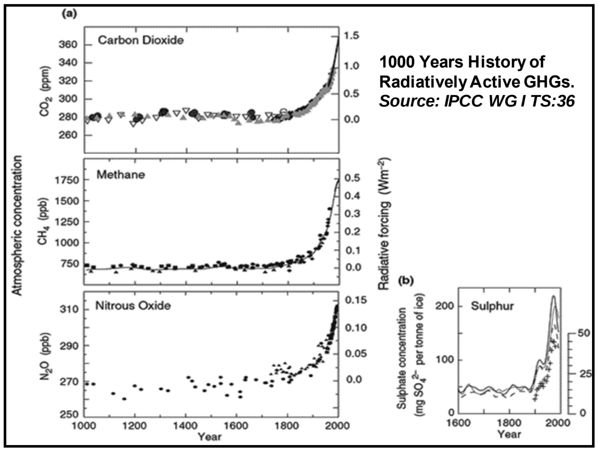
Reconstructed Paleoclimate



Greenhouse Gases

	H_2O	CO_2	CH_4	N_2O	CFC-11 CFC-12	O_3
Residence time years	short	5-200	12	114	45—130	<0.1
100 year GWP (note caveats!)	?	1	23	296	4600--10600	--
% contribution to natural greenhouse effect (30°K)	70%	23%	2%	2%	0	3%
Anthropogenic since 1750 (2°K)	??	60%	20%	6%	14%	??
Concentration in 1800	3000 ppm?	280 ppm	.7 ppm	.270 ppb	0	
Concentration in 2000	3000 ppm	370 ppm	1.75 ppm	.314 ppb	268—533 ppt	
Increase, absolute	???	1.5 ppm	0.007 ppm	0.8 ppb	-1.4—4.4 ppt	
Increase, %	???	0.4%	0.4% (~0% currently)	0.25%	-0.15%-0.8%	

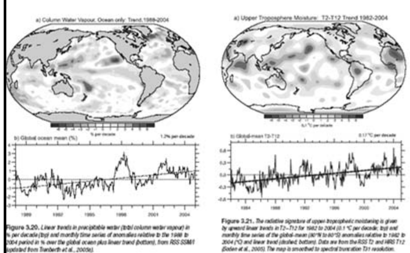
Source IPCC TAR WG I TS:38 and Ch 4:244



1000 Years History of Radiatively Active GHGs.
Source: IPCC WG I TS:36

Water Vapor News from IPCC AR4, 2007

Surface – lower troposphere	Upper troposphere	Stratosphere



Stratosphere: ???

Increase stopped since 1996

Source trends ill understood

Implications: cooling to warming?

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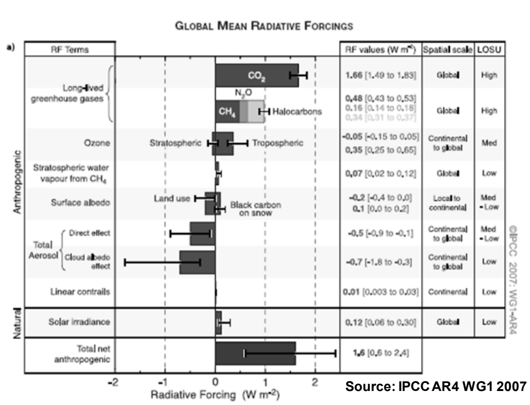
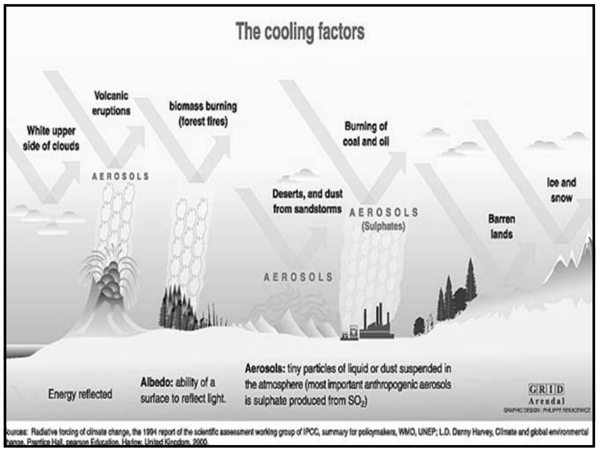
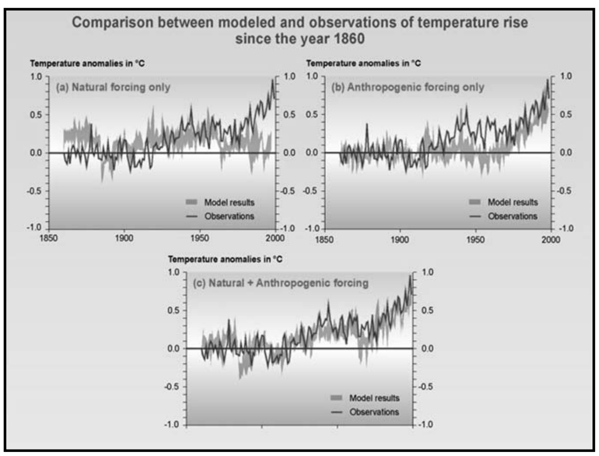
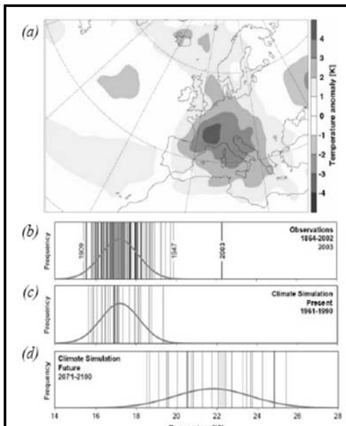


Source: IPCC AR4 WG1 2007



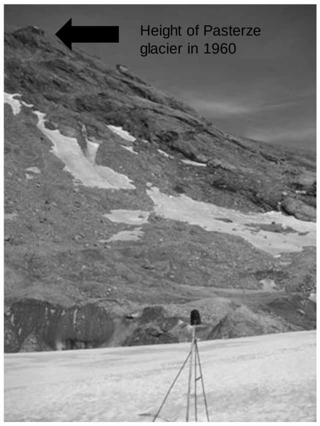




EU Regional Climate Variability: Observations (b) modeled for present (c) and future (d) conditions.

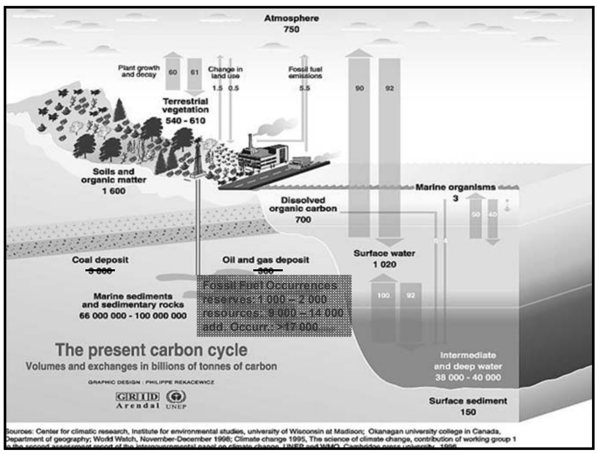
Note 2003 heat wave being far outside both observational and model range.

IPCC uncertainty terminology (adopted from Schneider and Moss) :
<1% probability ="exceptionally unlikely" (but 2003 happened!)

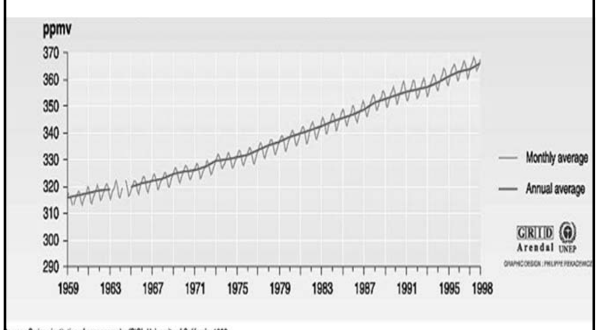


Current CC Impacts: 80 meters thinning of Pasterze glacier, Austria

But… uncovering 5000 yr old vegetation



Atmospheric CO_2 Concentration at Mauna Loa



Source : Scripps institution of oceanography (SIO), University of California, 1998.

Current Carbon Cycle

atmospheric increase =
+ industrial emissions
+ net land-use change
- **ocean uptake**
- **Residual (missing sink)**

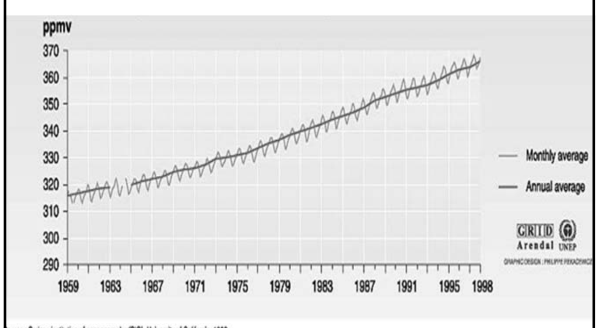
In GtC (mean over 1990-2000):
3.3 (±0.2) =
+ 5.5 (±0.5)
+ 1.1 (0-2.8)
- 2.0 (±0.8)
- 1.3 (0-3.3)

Table 1 Global carbon emissions as estimated for 1990 per major source category and uncertainty ranges (in Tg C $year^{-1}$)[a]

		Net	Gross	Uncertainty range
	Coal	2424		
	Oil (fuels)	2285		
	Oil (feedstocks)		324	
	Gas	1135		
	Cement	157		
	Gas flaring	60		
Industrial		6061	6385	5800–7000
	Fuelwood[b]		530	
	Traditional biofuels[b]		630	
Biofuels[b]			1160	??–1600
	Savannah fires[c]		1660	
Other biomass				??–1700
	Tropical forests[d]		1100	
	Temperate forests[d]		0	
Land-use change[b]			1100	0–2800[e]
Total		6061	8645	5800–>13 100

[a] Emission categories that are not balanced by (uncertain) biospheric carbon sinks or that are not released to the atmosphere in the same year are listed as gross emissions, all others as net emissions (see text). For land-use change related emissions, the net biospheric flux as estimated by IPCC (1995) for the 1980s (the latest period for which global estimates are available) and the uncertainty range as estimated by Houghton (1999) for the same period are given. (Data source: see text.)
[b] Emissions of biofuels and land-use change not necessarily entirely additive.
[c] Andreae (1991). Not included in total gross emissions.
[d] Estimated net biospheric flows (IPCC, 1995).
[e] Upper range for net biospheric flux due to land-use change (Houghton, 1999), no estimates of gross emissions available.

Atmospheric CO_2 Concentration at Mauna Loa



Current Carbon Cycle

atmospheric increase = industrial emissions

+ net land-use change emissions – ocean uptake

- residual (missing sink)

3.3(±0.2) = 5.5(±0.5)

+ 1.1(0-2.8) – 2.0(±0.8)

– 1.3(0-3.3)

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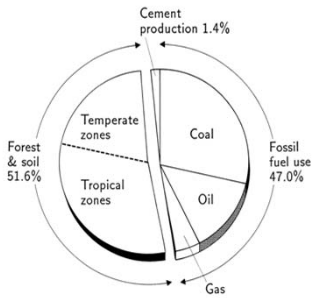
Contributions to CO_2 Concentration Increase since 1800 by Source



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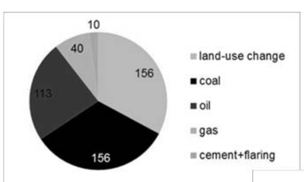
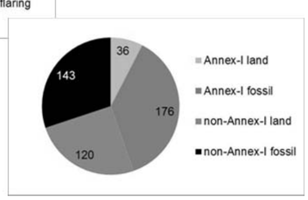
Cumulative Carbon Emissions by Source and Region 1850-2005 (320 GtC)

Data source: http://cdiac.ornl.gov/products.html





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North -- South

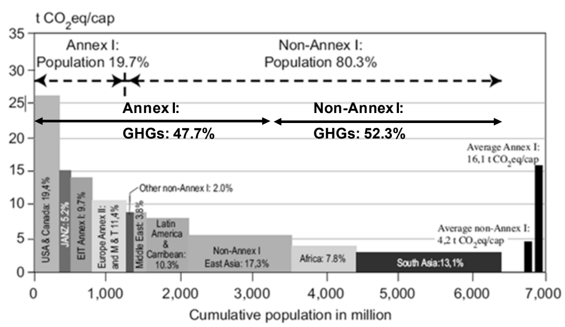
- Responsibility: Mostly in Annex-I
- Vulnerability: Mostly in "South"

- Adaptation capacity: Mostly in Annex-I
- Future emission growth: Mostly in "South"

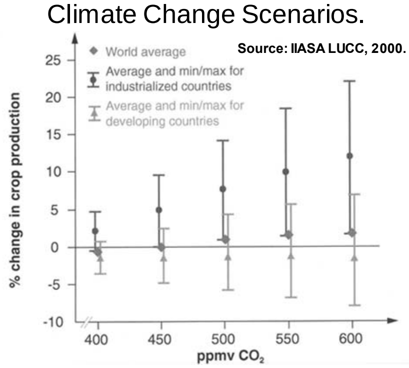
- Near-term mitigation potential: highest in Annex-I
- Near-term mitigation costs: lowest in "South"

Per Capita GHGs by Region vs. Population in 2004

Source: IPCC AR4, 2007



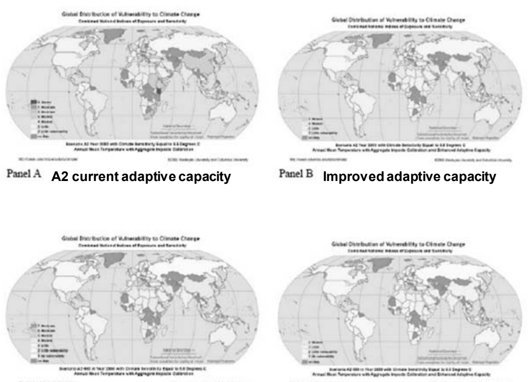
Agricultural Impacts for Alternative Climate Change Scenarios.



Reducing CC Vulnerabilities

- Economic & Social Development
  un-targeted and asymmetrical
  poverty vulnerability: -
  affluence vulnerability: +
- Adaptation
  targeted to CC
- Emissions reduction (mitigation)
  lowering CC but not eliminating it

Vulnerability to CC by 2050 (IPCC AR4 WG2 2007)



Panel A A2 current adaptive capacity

Panel B Improved adaptive capacity

Panel C Mitigation only (550 stab)

Panel D Mitigation + improved adaptation

Mitigation Options

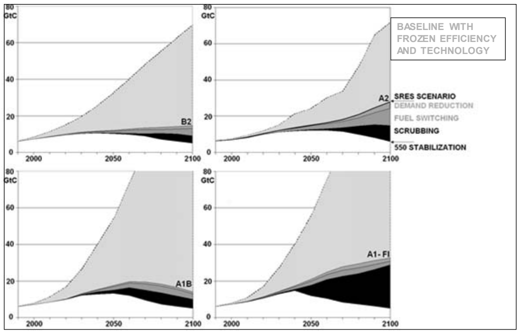
- Demographic change
- Economic development
- Social behavior

- Efficiency Improvements
- Low carbon intensity
- Zero carbon (solar, nuclear)
- Carbon removal

- End deforestation
- Sink enhancements
- “geo-engineering”

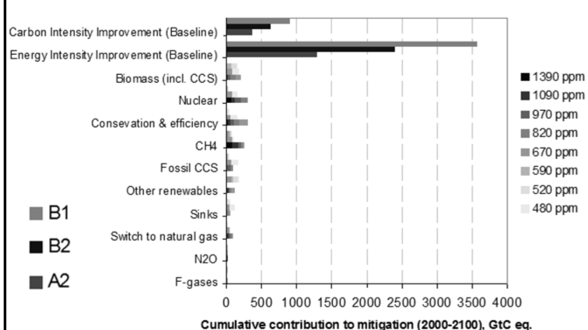
Technology as Source and Remedy of Climate Change:

IPCC Baselines and 550 ppmv Stabilization Scenarios (in GtC), Source: IIASA, 2002.



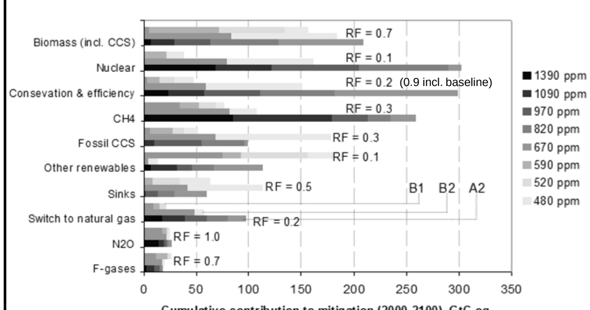
Σ: With "frozen" efficiency and technology improvements emissions grow "through the roof". Even with continued improvements, additional emission reduction is needed for climate stabilization

Emission Reduction Measures Riahi et al. TFSC 2007



Σ: Technological change in Baseline best hedging against target uncertainty

Emission Reduction Measures Riahi et al TFSC 2007

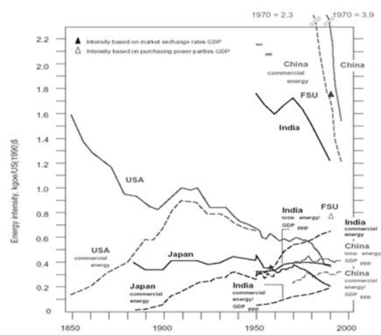


RF = Robustness factor of options across scenario uncertainty is highest for: F-gases and N2O reduction, energy conservation & efficiency, and biomass+CCS "wildcard" (if feasible)

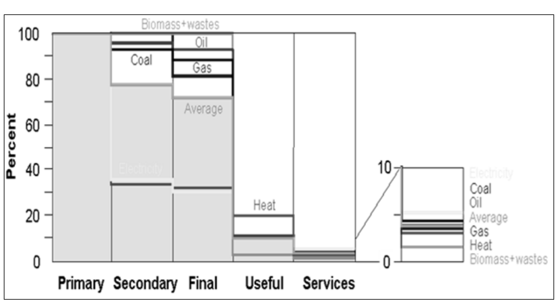
Energy Carbon and Climate: How far to go?

- Energy: ÷ 20 (5% exergy efficiency)
- Carbon: Zero (H2-economy)
- Damages: committed warming (>1.5 C?)
- Non-linear (catastrophic) change: ???
- “Collateral damages”
  -- Geoengineering, e.g. aerosol cooling (white sky)
  -- sequestration (leakage, marine ecology)
  -- biomass (soil carbon, biodiversity, agriculture)
  -- solar (albedo changes)

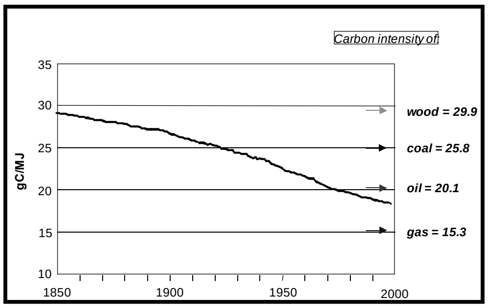
Energy Intensities (PE/GDP)



WORLD-Exergy Efficiency (as percent of primary exergy)



Carbon Intensity of Energy



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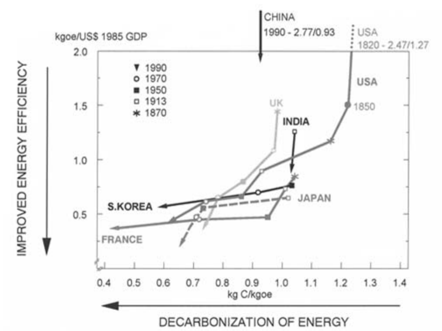
Improvements in Efficiency and Decarbonization: Diverse Paths



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Policy Conundrums

- Equitable quantitative targets at odds with economics or infeasible
- Cost optimal emission reduction: Start with inefficiencies in DCs but requires new instruments (CDM+)
- Separation of equity and efficiency (e.g. via tradable permit allocation) might be politically infeasible (unprecedented N-S resource transfers)
- Uncertainties cannot be ignored (soil C, avoided deforestation)
- Mitigation technology innovation “recharge” chain broken (declining R&D)

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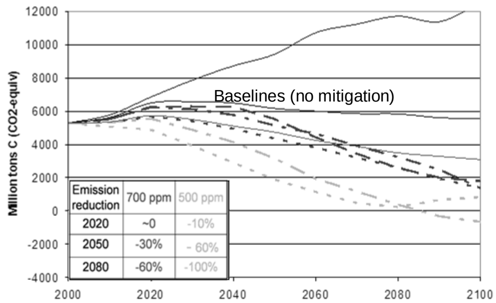
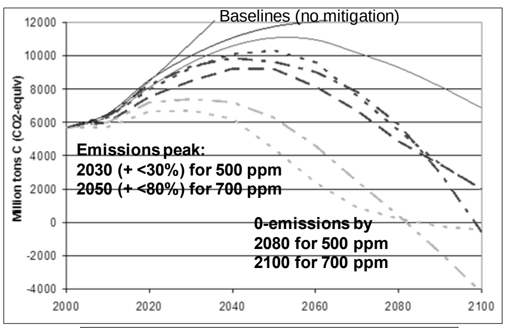
UNFCC Annex-I GHGs Emissions
(global cost minimum scenarios)



Climate stabilization: 700 ppm by 2100 (2.5°C)
500 ppm by 2100 (<2°C)

Developing Countries
(global cost minimum scenarios)



Climate stabilization: 700 ppm by 2100 (2.5°C)
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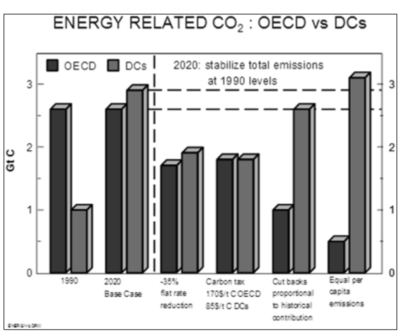
ENERGY RELATED CO2 : OECD vs DCs



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Costs to Address Enegy Issues:
Zero-order Estimates
in billion $/year over 20 years

- Efficient stoves to 2 billion ~$10
- Modern fuels for cooking ~$15
- PV costs until competitive >$10
- FC costs until competitive >$20
- Electrification of rural areas ~$50

How to strike a balance between intra- and intergenerational transfers?