POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Prof. Dr. Ottmar Edenhofer

Nach Kopenhagen – Eckpunkte einer globalen Klima- und Energiepolitik

Freie Universität Berlin, 15. Juni 2010

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

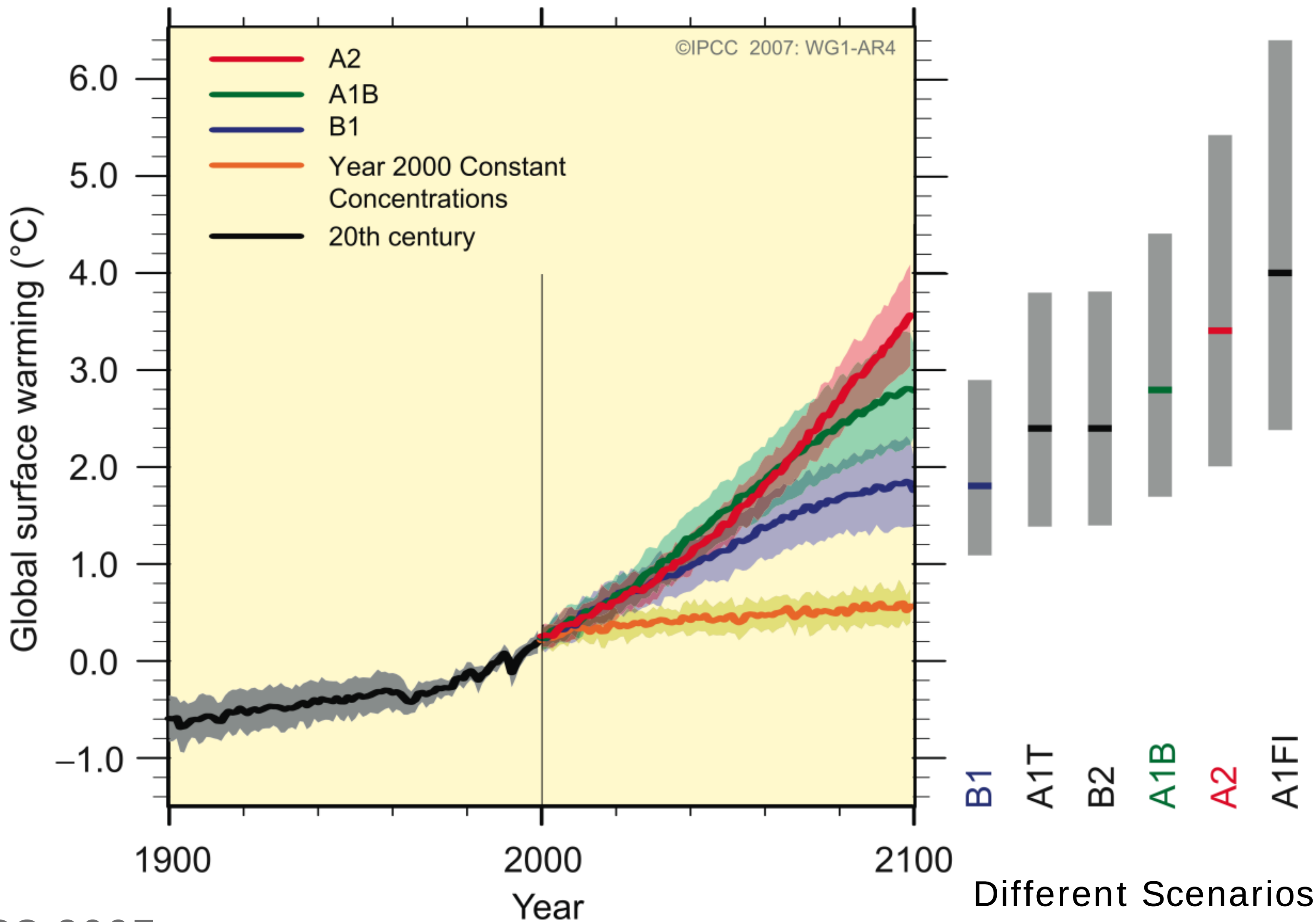
Working Group III
Mitigation of Climate Change

WMO

UNEP

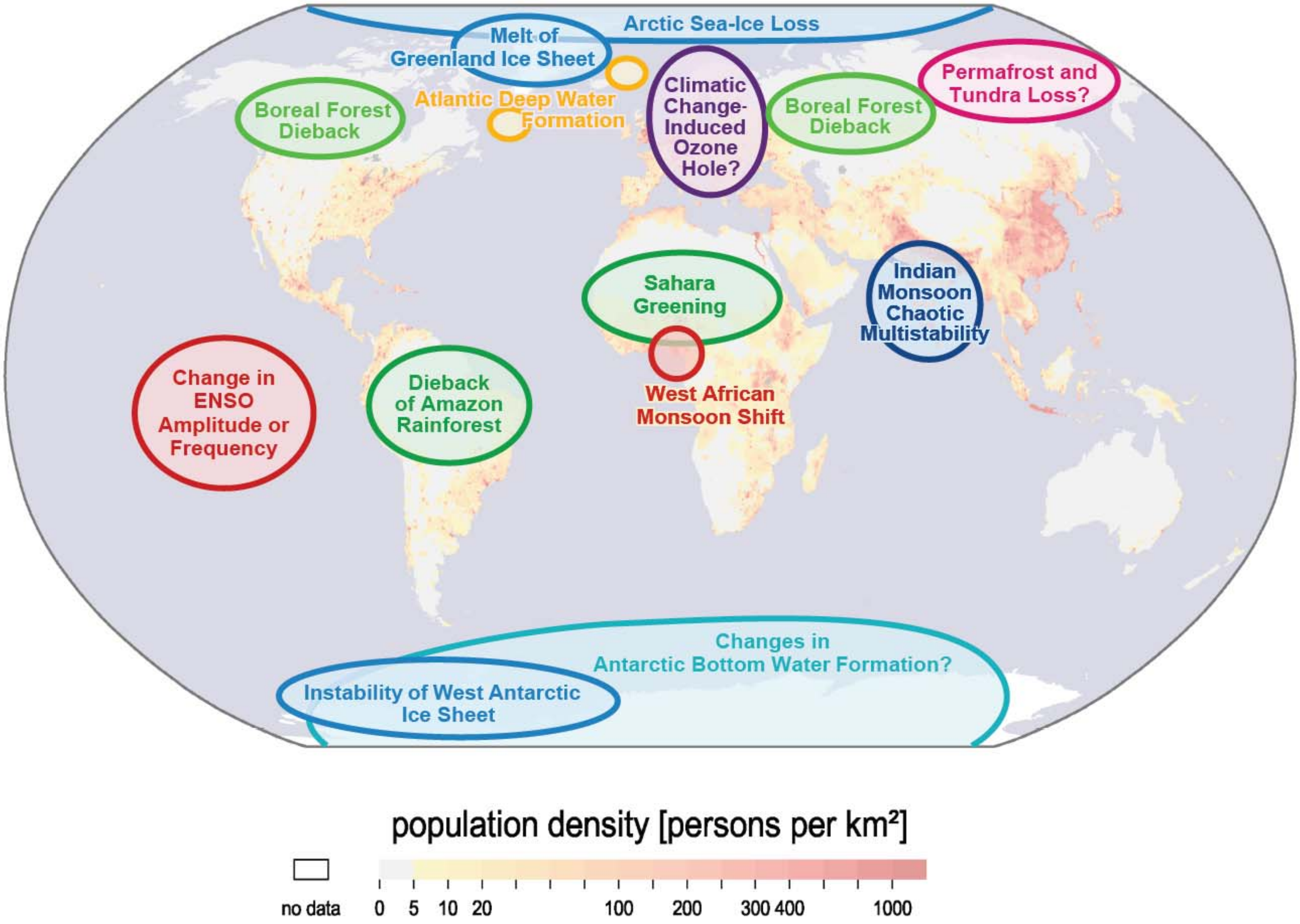
Technische Universität Berlin

Projections of Global Mean Temperature



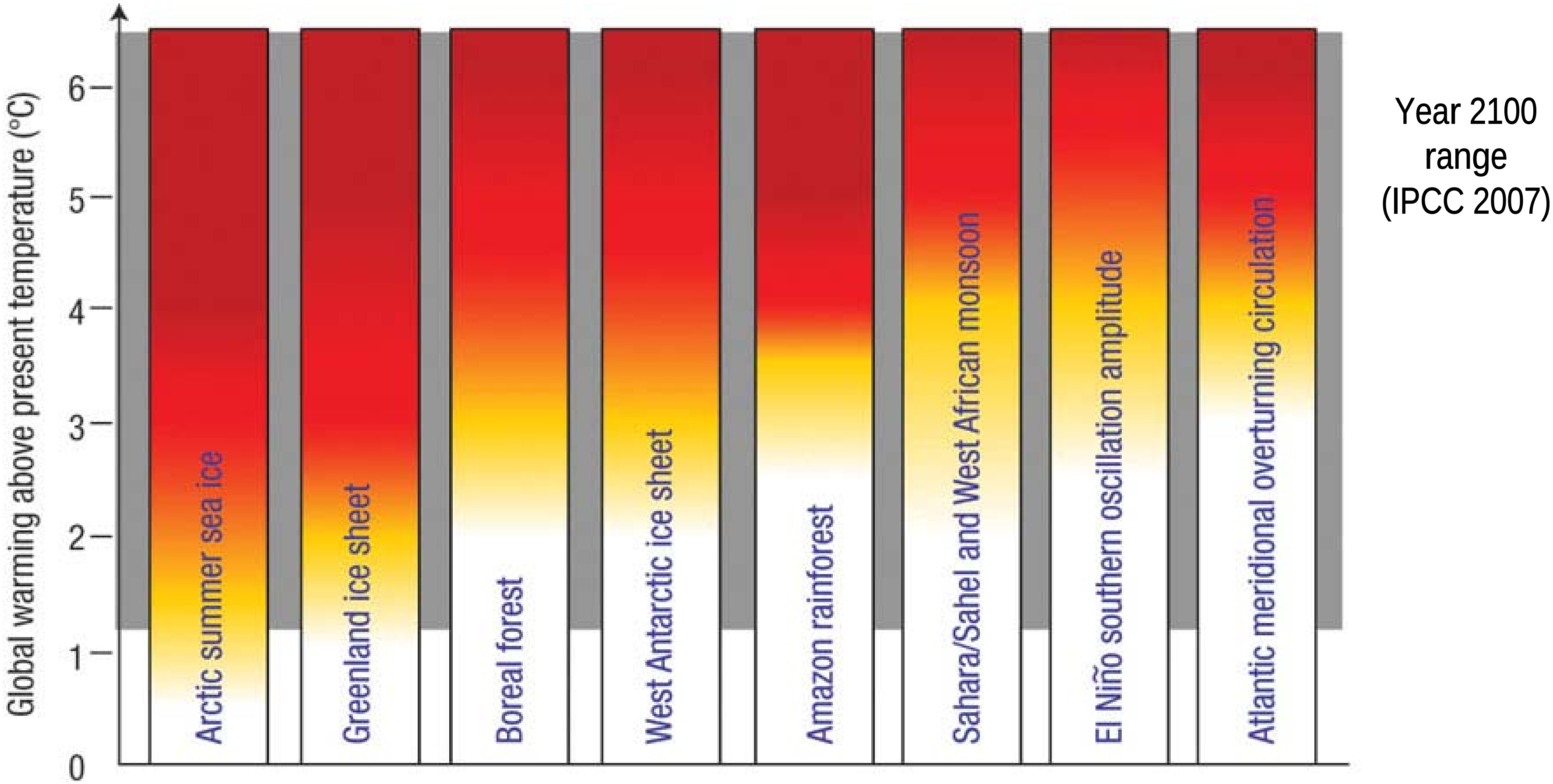
IPCC 2007

Tipping Points in the Earth System



T. M. Lenton & H. J. Schellnhuber (Nature Reports Climate Change, 2007)

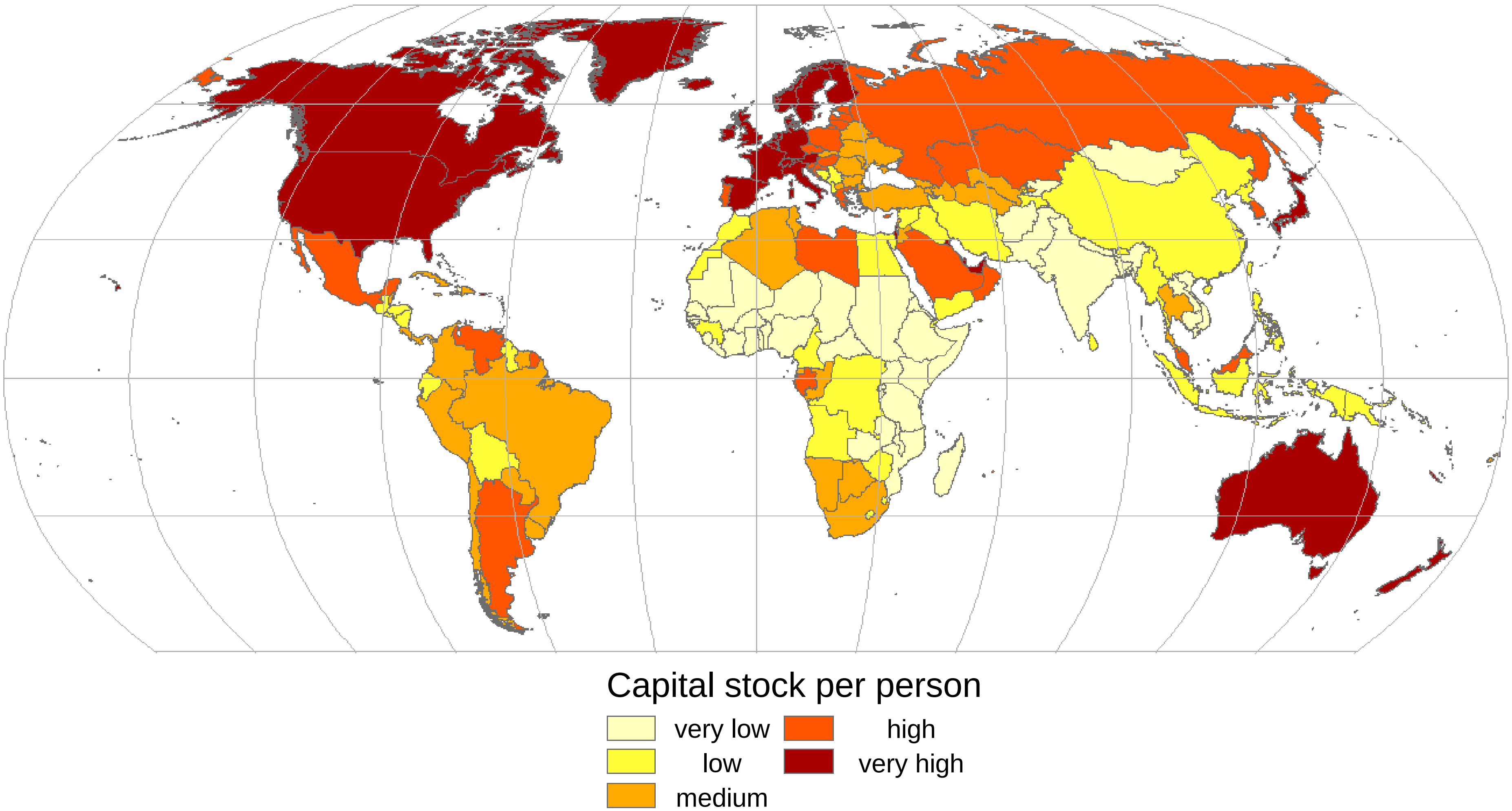
Burning Embers



Potential policy-relevant tipping elements that could be triggered by global warming this century, with shading indicating their uncertain thresholds. For each threshold, the transition from white to yellow indicates a lower bound on its proximity, and the transition from yellow to red, an upper bound. The degree of uncertainty is represented by the spread of the colour transition.

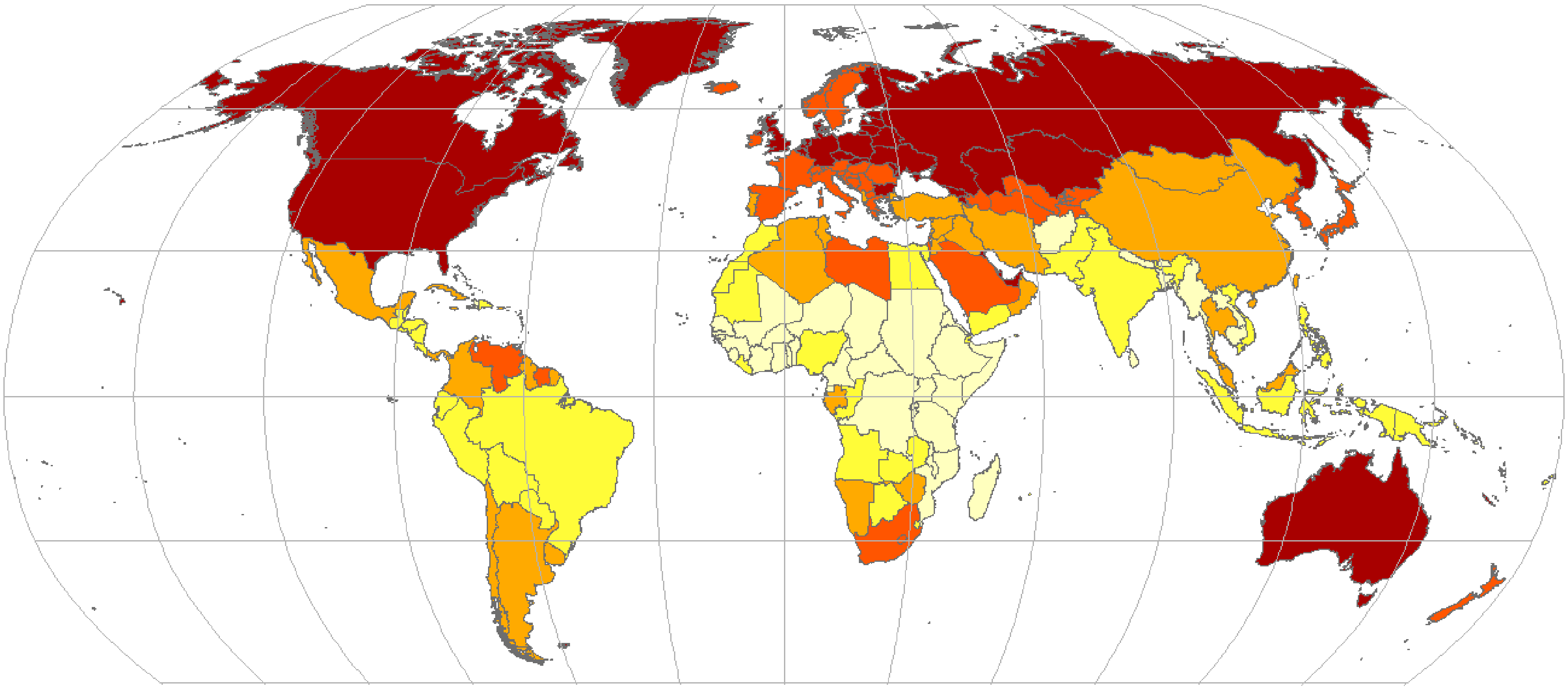
T. M. Lenton & H. J. Schellnhuber (Nature Reports Climate Change, 2007)

World Map of Wealth



Source: Füssel (2007)

World Map of Carbon Debt

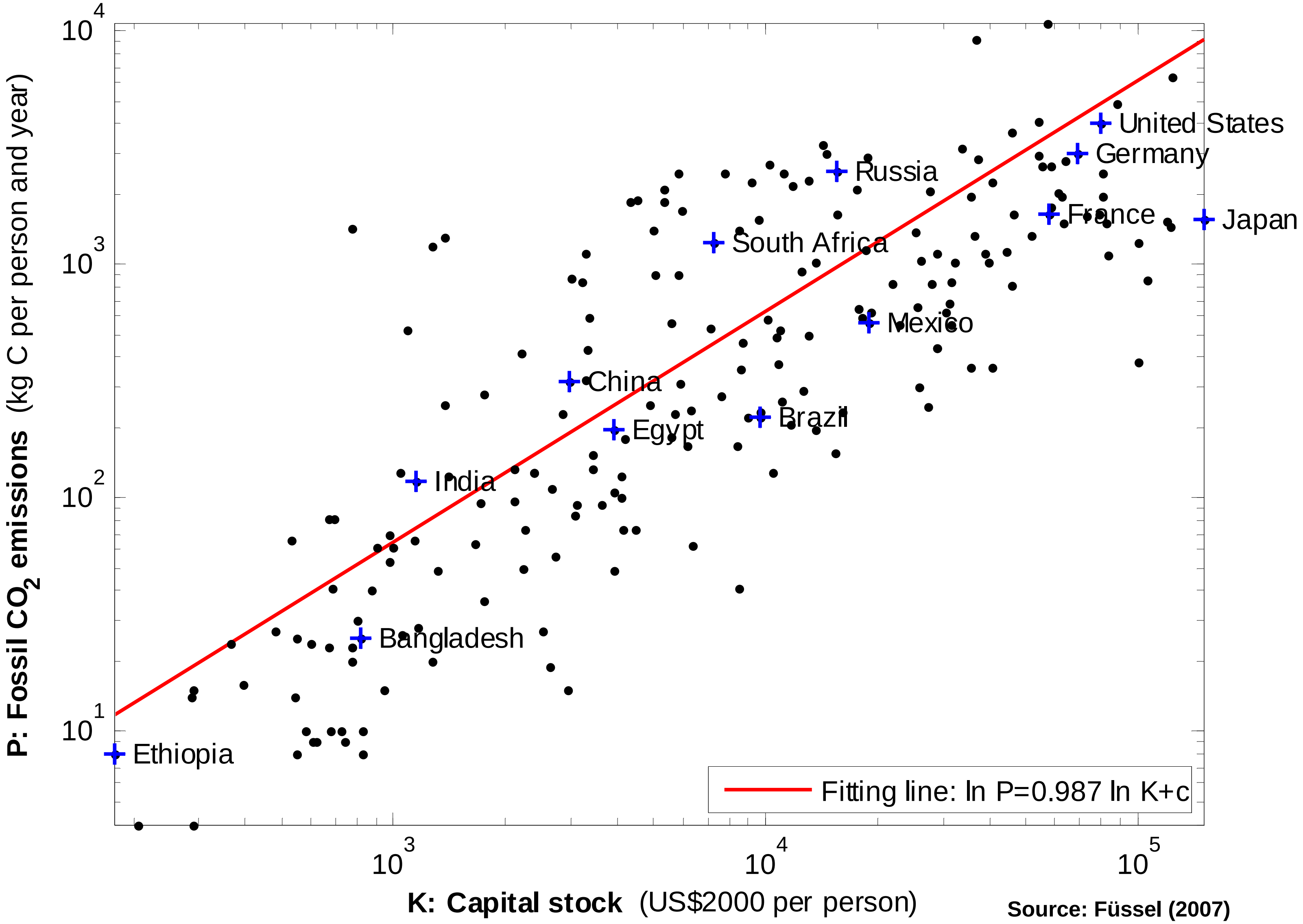


Carbon emissions per person from fossil fuel burning (1950-2003)

very low
low
medium
high
very high

Source: Füssel (2007)

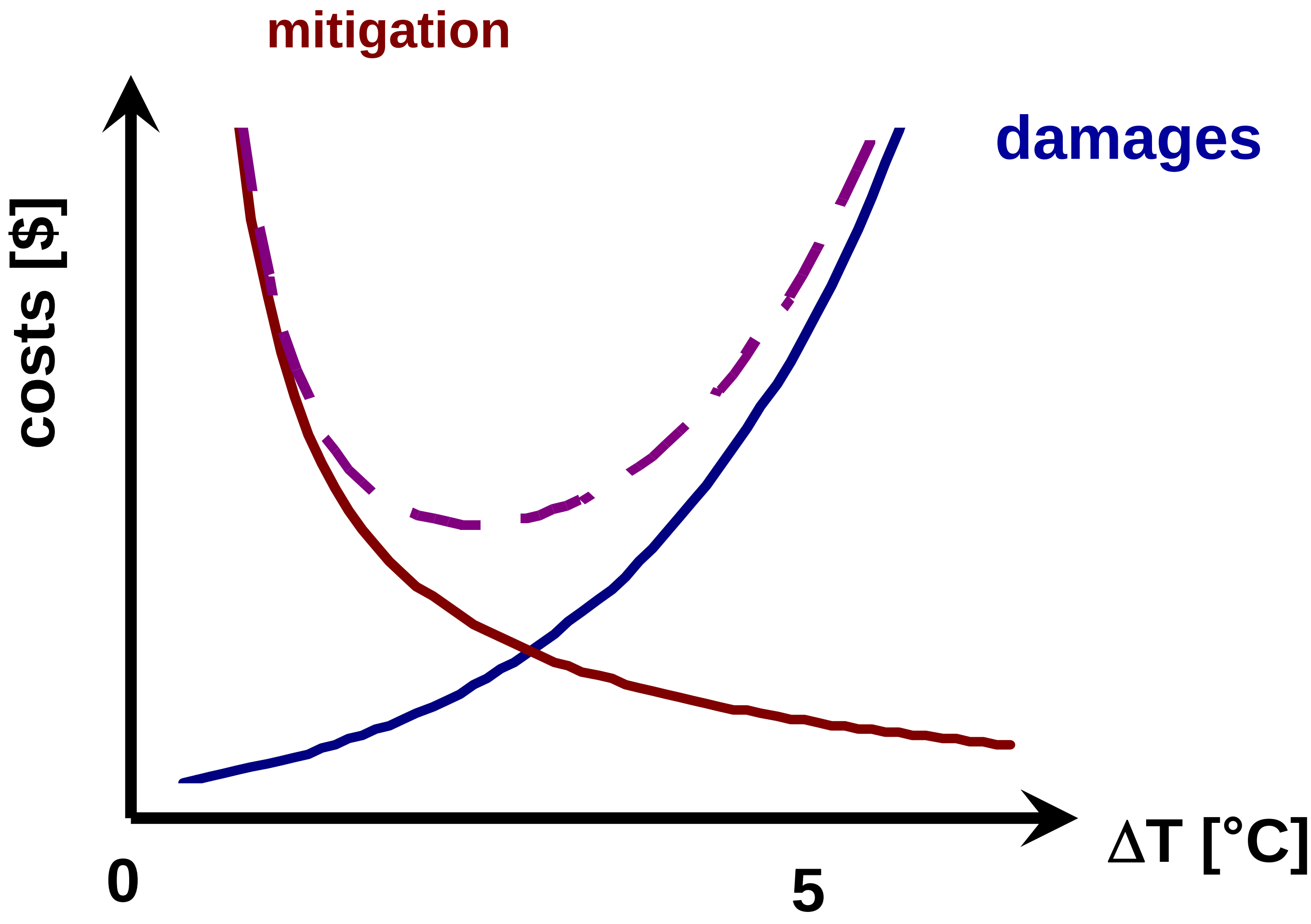
Carbon Dept and Wealth



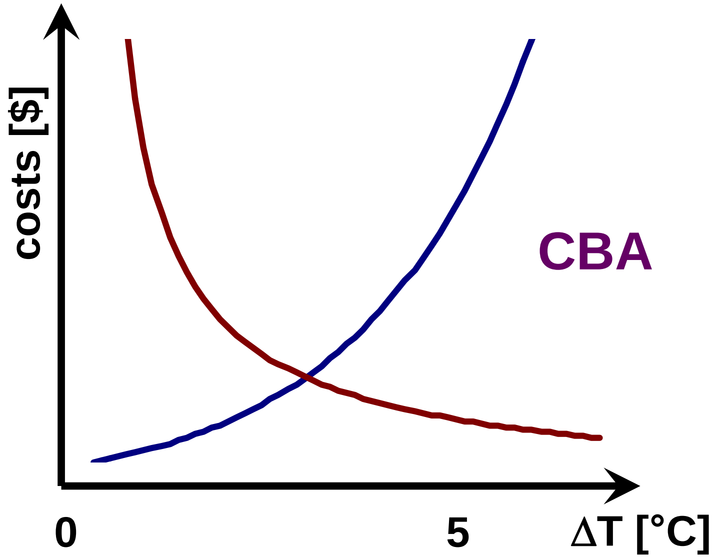
Source: Füssel (2007)

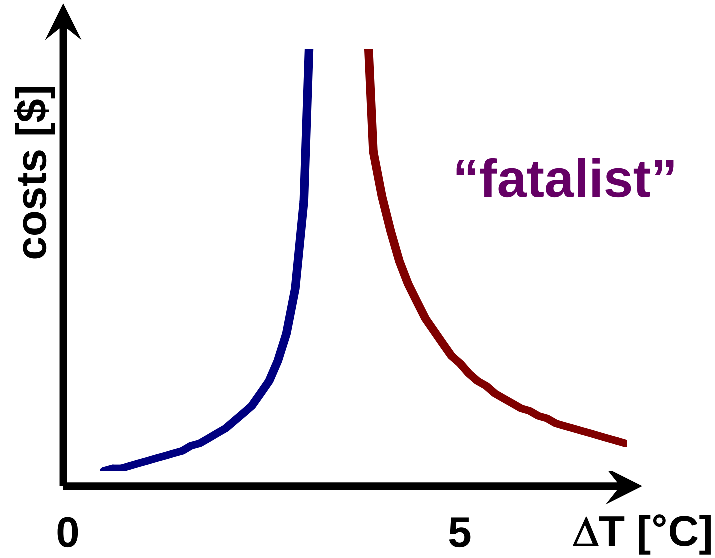
What is the Optimal Level of Mitigation?

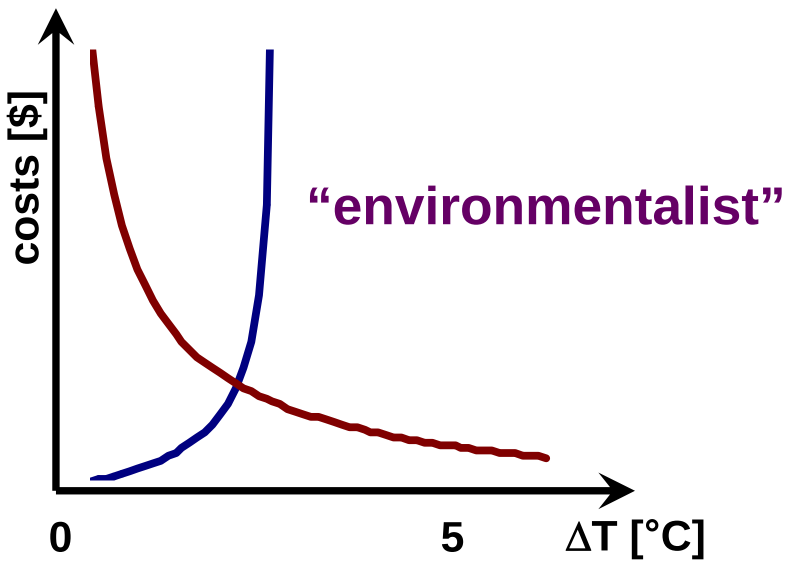
Economist's perspective:

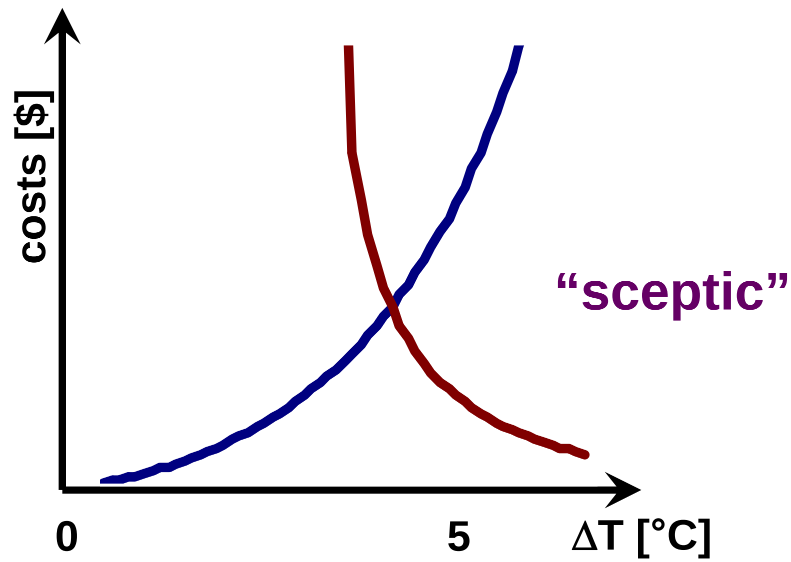


Different Perspectives

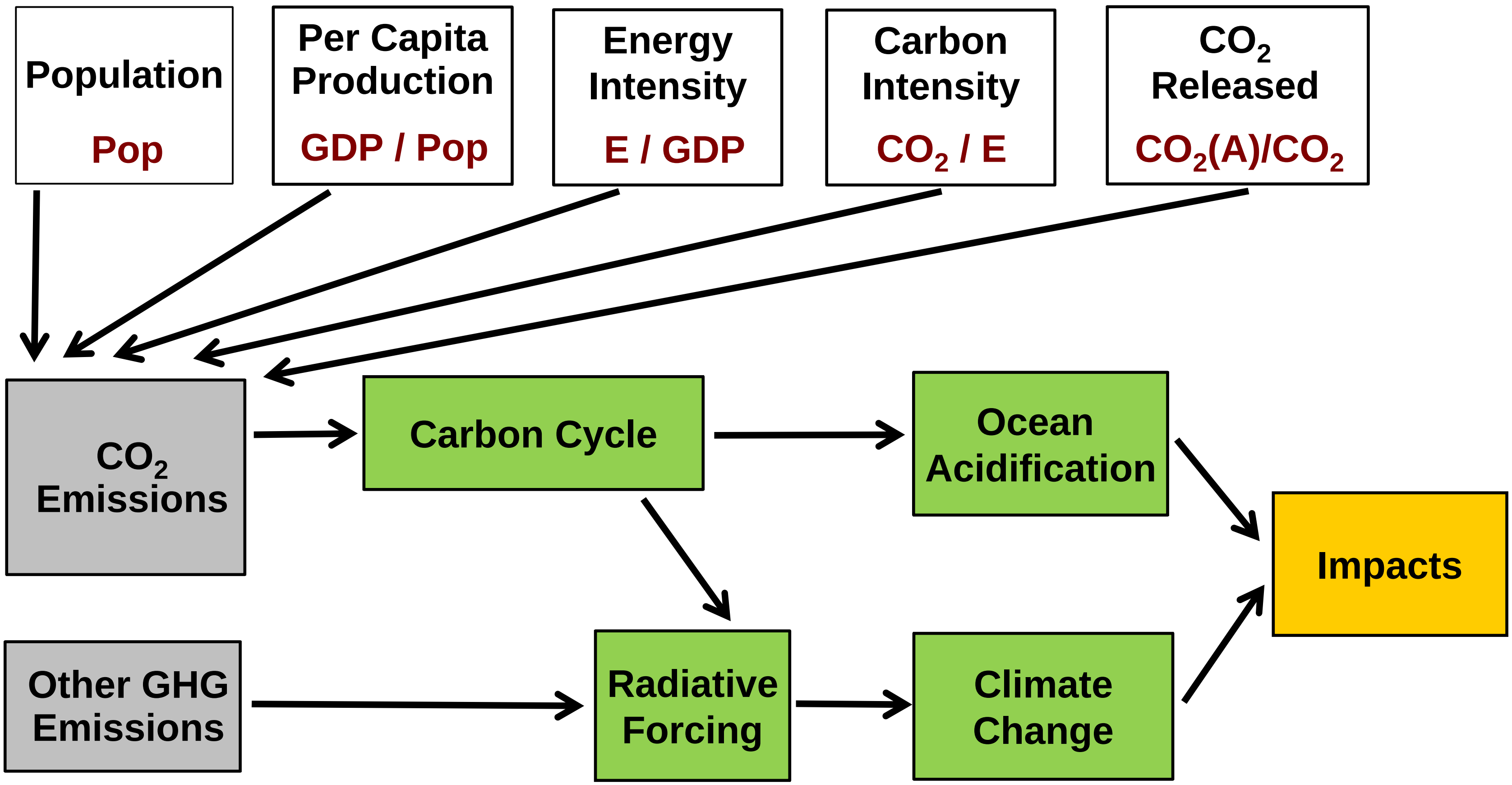




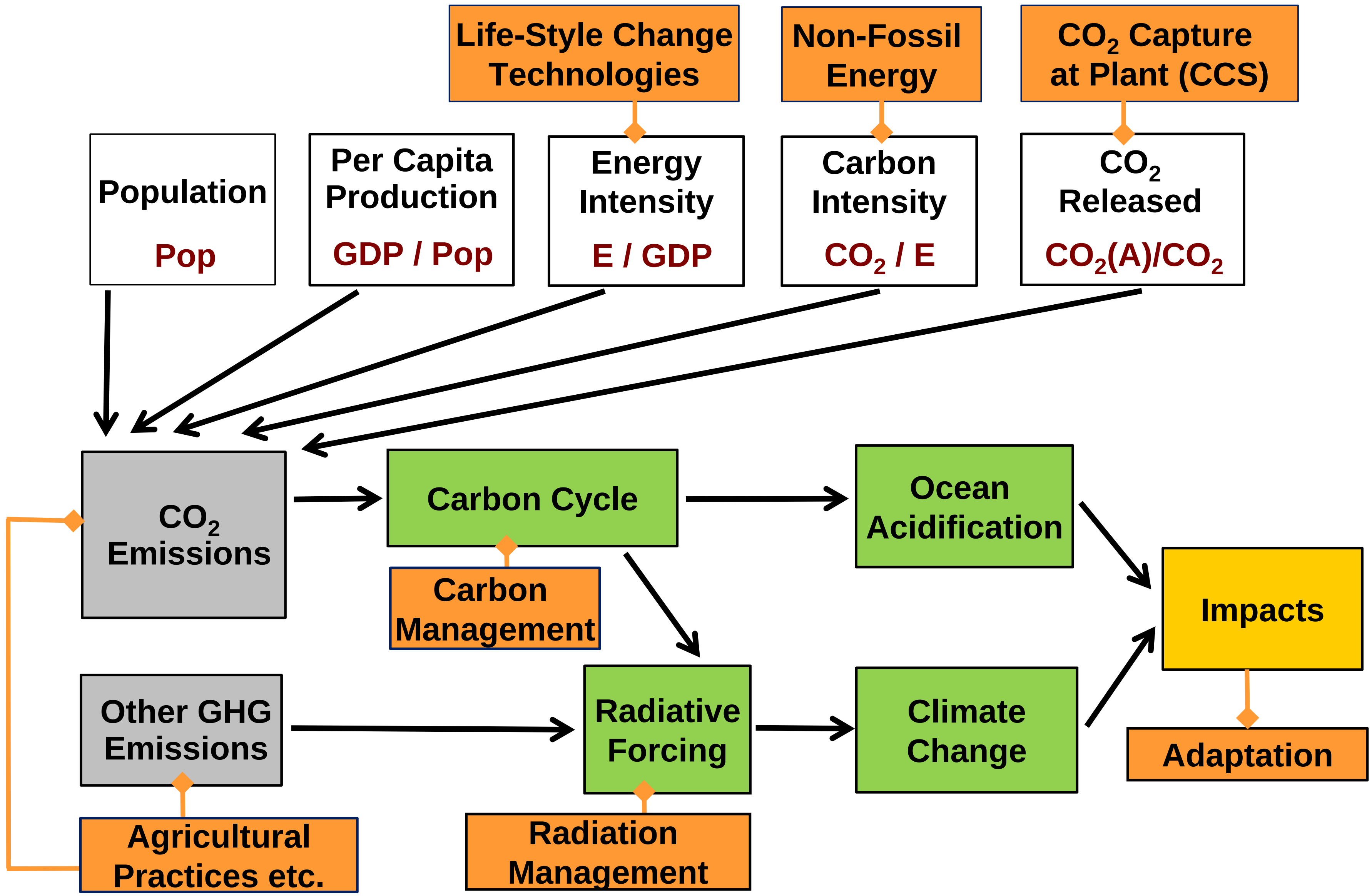




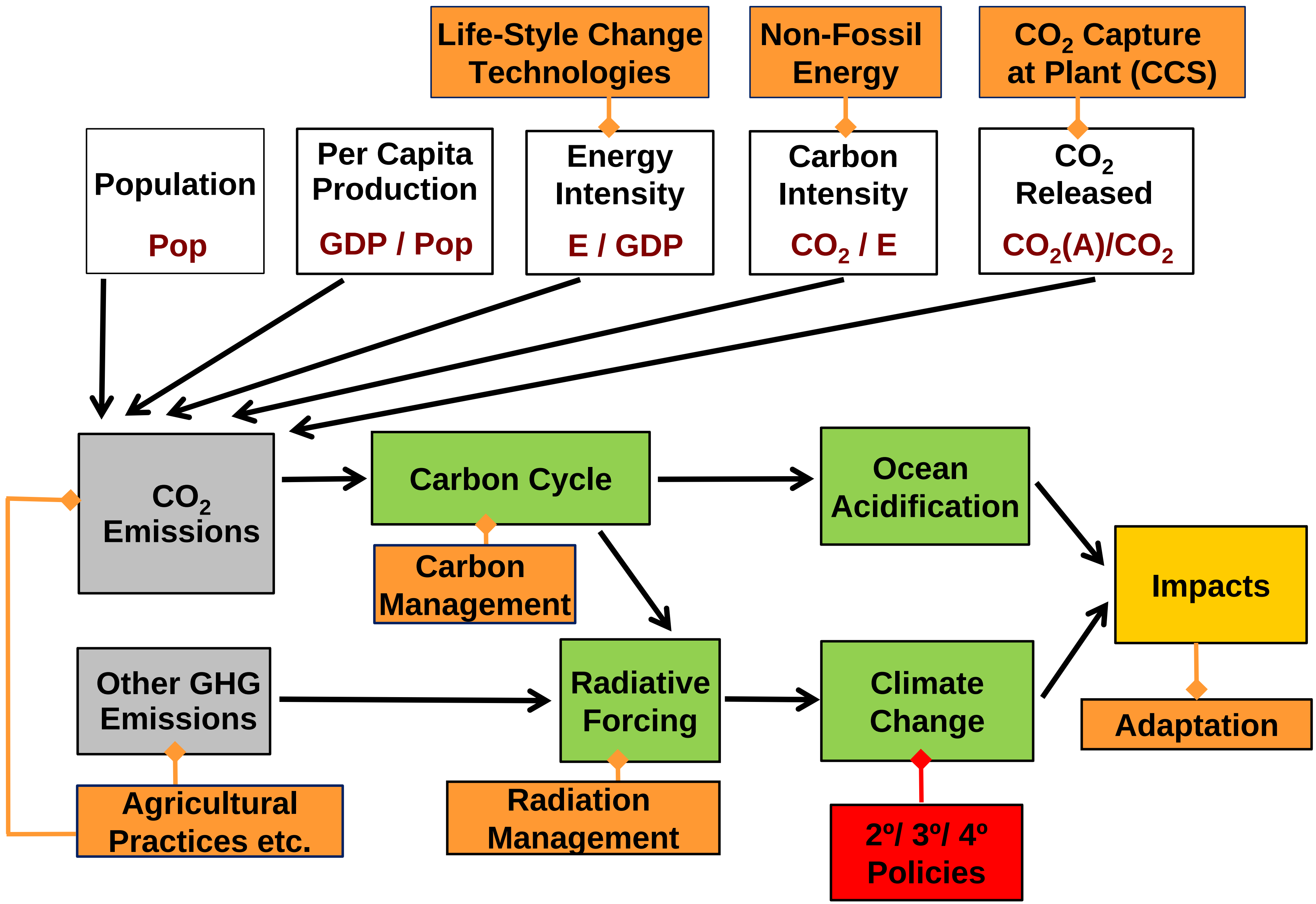
Driving Forces



Assessing the Solution Space

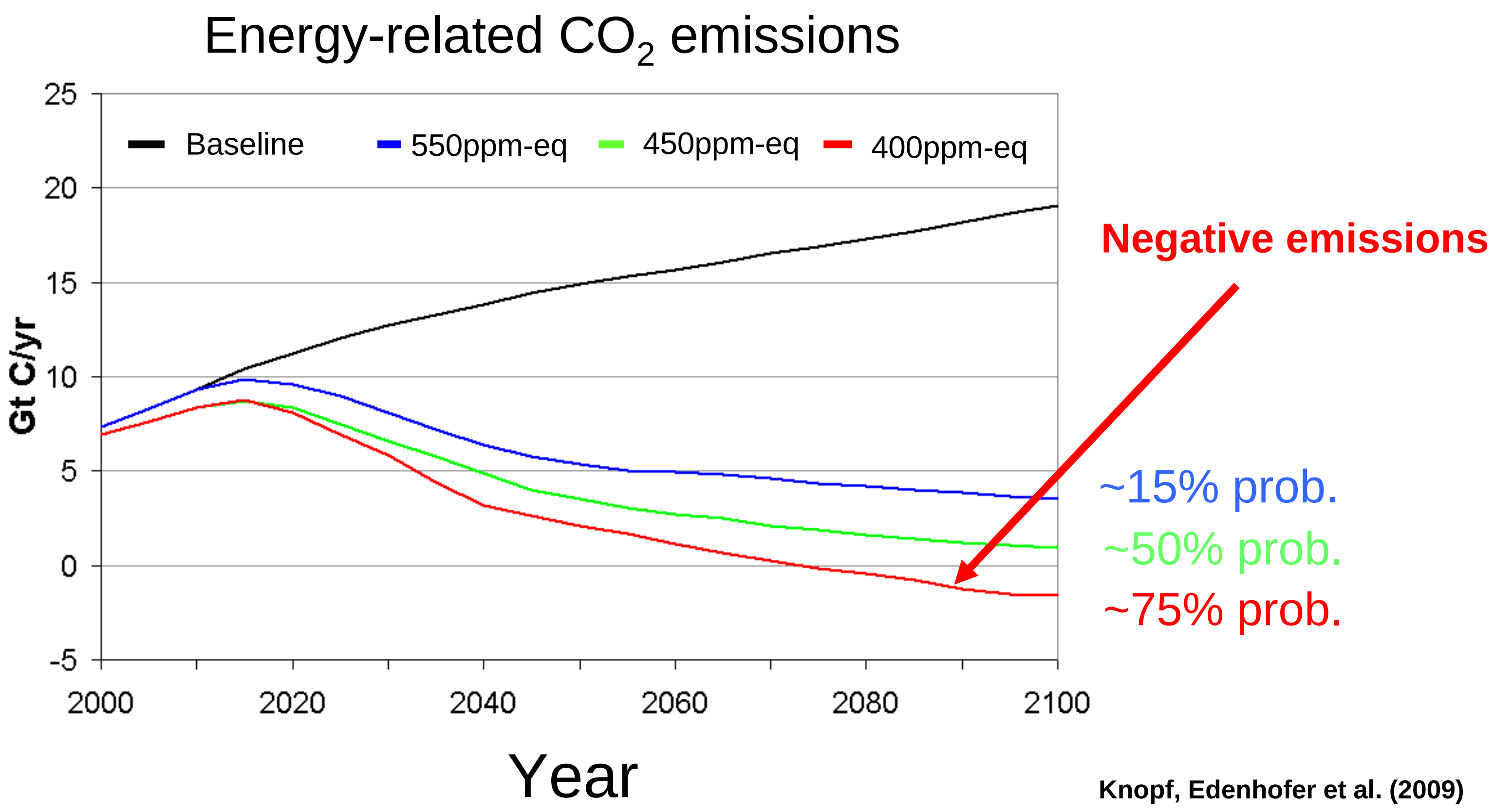


Assessing the Solution Space



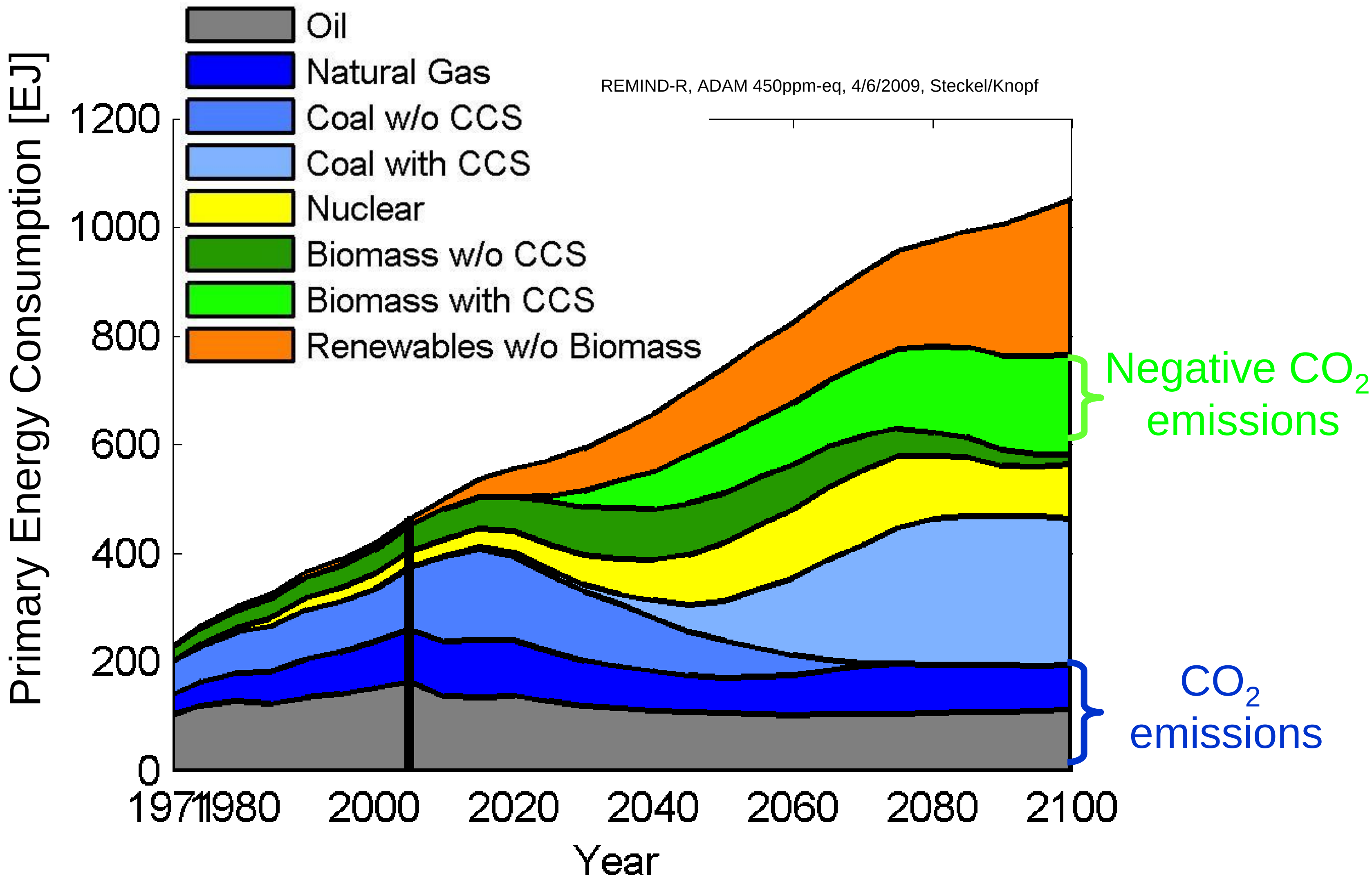
The Economics of Atmospheric Stabilisation

3 stabilisation targets with different probabilities to reach the 2° target:
550ppm-eq, 450ppm-eq, 400ppm-eq



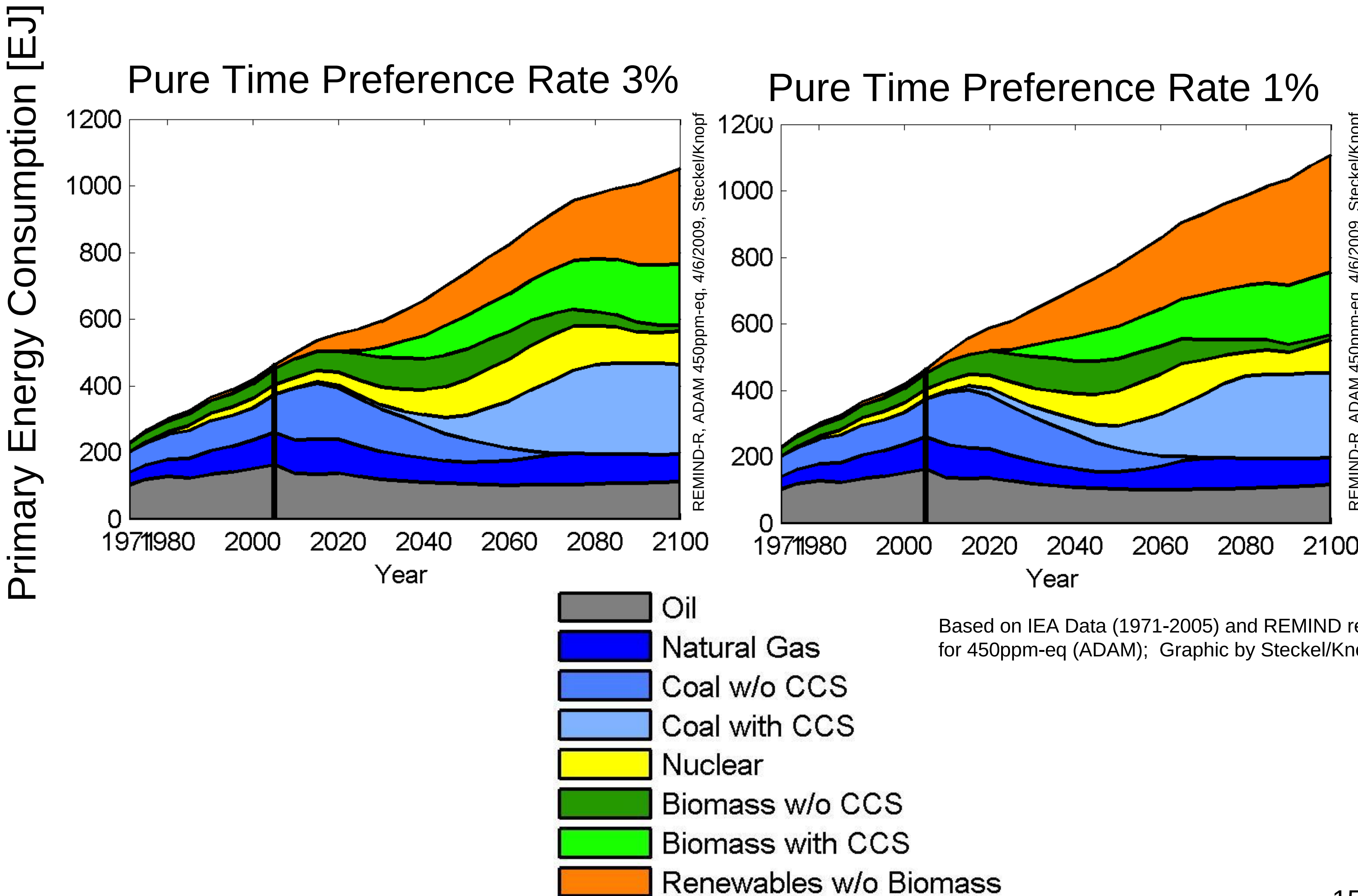
Knopf, Edenhofer et al. (2009)

The Great Transformation



Based on IEA Data (1971-2005) and REMIND-R results for 450ppm-eq (ADAM); Graphic by Steckel/Knopf (PIK)

Discounting and Technological Change



Based on IEA Data (1971-2005) and REMIND results for 450ppm-eq (ADAM); Graphic by Steckel/Knopf

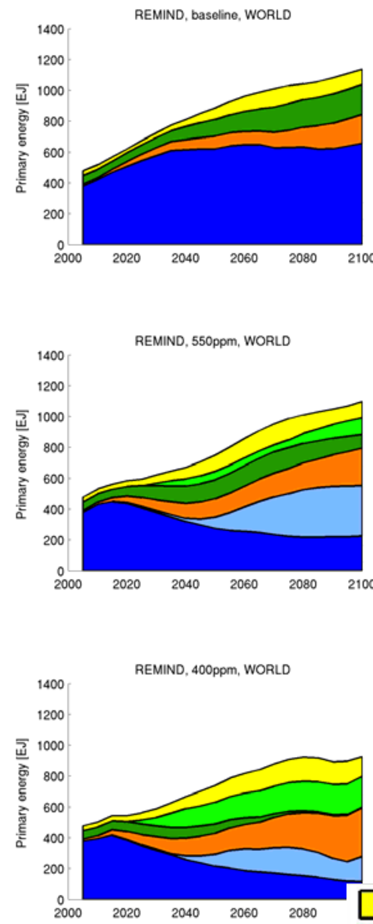
There is more than one path towards a carbon-free economy

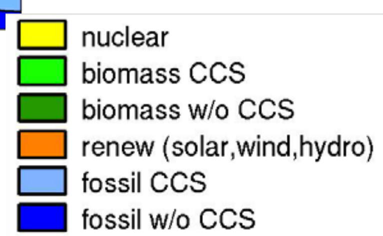
MERGE TIMER POLES REMIND E3MG

baseline

550 ppm

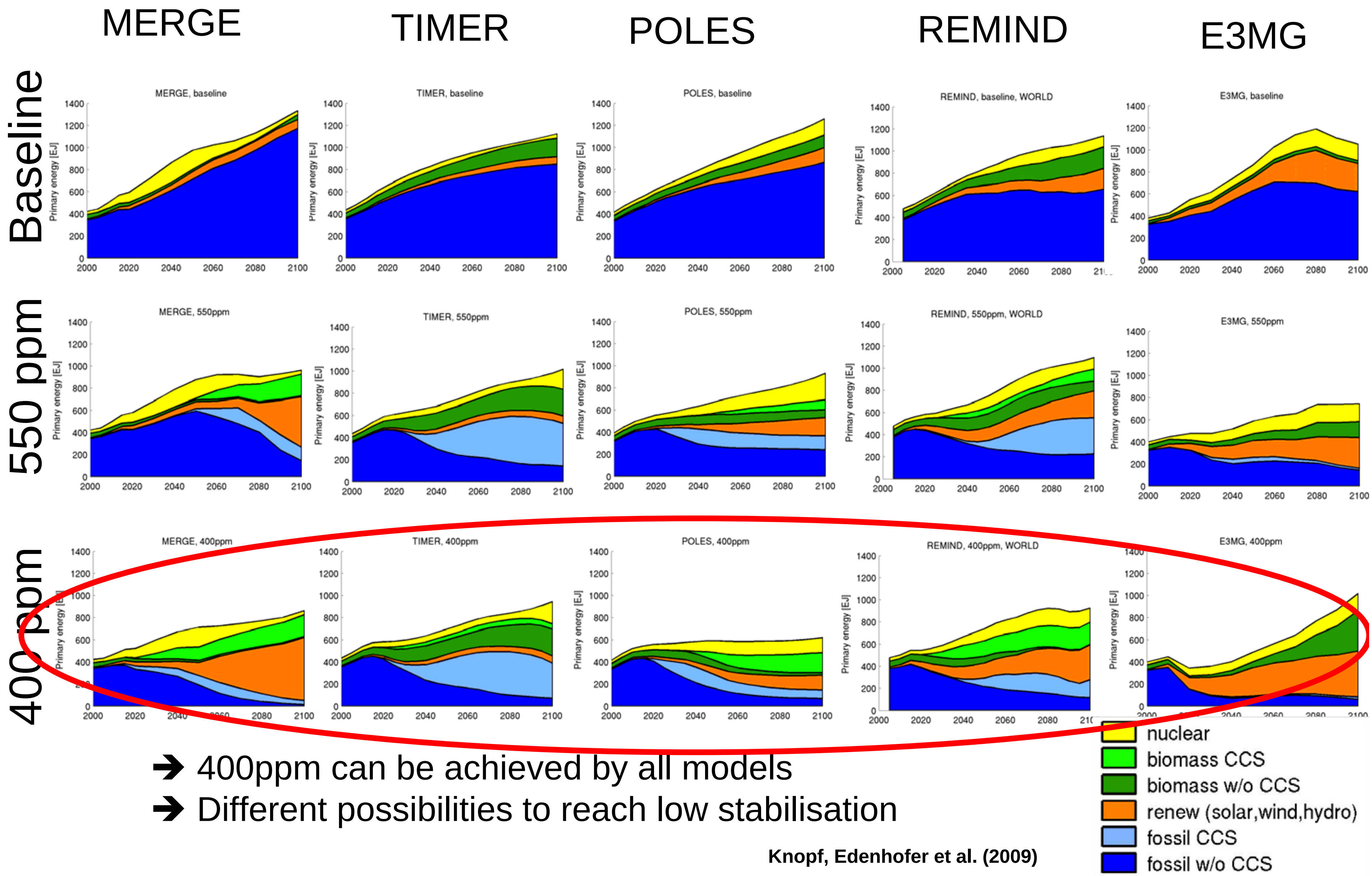
400 ppm





Knopf, Edenhofer et al. (2009)

There is more than one path towards a carbon-free economy

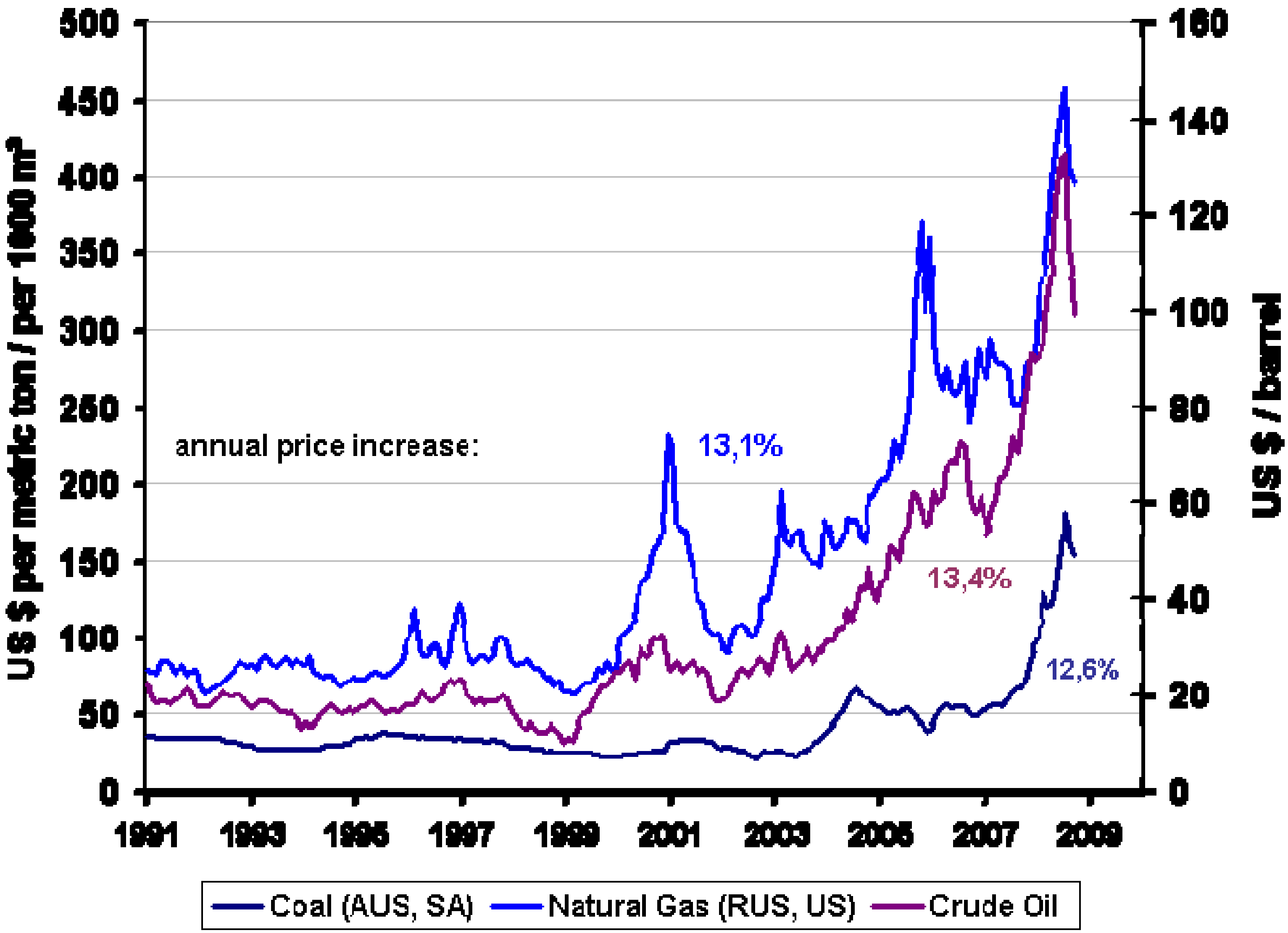


➔ 400ppm can be achieved by all models

➔ Different possibilities to reach low stabilisation

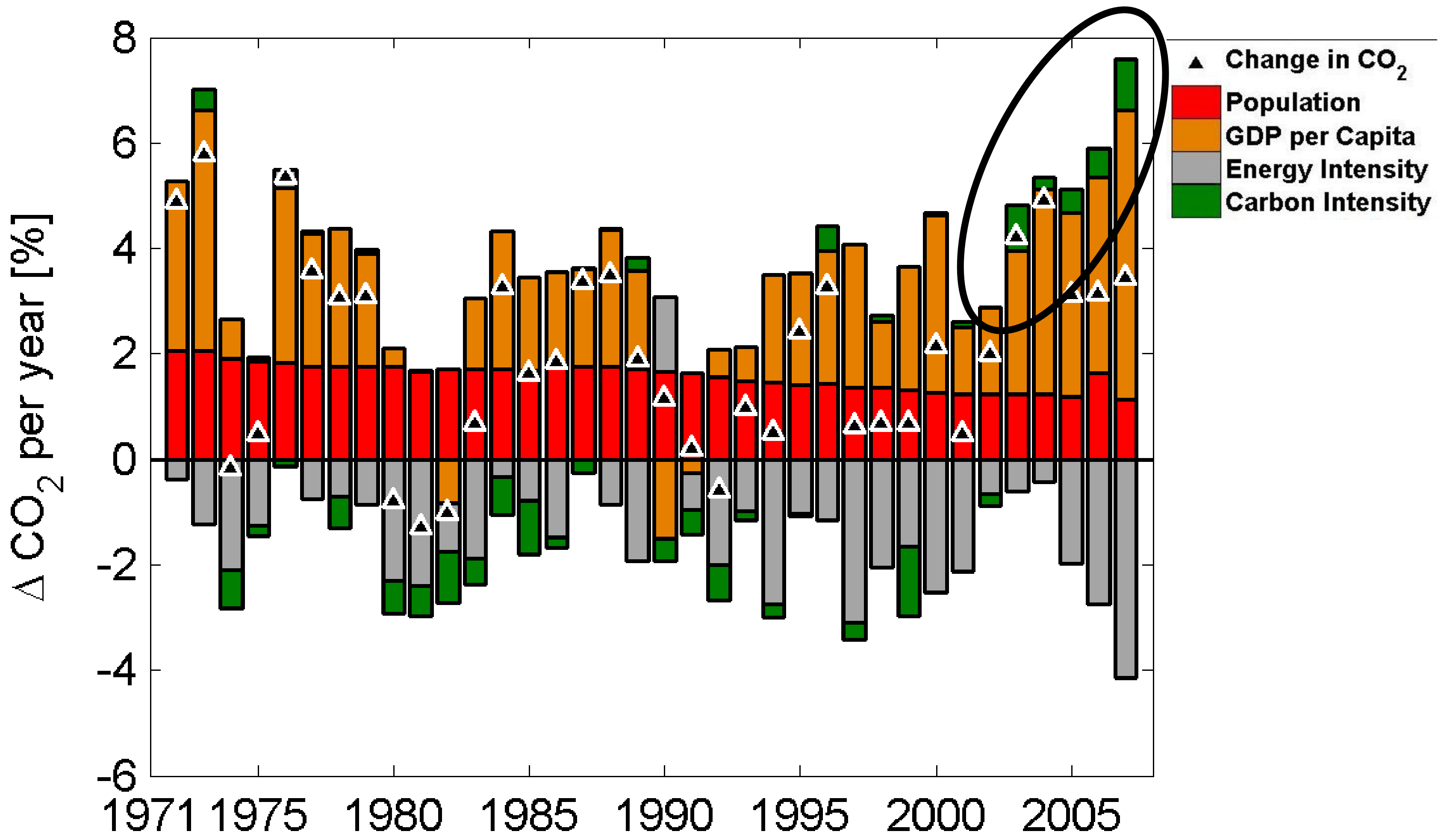
Knopf, Edenhofer et al. (2009)

Global Fossil Fuel Prices 1991 - 2008

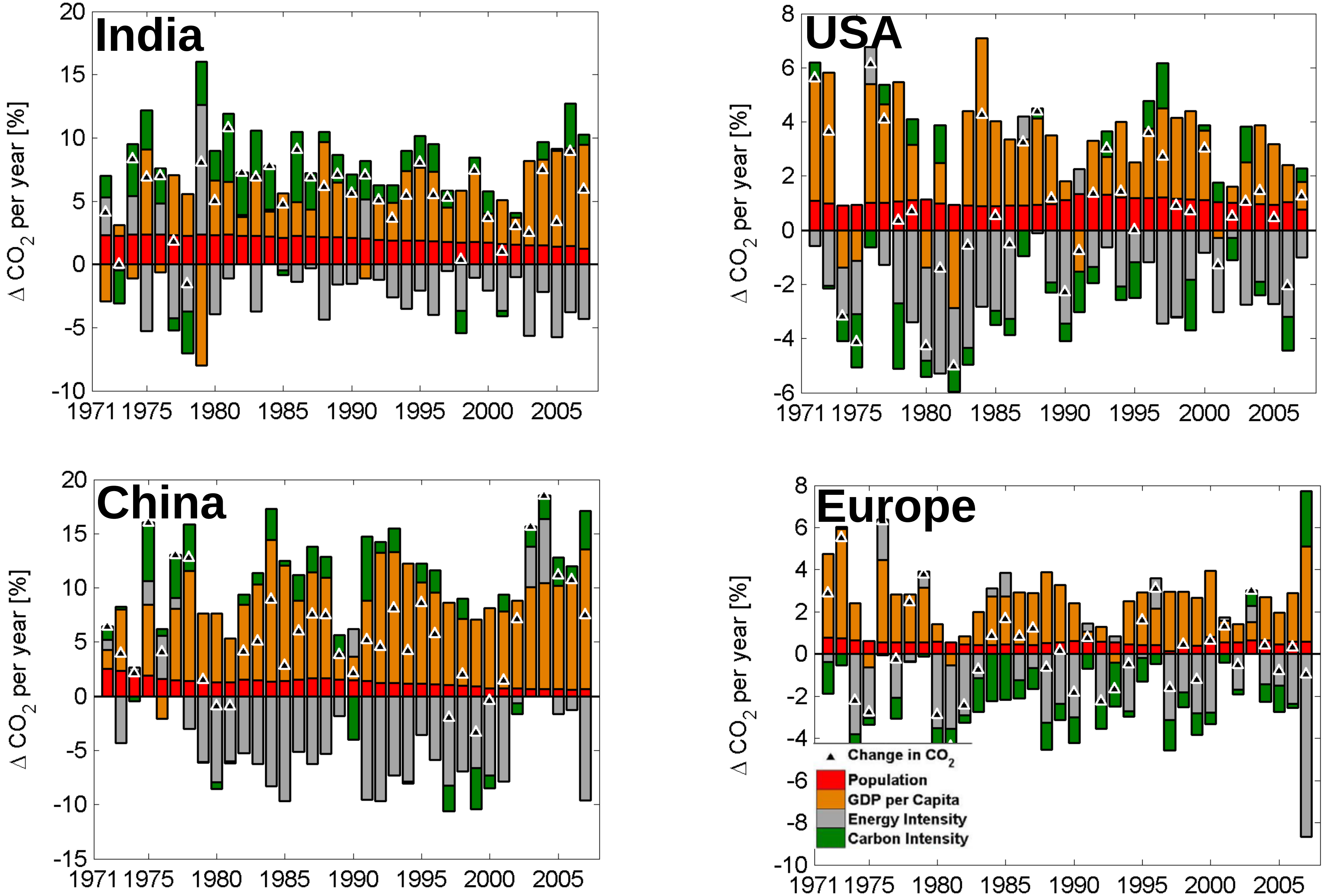


Source: IMF International Commodities Database

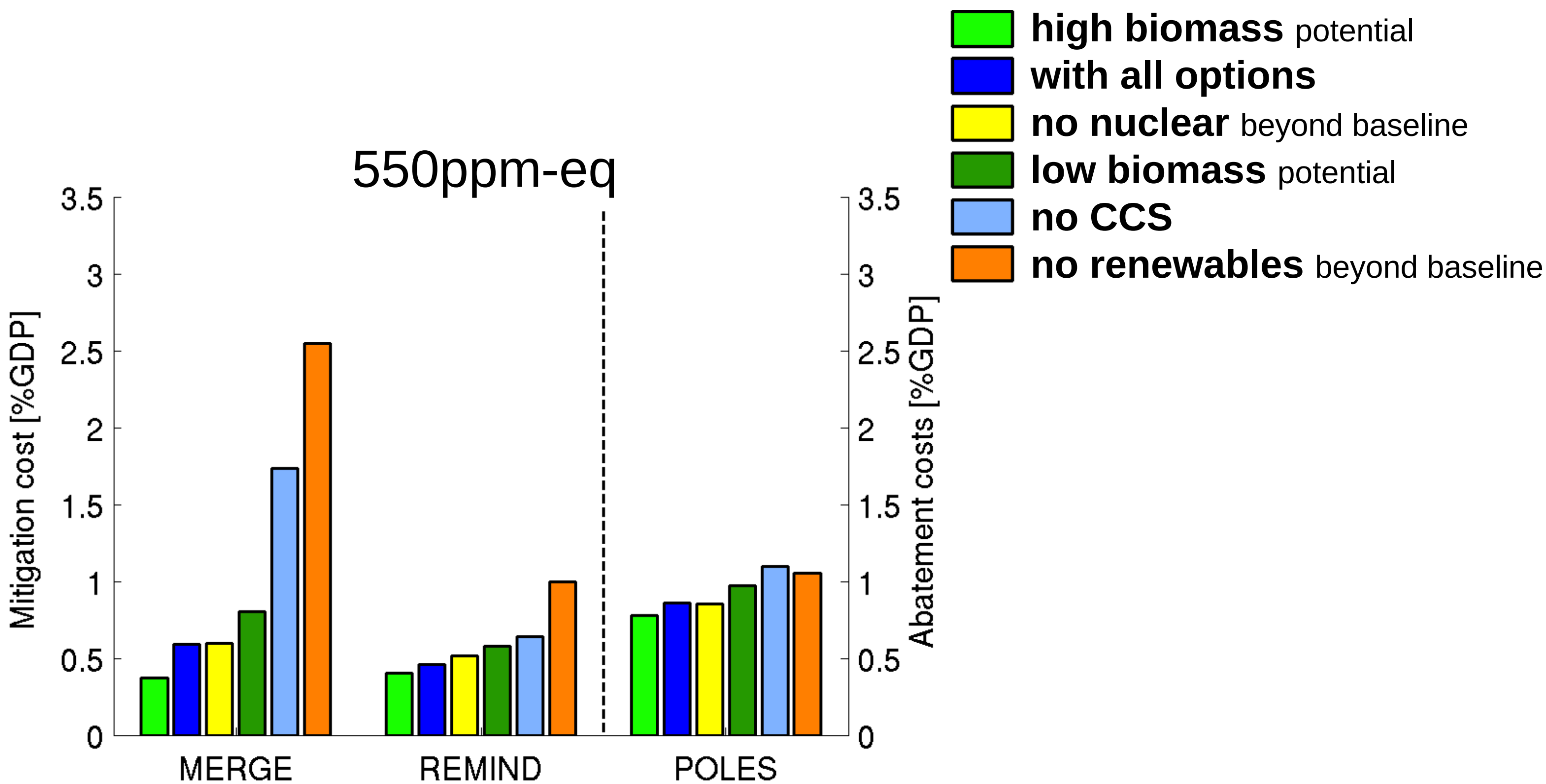
Renaissance of Coal



Carbonization Pathways



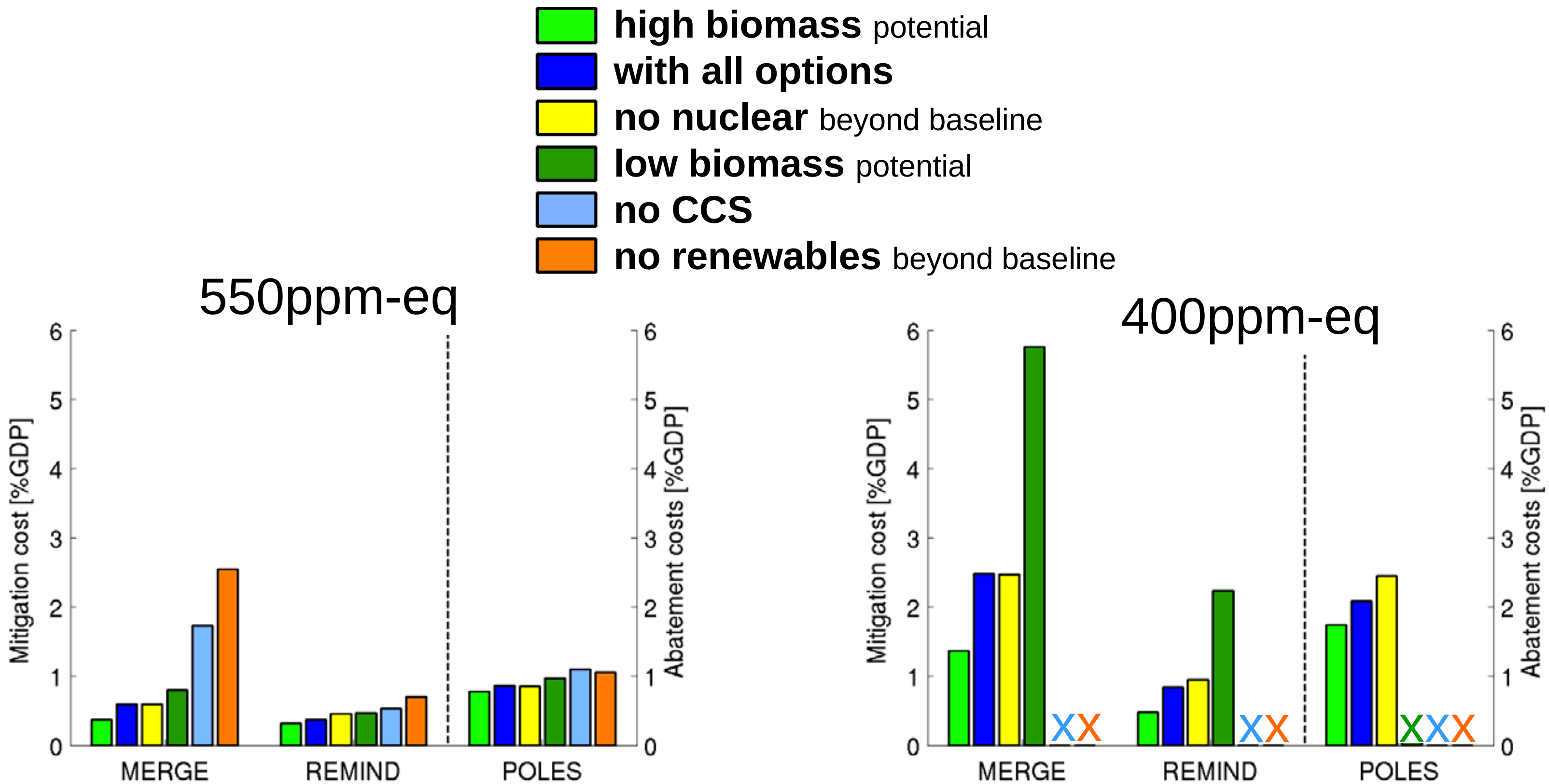
Mitigation Costs: Technology Options, 550ppm



Knopf, Edenhofer et al. (2009)

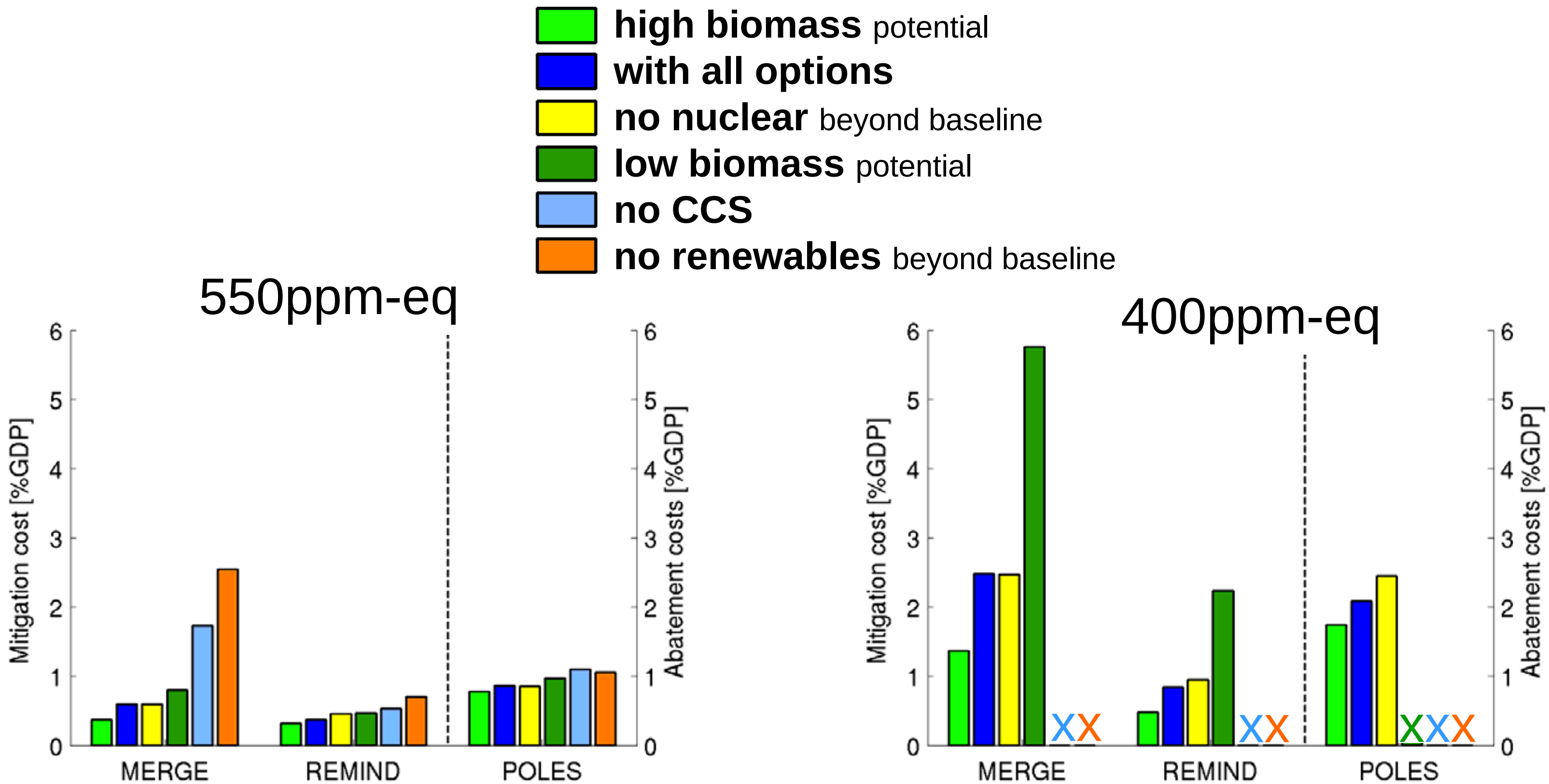
➔ Renewables and CCS are the most important options
➔ Ranking of options: Robust picture throughout all models

Technology Options for Low Stabilisation



Knopf, Edenhofer et al. (2009)

Technology Options for Low Stabilisation



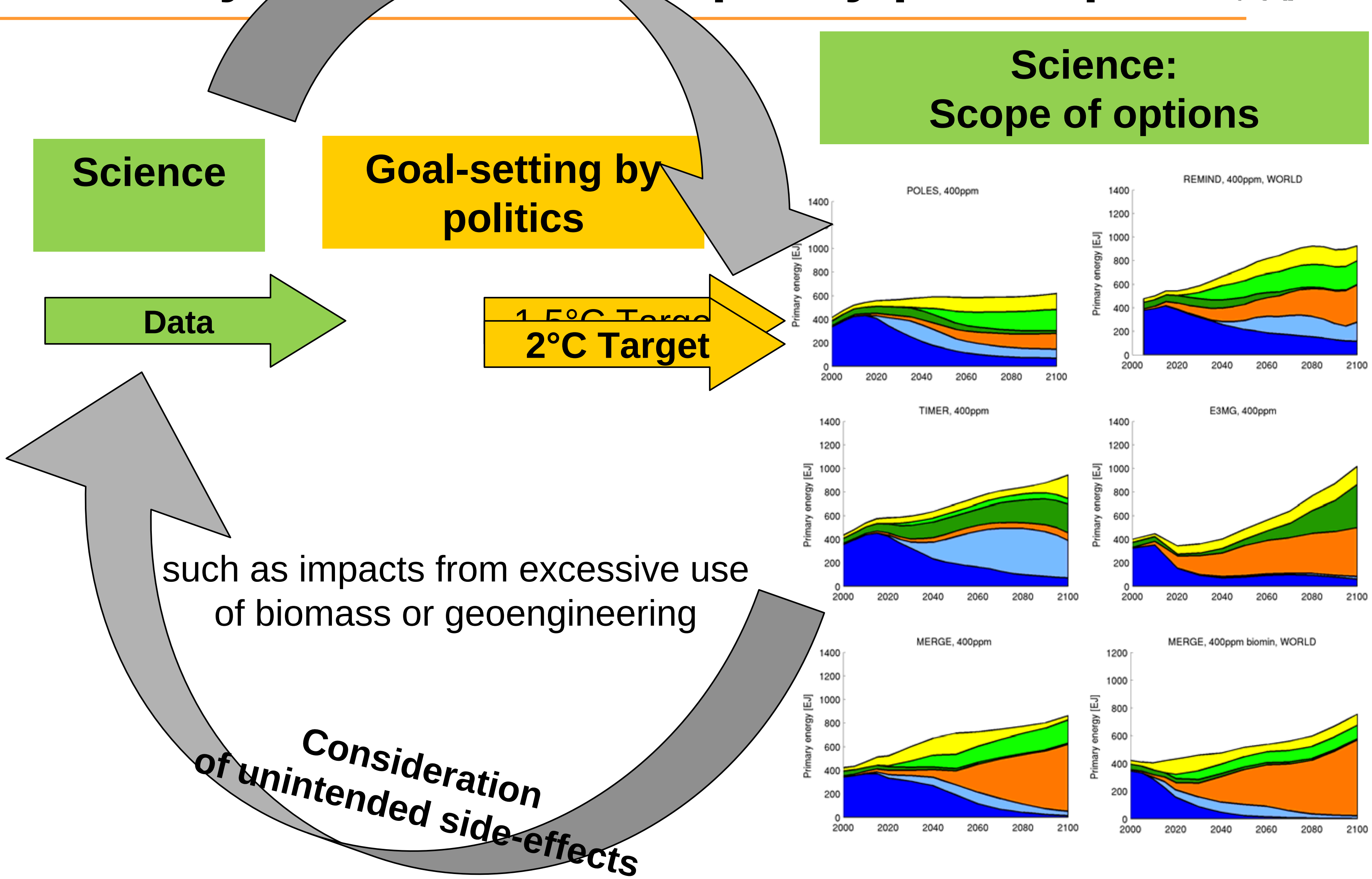
Knopf, Edenhofer et al. (2009)

➔ 400 ppm neither achievable without CCS nor without an extension of renewables

➔ Biomass potential dominates the mitigation costs of low stabilisation

➔ Nuclear is not important beyond its (high) use in the baseline

“Policy relevant but not policy prescriptive“



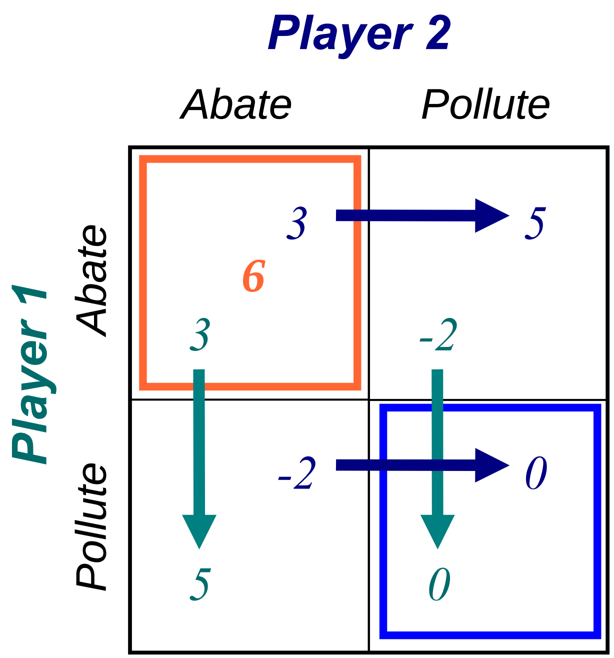
International Environmental Agreements

- In many cases global climate policy implicitly assumes full international cooperation
- In reality: lack of a global authority
  instead: international environmental agreements (IEA)
- Participation is low whenever IEA (Barrett 1994) actually achieve something

Bali 2007

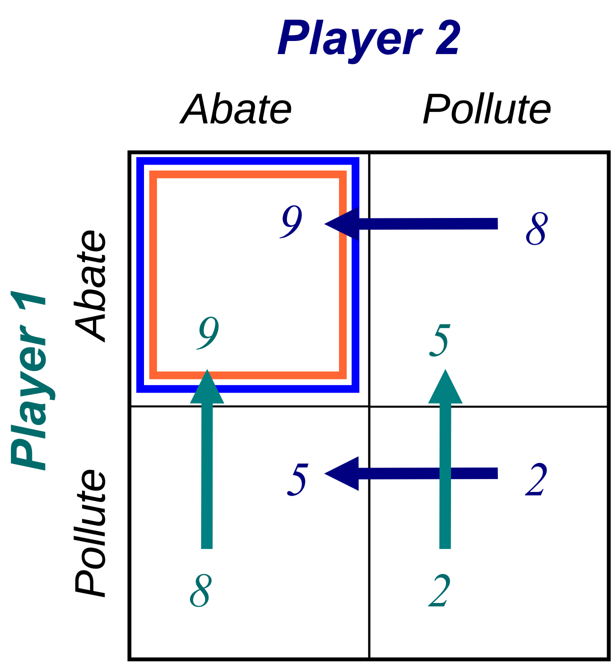
Public Good Provision as a *Prisoners' Dilemma*

- Provision of a global Public Good:
  - (Same) benefits for everyone, say e.g. *5* (*per contributing party!*)
  - (Same) costs to contribute, say e.g. *7*
- Game Structure of the ***Prisoners' Dilemma:***
  - Individual rationality for players to act selfishly
    - → Incentive to *free-ride*
    - → *Suboptimal outcome*



- If abating global warming resembles a Public Good, then climate negotiations will face a Prisoners' Dilemma

Co-Benefits – An *Assurance Game*?



- Nash Equilibrium and Social Optimum coincide

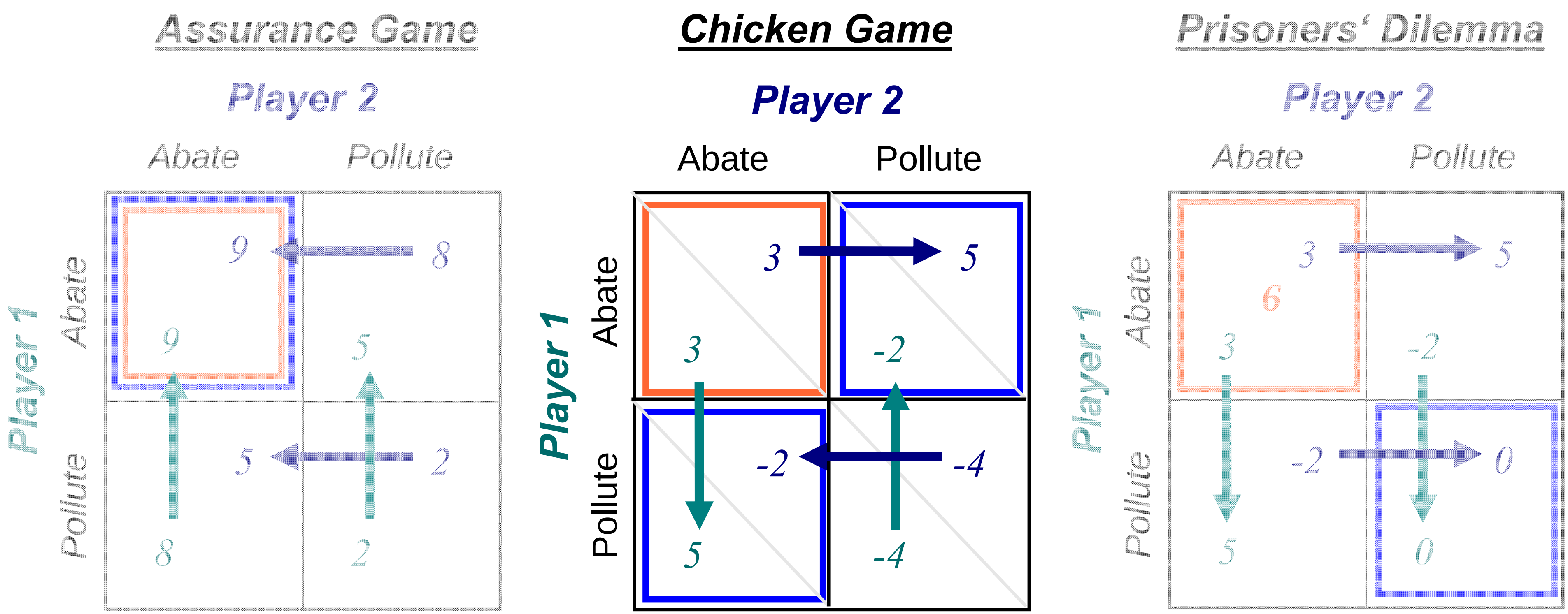
- Attempt to create focal point on Social Optimum:
  - 'Co-Benefits of mitigation so high that unilateral abatement pays, irrespective of others' decision'

  → A mere issue of proper perception

→ Co-Benefits matter, but really large enough to resolve PD automatically?

→ The Hartwell-Paper argues that climate policy should be an indirect outcome of achieving Co-Benefits

Public Good Provision as a *Prisoners' Dilemma*



- Carraro: *Prisoners' Dilemma (PD)* –IEA→ *Chicken Game (CG)*
- Chicken Game shows partially cooperative behaviour

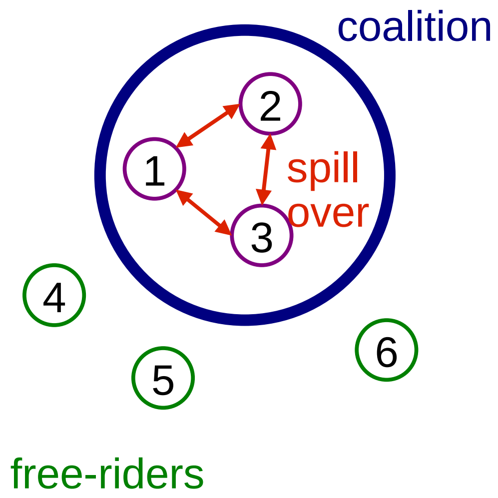
The Challenge

- Can a clever design of environmental agreements achieve higher participation?

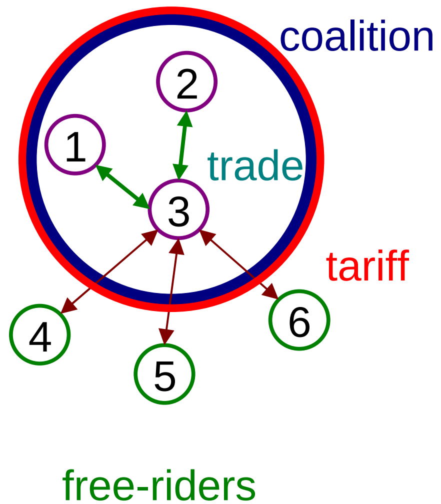
- Possibilities:
  - Promoting growth policy and new technologies
  - Trade restrictions
  - Permit trade with non-members of the agreement

Reward: Technology Cooperation and
Punishment: Import Tariffs

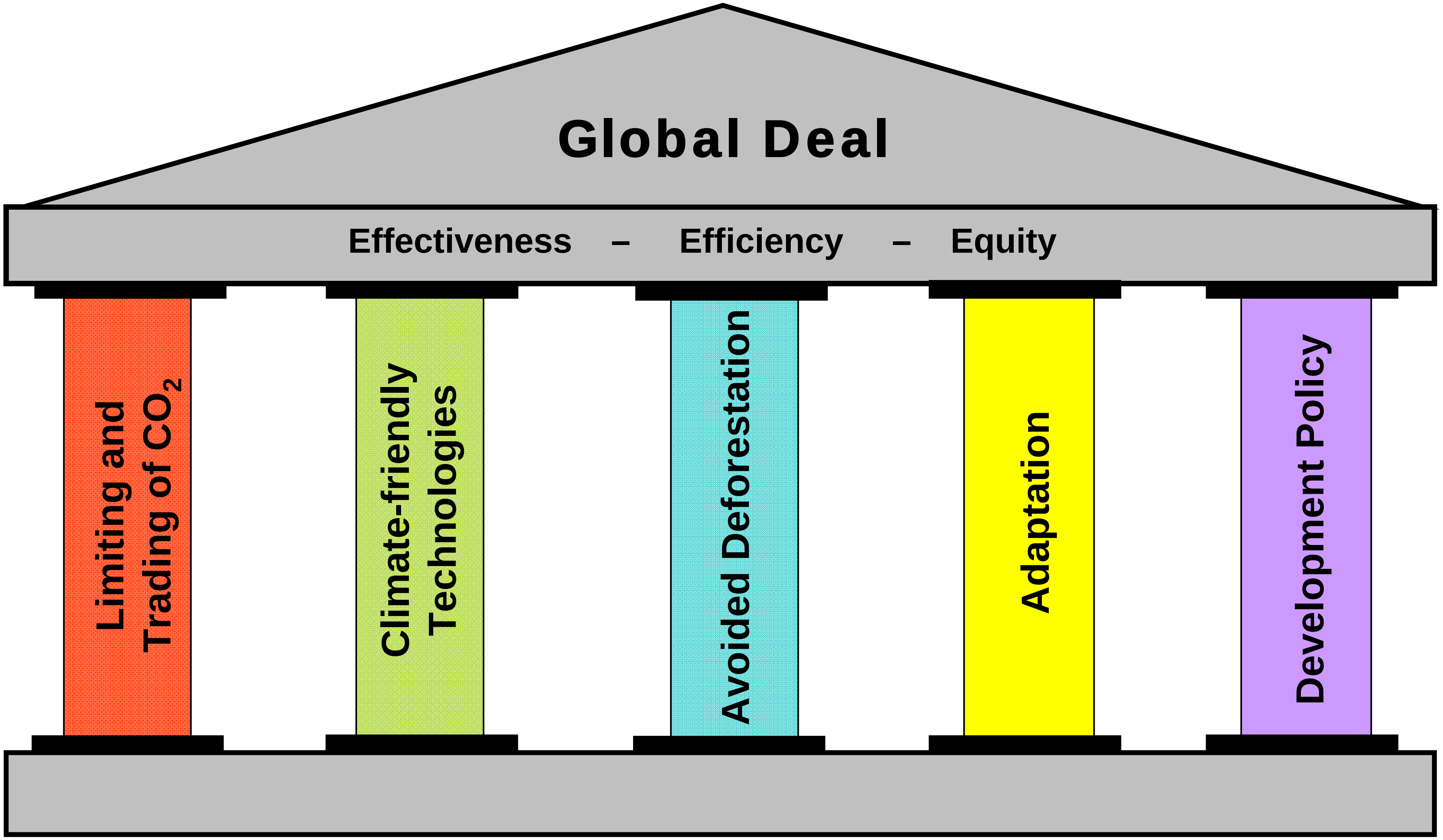
- Tuning incentives by treaty design:
  - Positive incentive: *Research Cooperation*
    - R&D spill-over within coalition
    - Participation rises with spill-over intensity
    - Improving *productivity* by R&D shown to be a stronger incentive than improving *abatement*
  - Negative incentive: *Import Tariffs*
    - Coalition levies tariffs on imports from free-riders
    - Tariffs induce up to full cooperation
    - Tariffs are individually + socially rational



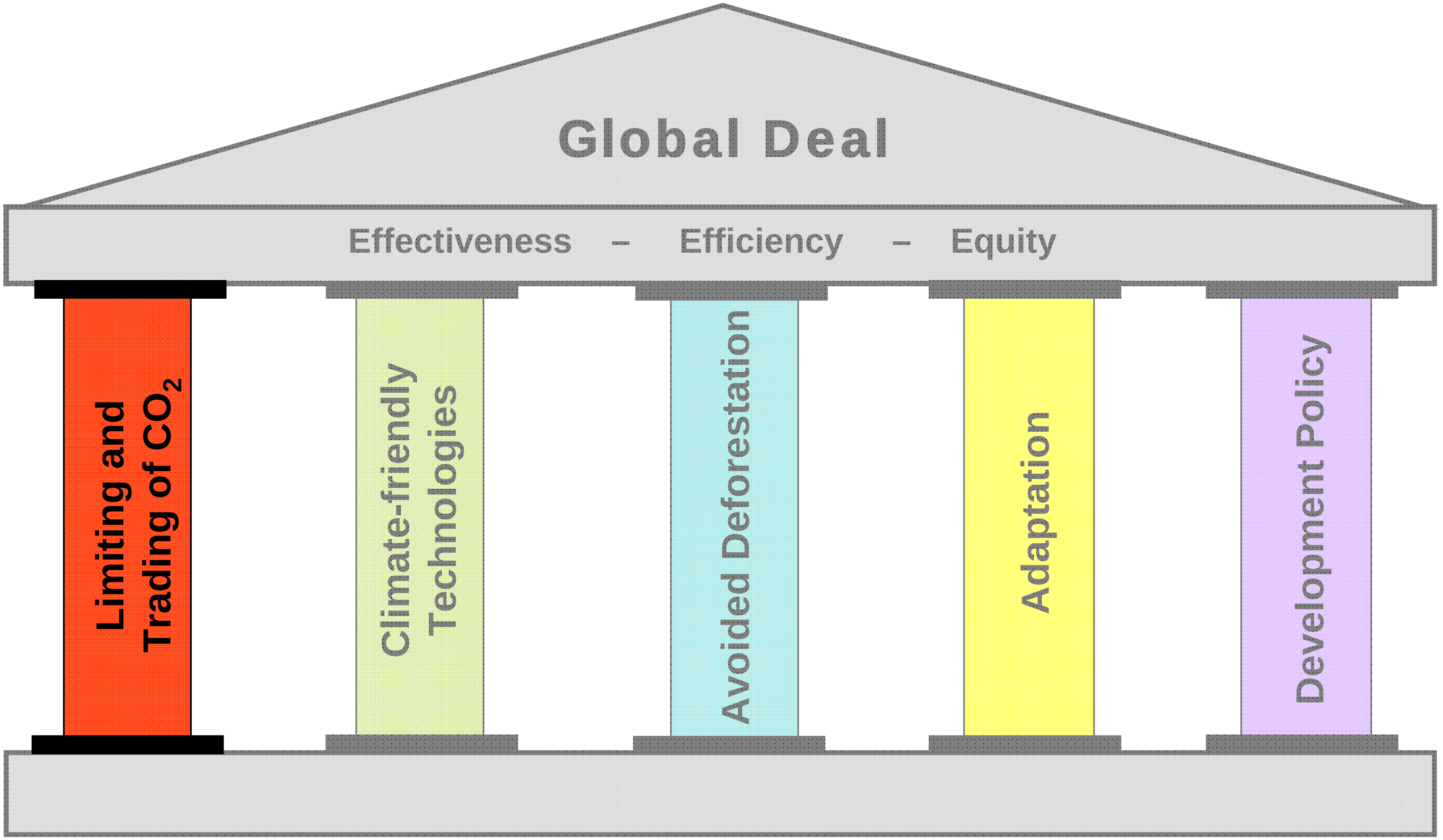
- Examples, where IEA design changed the game from a dilemma to an assurance game



- For details see
  - Lessmann et al. (2009), Economic Modelling
  - Lessmann and Edenhofer (2010), Resource and Energy Economics



Global Deal
Effectiveness – Efficiency – Equity
Limiting and Trading of CO2
Climate-friendly Technologies
Avoided Deforestation
Adaptation
Development Policy



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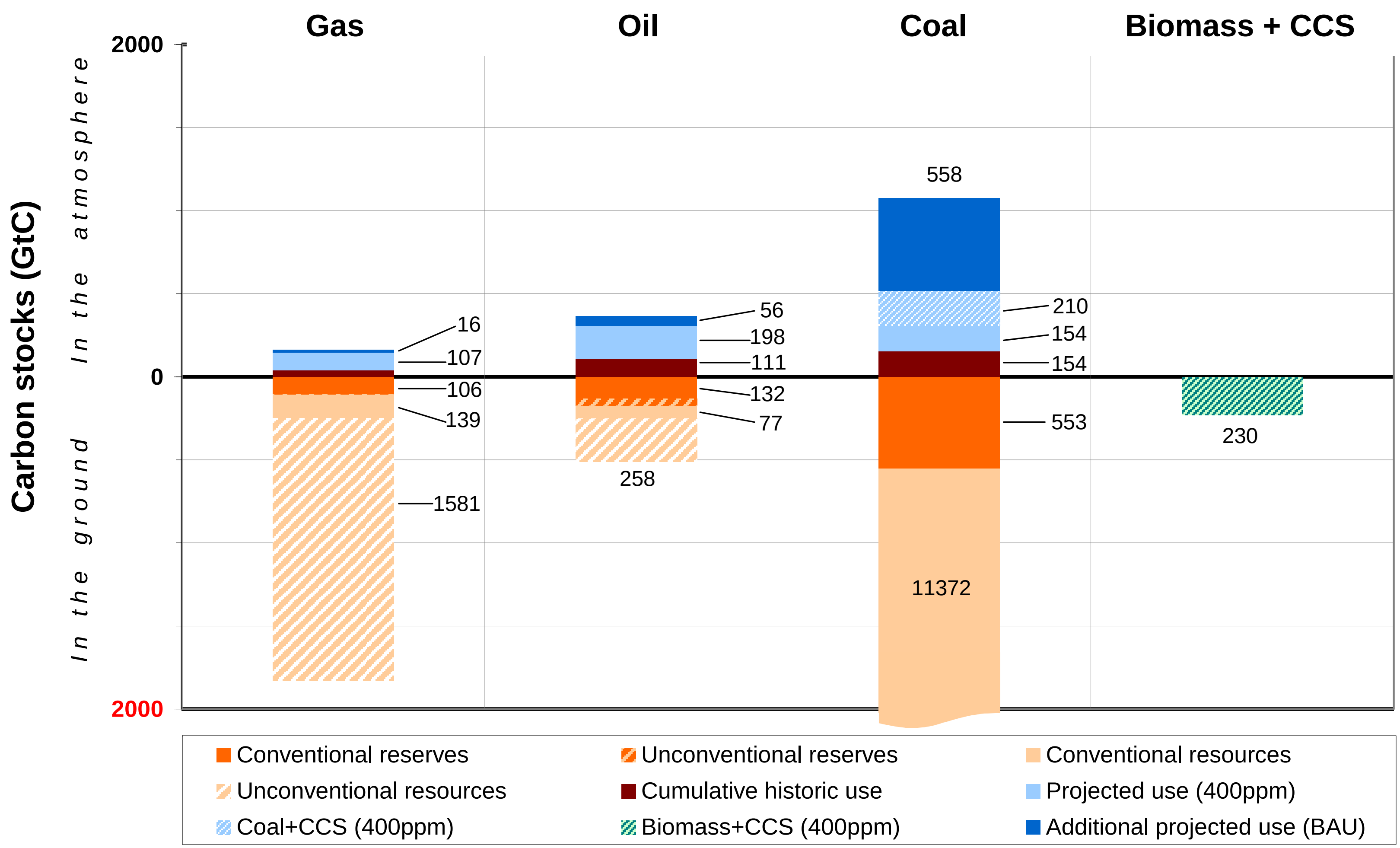
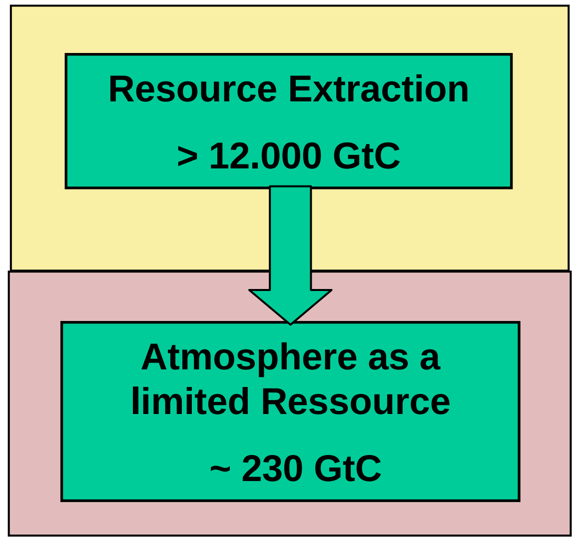
The Supply-side of Global Warming



Cumulative historic carbon consumption (1750-2004), estimated carbon stocks in the ground, and estimated future consumption (2005-2100) for business-as-usual (BAU) and ambitious 400-ppm-CO_2-eq. scenario

Source: Kalkuhl, Edenhofer and Lessmann, 2009

The Supply-side of Global Warming



- Atmosphere is a scarce resource – fossil carbon is not
- Economic approach to deal with scarcity in an efficient way:
  - Establish prices on scarcities
- Who should determine scarcity prices?
  - Regulator (establish prices on the use of scarce resources – carbon tax)
  - Market (assigning property rights according to the scarcity of the atmosphere – ETS)

CO_2 Tax: Regulator Determines Scarcity Prices

Optimal tax requires for the regulator to know:

- Environmental scarcity (damage function or carbon budget)
- Economic development for the entire time horizon *ex ante*
  - Extraction costs
  - Economic growth, carbon demand, technological progress, development and costs of backstop technologies
- Optimal tax path (cost-benefit framework):

$$\theta(t) = F_S(S^*(T))e^{-r(T-t)} - \int_t^T d_S^* e^{r(t-\xi)}\, d\xi$$

- Optimal tax path (carbon budget framework):

$$\theta(t) = \mu_T^{CB} e^{-r(T-t)}$$

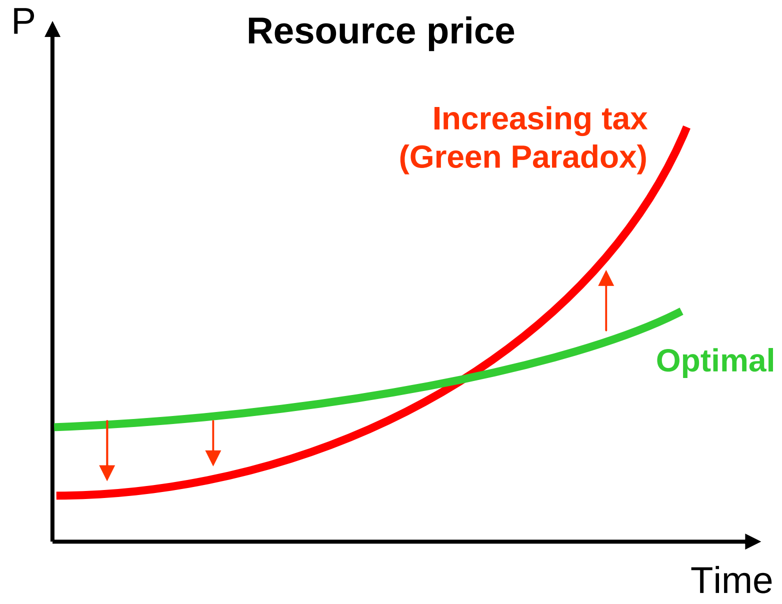
d(S)	damages (of stock S)
d_S^*	marginal damages along socially optimal resource stock path
r	discount rate
$F_S(S^*(T))$	marginal scrap value of socially optimal resource stock at T
μ_T^{CB}	socially optimal resource shadow price at T

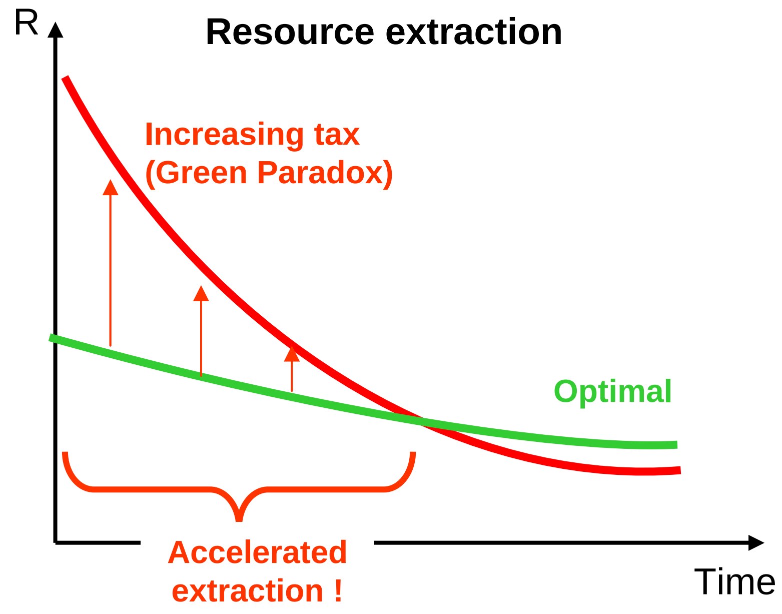
- "Progressive" (stock-dependent) carbon tax rule: $\tau^i(S^i) = \dfrac{-d_S(nS^i)}{r}$
  (individual tax for each resource owner)

  Final-period payment rule (optimal transversality condition): $\varsigma^i(S^i(T)) = \dfrac{1}{n}\left(\dfrac{d(nS^i(T))}{r} - F(nS^i(T))\right)$

Lessons from the "Green Paradox"

- Resource taxes change time path of net resource price
  - time-path of extraction is changed
  - fast increasing taxes can provoke an accelerated resource extraction





Lessons from the "Green Paradox"

Effect of an exponentially increasing resource tax $\tau = \tau_0 \, e^{\theta t}$

	Slowly increasing tax $\theta < r$		Tax increases at discount rate $\theta = r$		Fast increasing tax $\theta > r$	
	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$
Timing effect	postpone extraction	postpone extraction	none	none	accelerate extraction	accelerate extraction
Volume effect	none	conservative	none	conservative	none	conservative
Green paradox	none	none	none	none	yes	ambiguous
Impact on damages compared to zero-tax case	- timing effect	-- timing and volume effect	none	- volume effect	++ timing effect	-/+ timing vs. volume effect

Source: Edenhofer and Kalkuhl (2010)

Critical initial tax level τ_0^*

$$\int_0^\infty q(\tau_0^* e^{\theta t} + c)dt = S_0$$

Emissions Trading Scheme (ETS):
Market Determines Environmental Scarcity Prices

Cost-benefit framework: Regulator issues permits

- For intertemporal efficiency, same informational requirements as in the carbon tax case
- Market determines scarcity prices – but regulator has to know them *ex ante* to calculate optimal permit path

Carbon-budget framework: Regulator issues permits and allows for free banking and borrowing

- Market determines scarcity prices
- Regulator needs no information about future economic development
- Assigning property rights according to environmental scarcity
- Scarcity rent can be distributed without efficiency losses (auctioning, grandfathering)

Cost-Benefit vs. Carbon Budget

Intertemporal rent dynamics

$$\theta(t) = F_S(S^*(T))e^{-r(T-t)} - \int_t^T d_S^* e^{r(t-\xi)}\, d\xi$$

$$\theta(t) = \mu_T^{CB} e^{-r(T-t)}$$

Can regulator use markets to find intertemporally optimal pathways?

"progressive"
(stock-dependent) tax

ETS with free
banking & borrowing

Ownership and Management of the Climate Rent

Cost-Benefit

Management / Ownership	Regulator	Resource Owner
Regulator	• Resource tax • ETS with auctioning; with and w/o banking	• "Progressive" (stock-dependent) tax
Resource Owner	• ETS with grandfathering; with and w/o banking	

Carbon-Budget

Management / Ownership	Regulator	Resource Owner
Regulator	• Resource tax • ETS w/o banking and with auctioning	• ETS with banking and with auctioning
Resource Owner	• ETS w/o banking and with grandfathering	• ETS with banking and with grandfathering

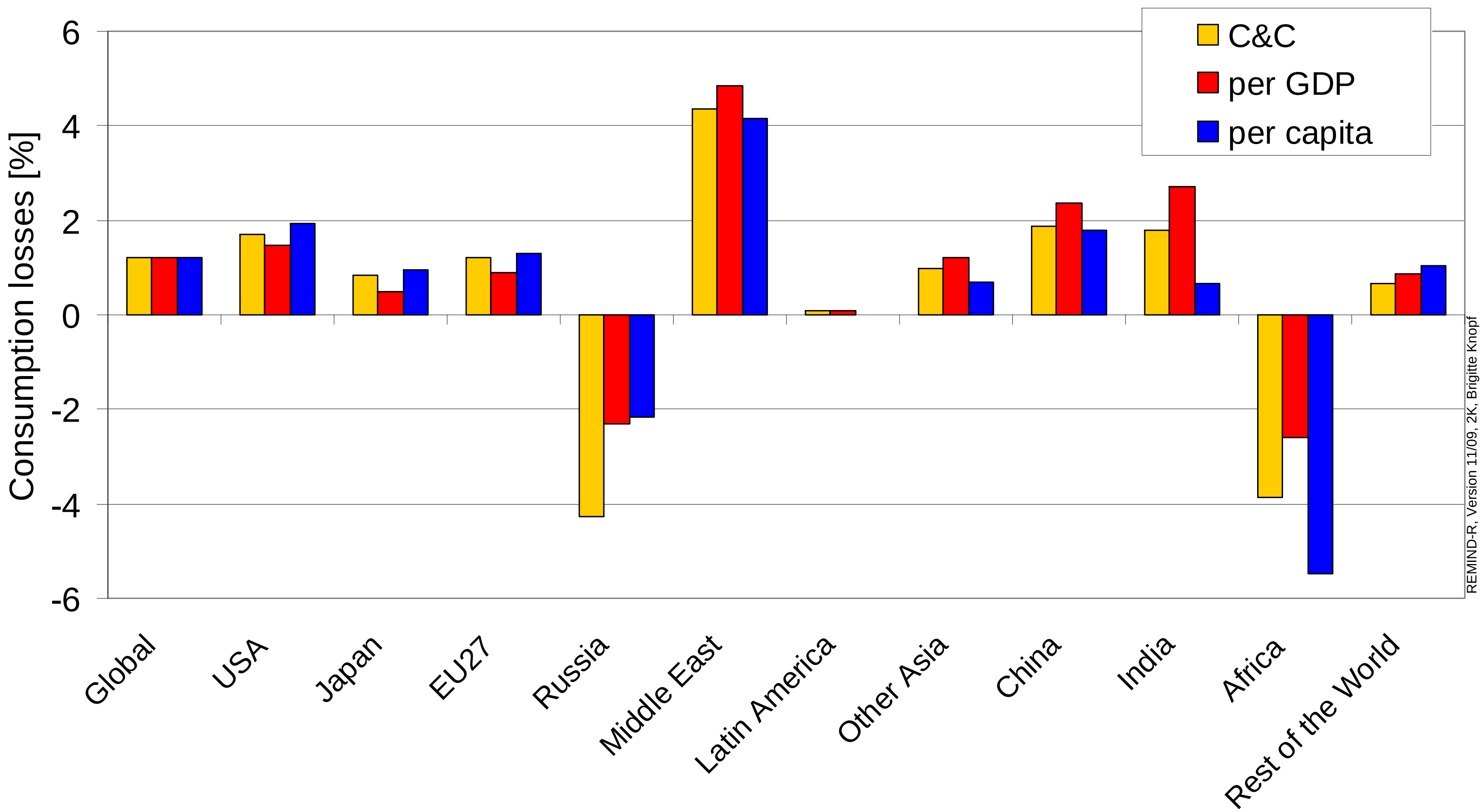
Carbon Budget Approach and ETS

- Carbon budget approach with intertemporal ETS allows for shifting daunting intertemporal management to the market or to independent institutions (carbon trust, carbon bank)
  - What-flexibility: Coal, oil, gas, conventional/unconventional
  - When-flexibility: Banking and borrowing of permits
  - Respective market structures are required (futures markets)

- A green paradox cannot occur

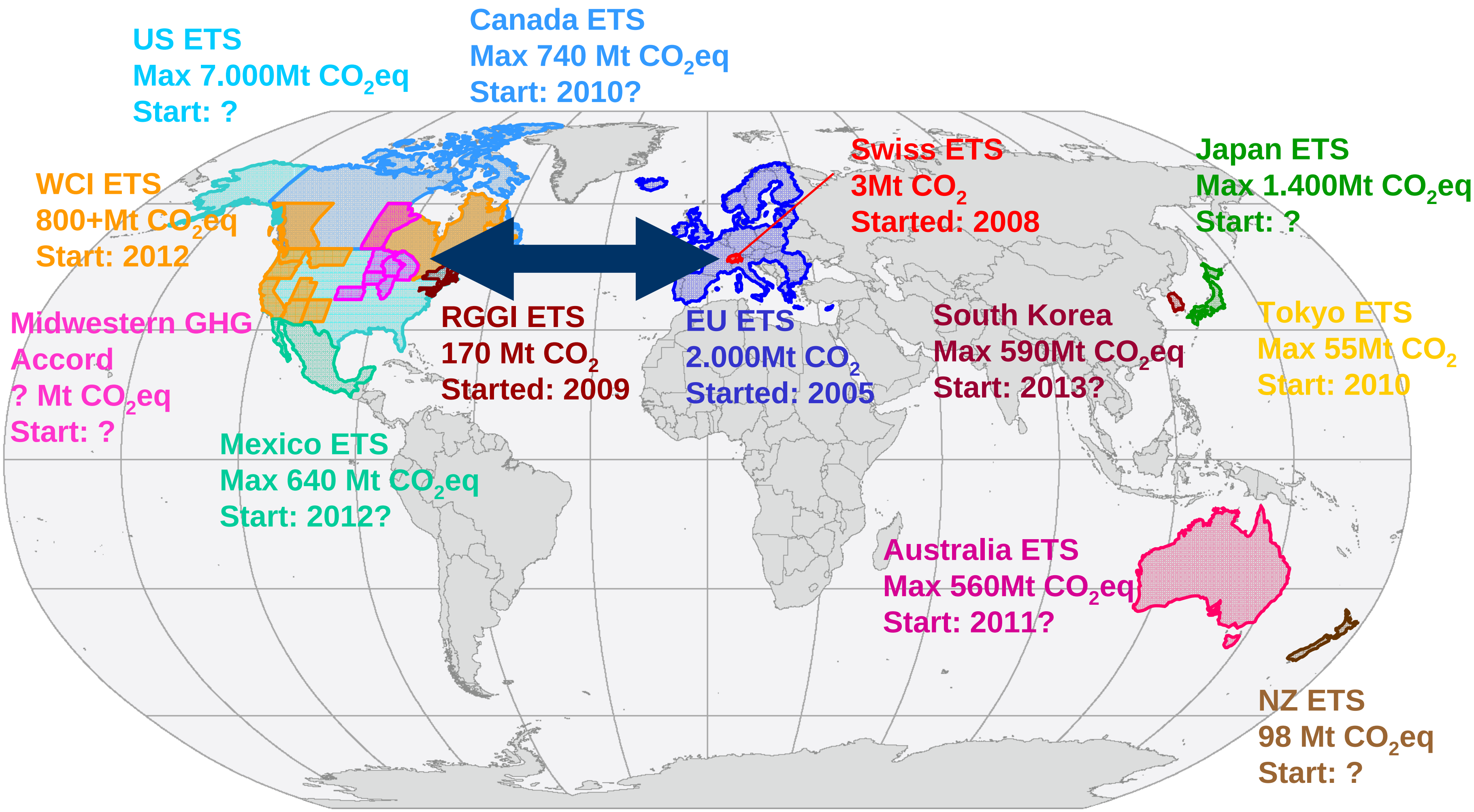
- But: intertemporal efficient allocation of climate damages cannot be achieved

Regional Mitigation Costs: Winners and Losers



Edenhofer et al., 2009

Domestic Cap and Trade: Linking Emerging CO_2-Markets



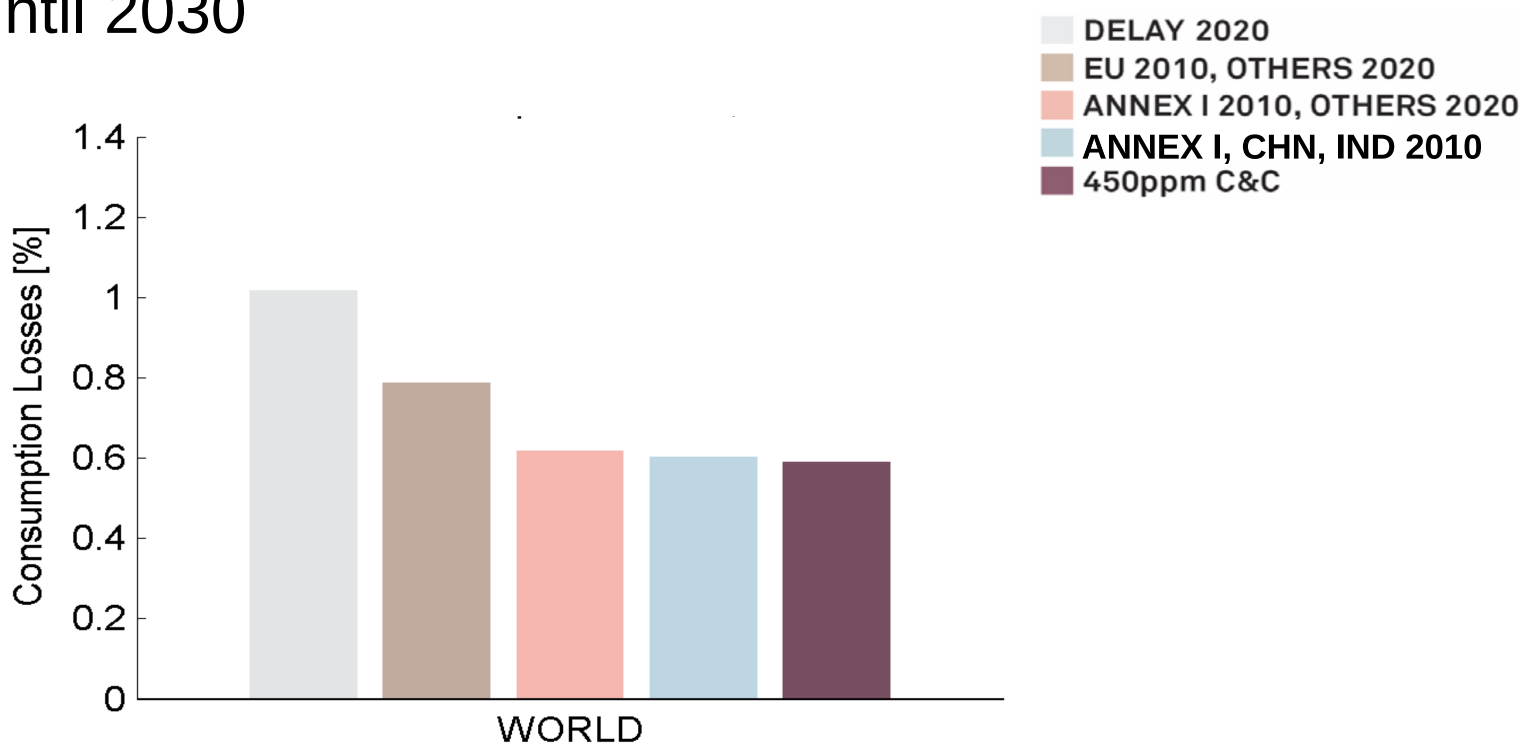
"The European Commission is preparing to call on the United States to create a trans-Atlantic system of carbon trading"

- Herald Tribune, Friday, January 23rd, 2009

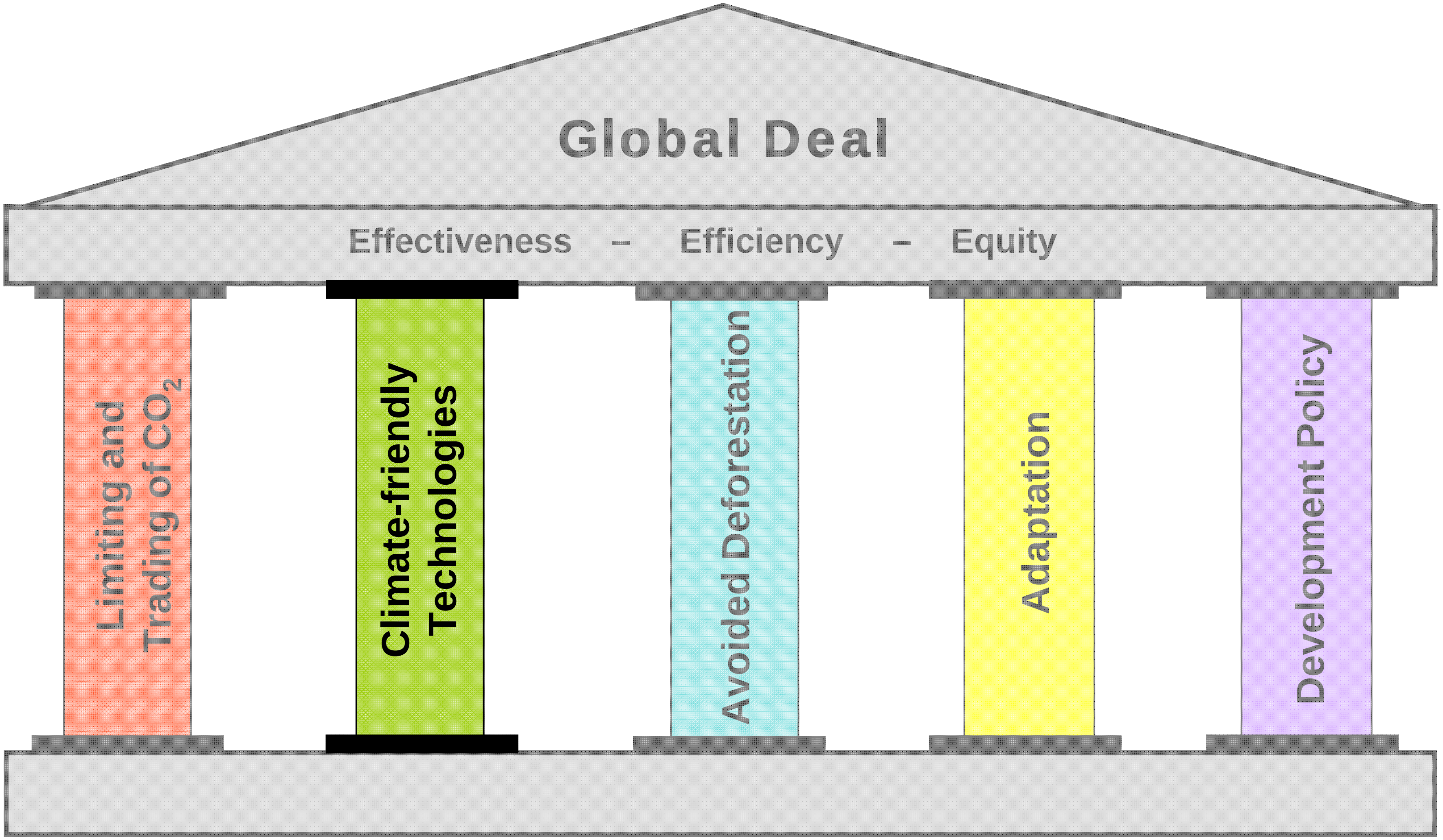
Source: Flachsland (2009)

The Value of Early Action (REMIND)

- Delay of mitigation action until 2020 will increase global costs by 70%
- Stabilisation at 450 ppm CO_2 is not feasible when delaying action until 2030



Source: RECIPE 2009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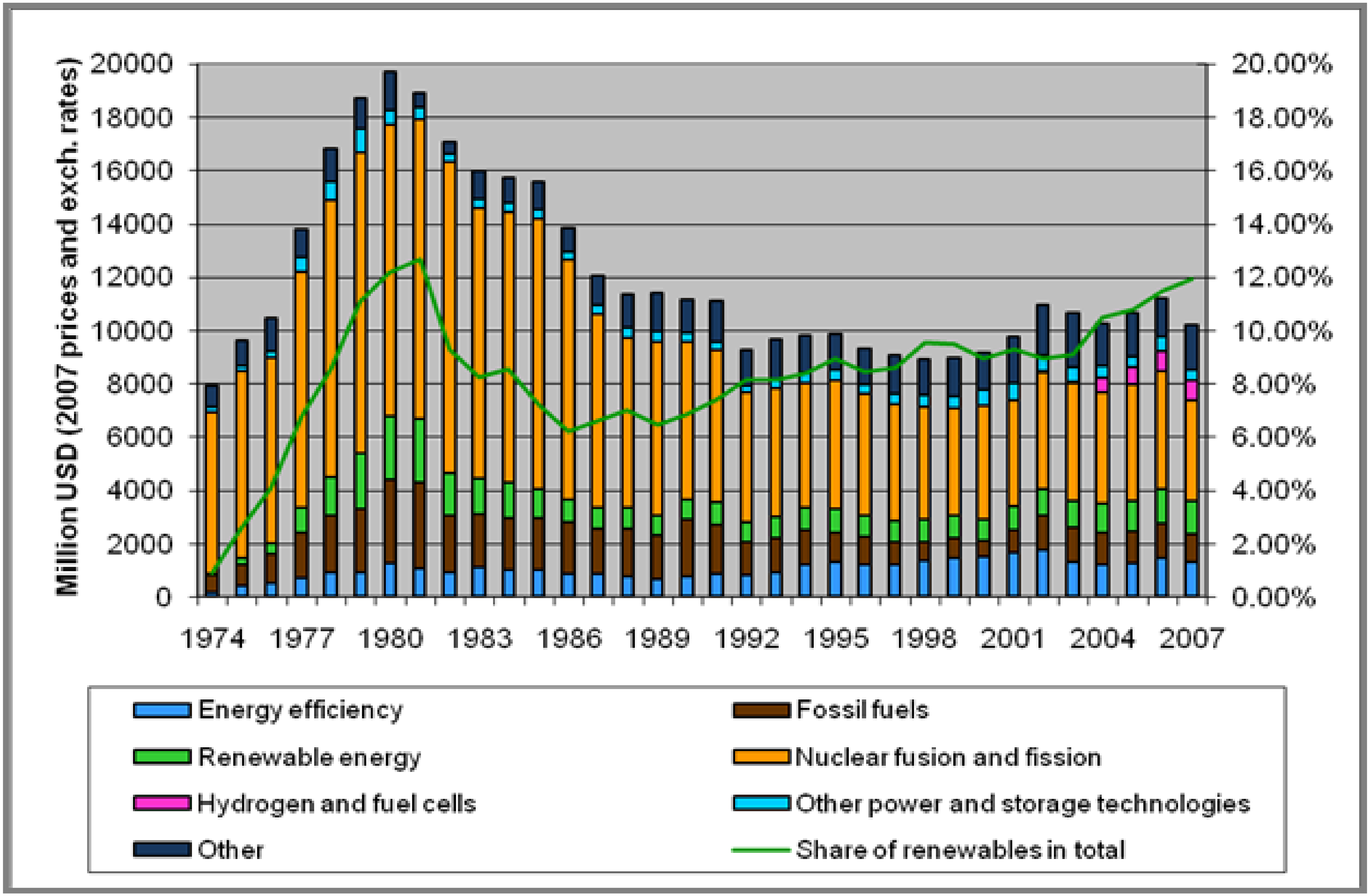
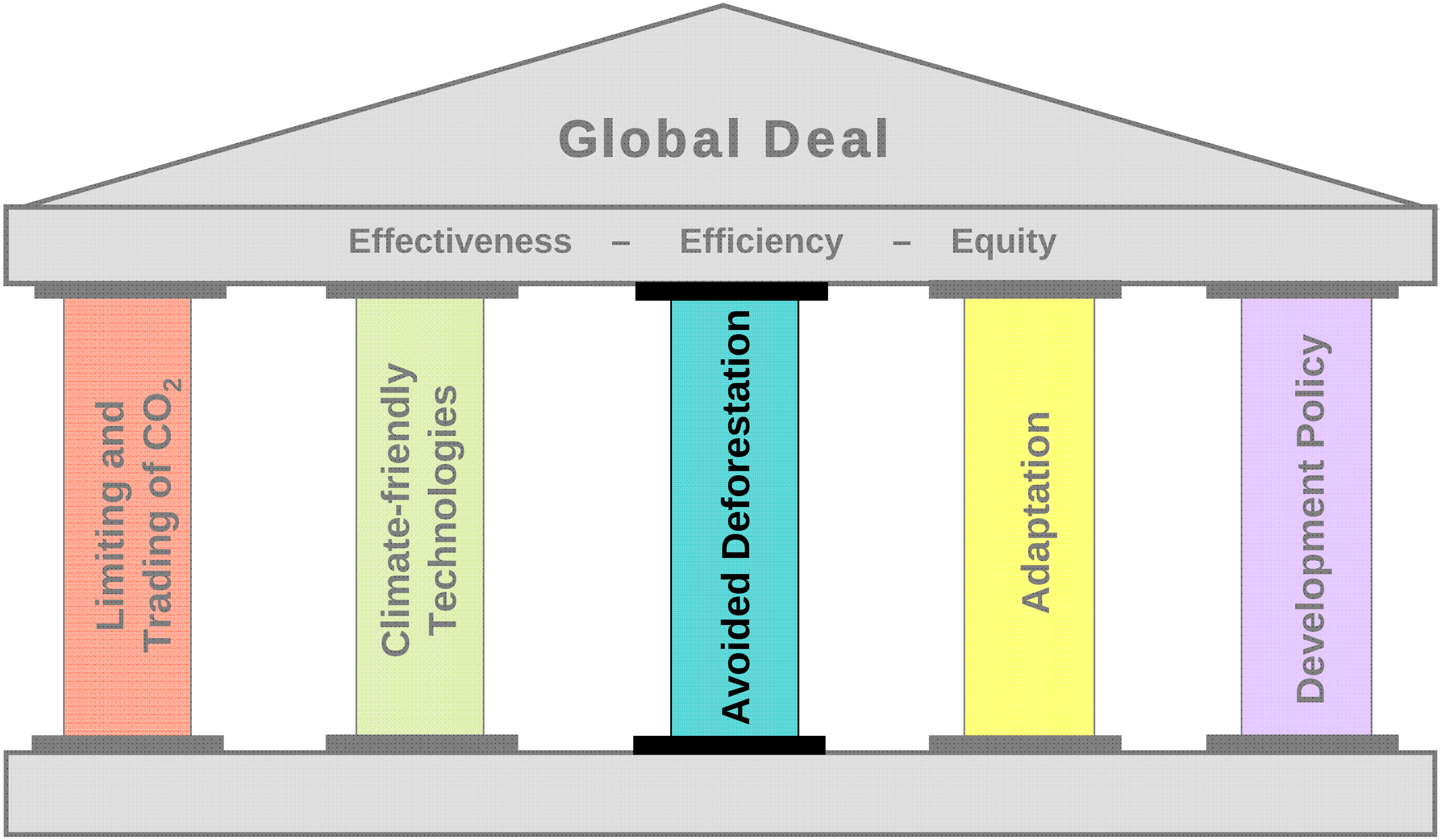
R&D-Investment in Energy Technologies



Source: Updated version of IPCC (2007), AR4



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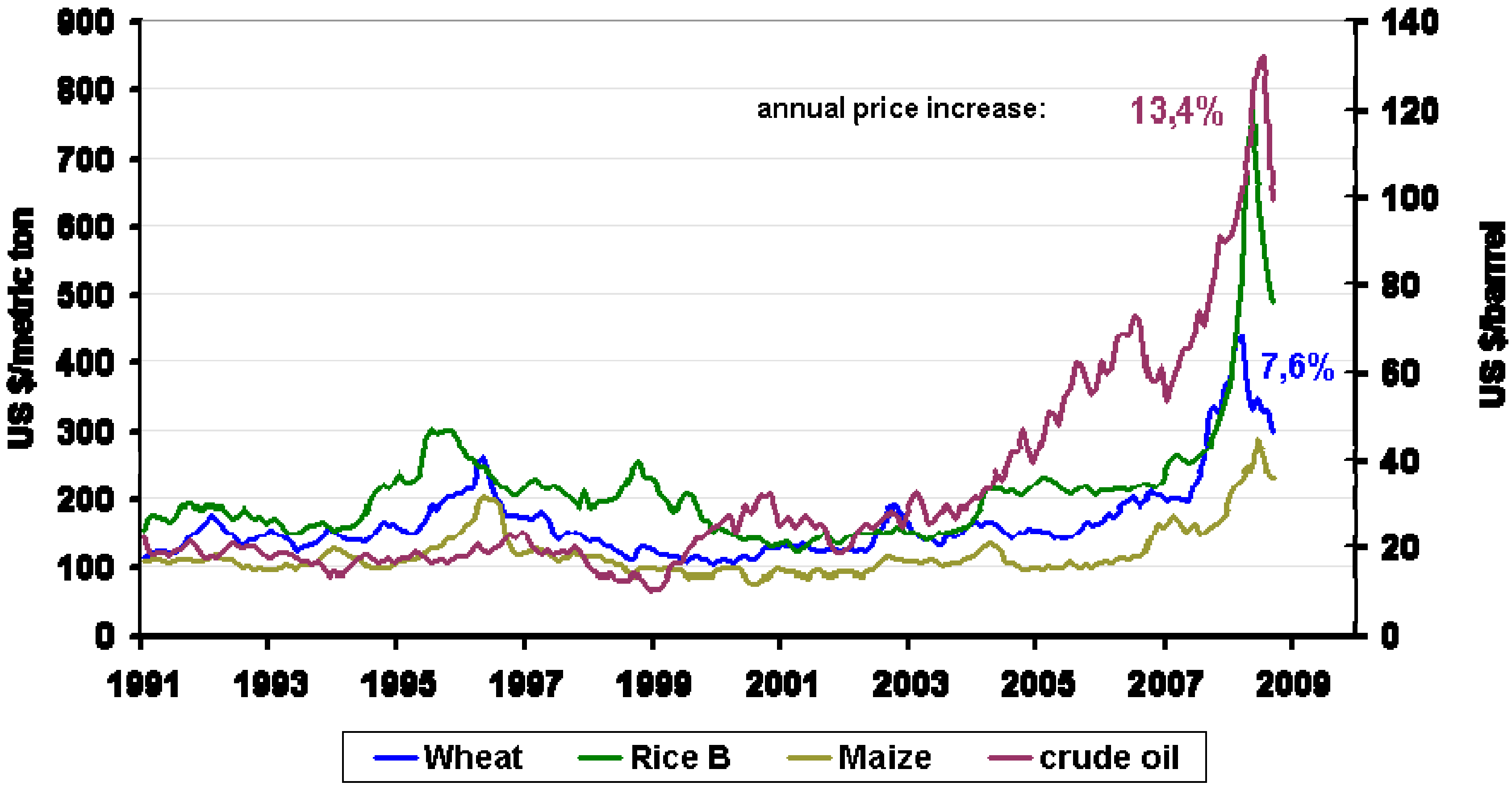
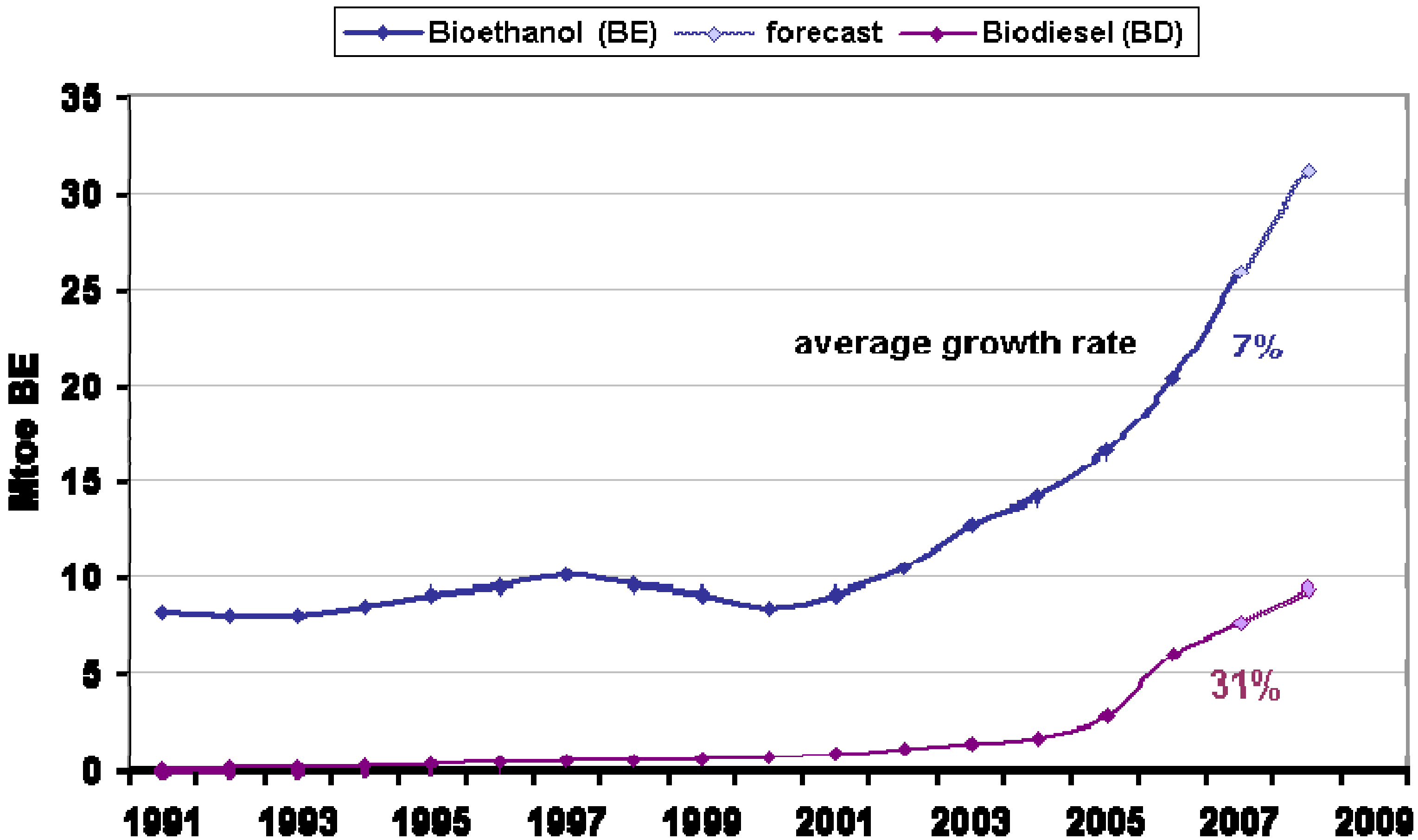
Market Prices for staple foods and crude oil monthly averages 1991 - 2008



Source: IMF; FAO International Commodity Prices

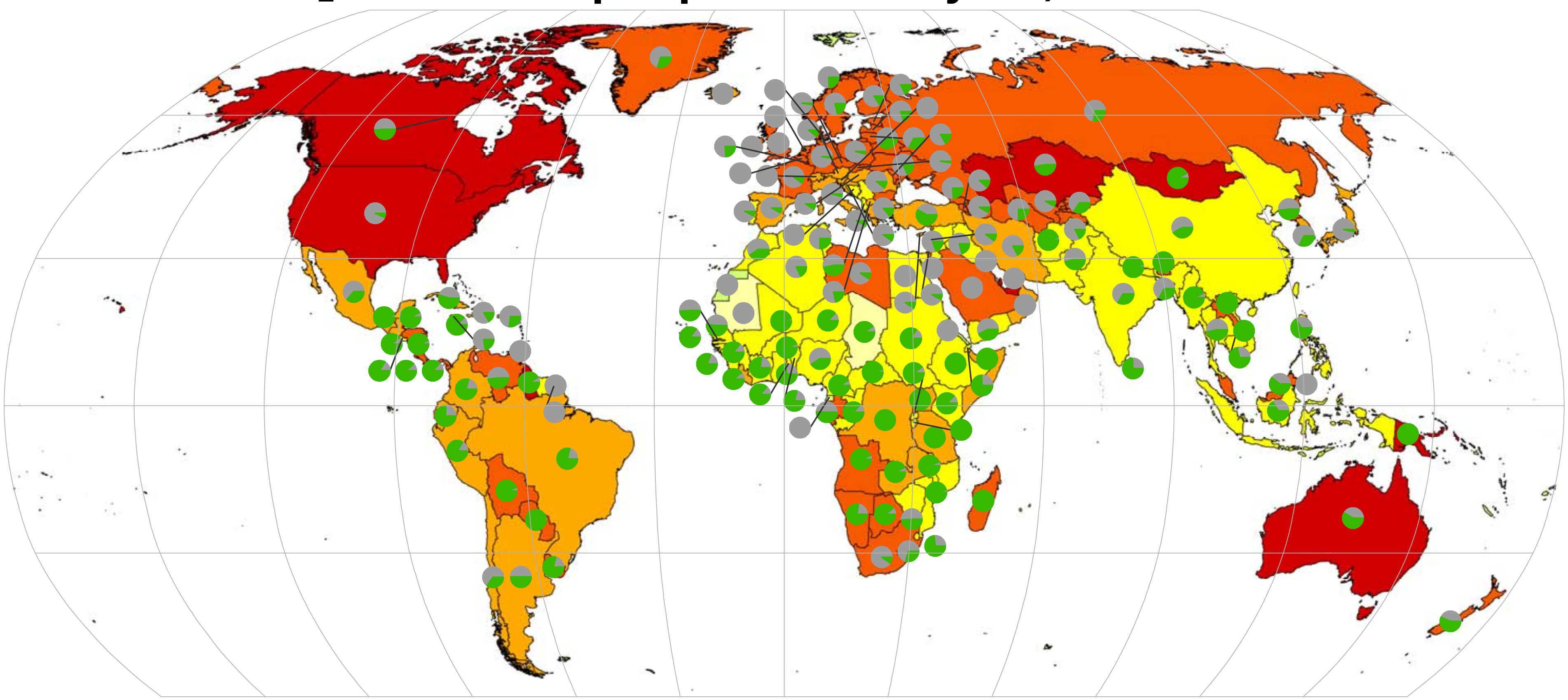
Annual World Biofuel Production 1991 - 2008



Source: BP Statistical Energy Review; WRI

Reducing Deforestation: Fossil vs. LUCF CO_2 Emissions

CO_2 emissions per person and year, 1950 - 2003



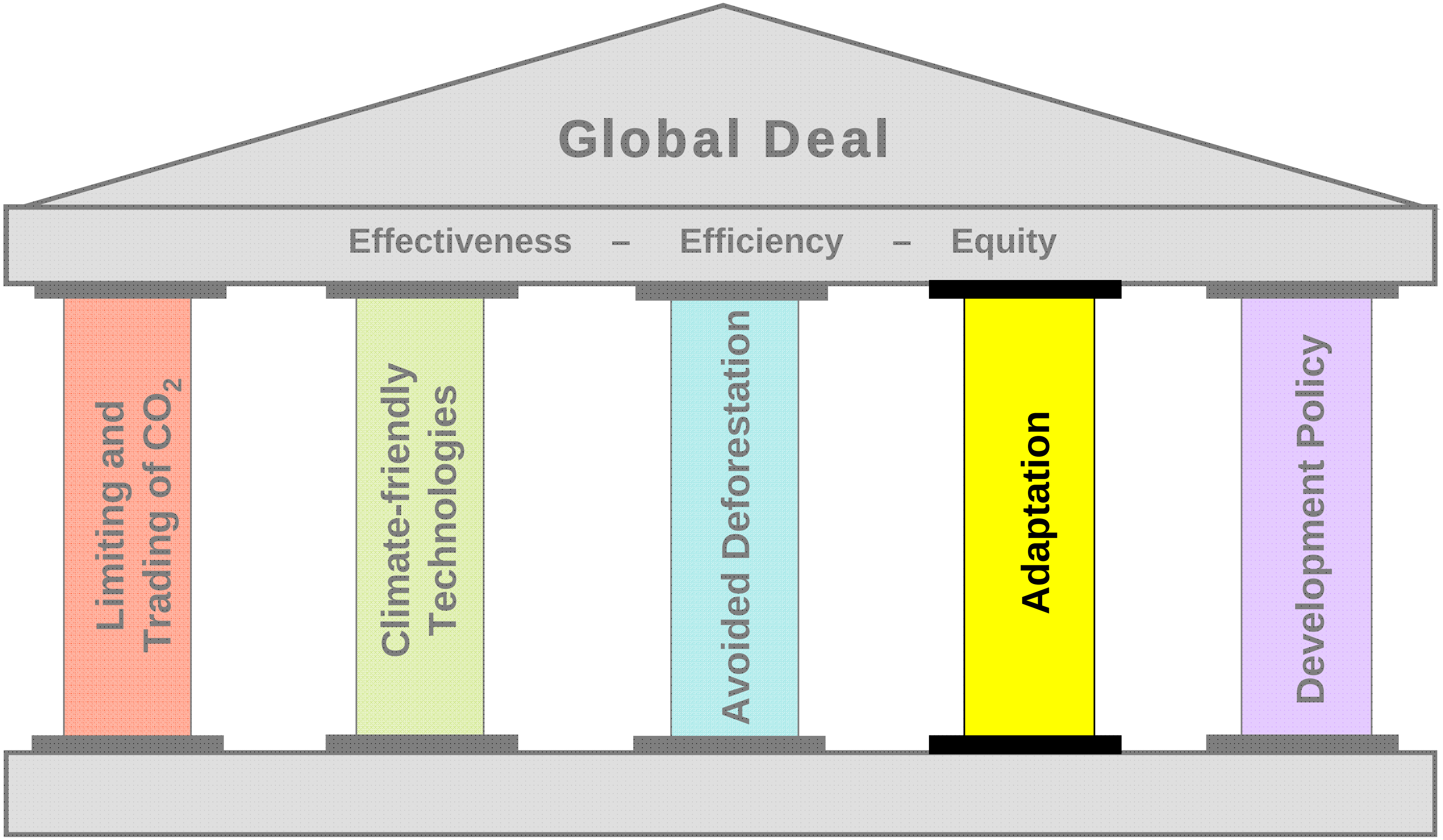
CO_2 emissions from fossil fuel combustion and cement production, and including land use change (kg C per person and year from 1950 - 2003)

- -1000 - 0
- 0 - 100
- 100 - 1000
- 1000 - 2000
- 2000 - 5000
- 5000 - 15000

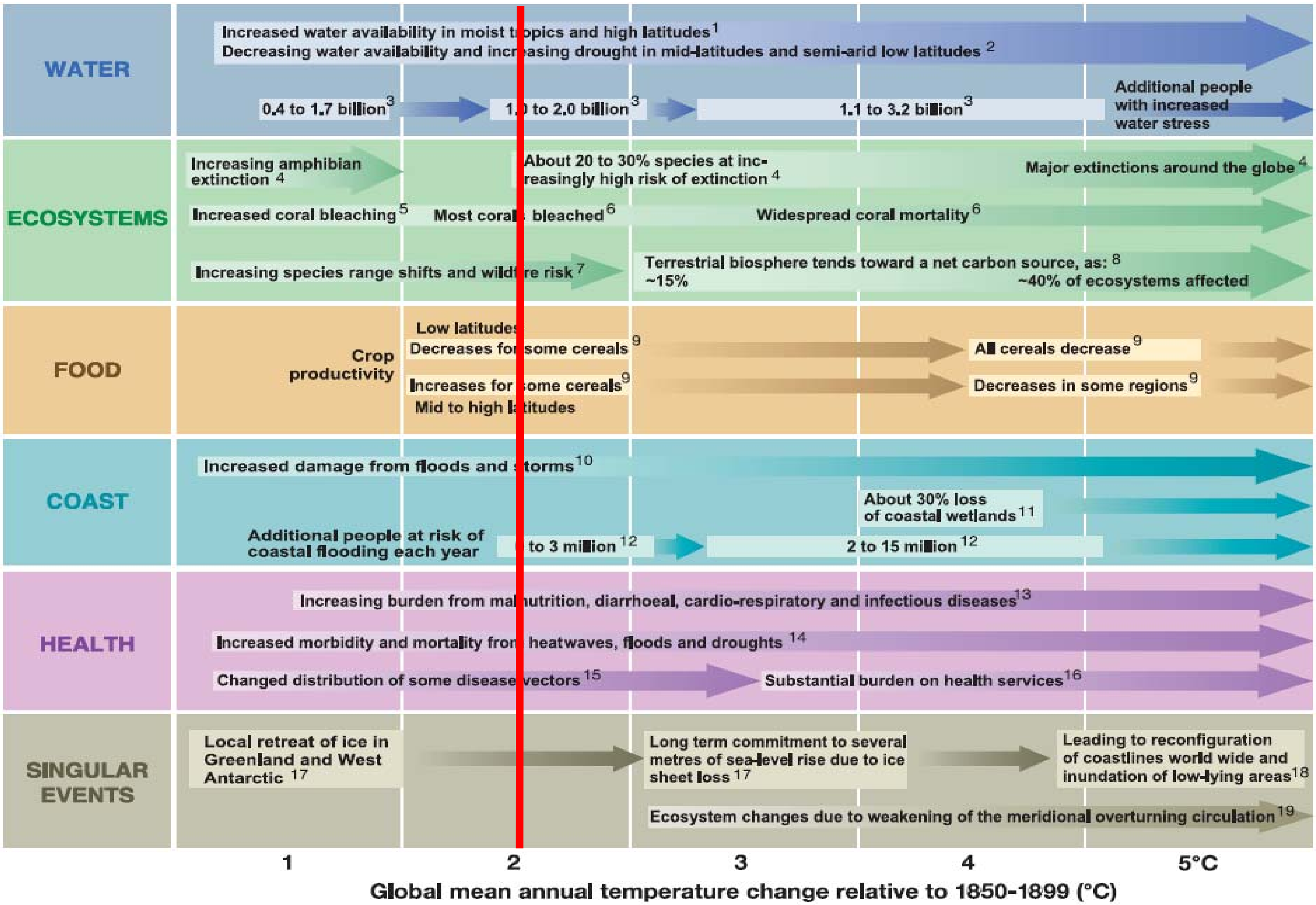
Ratio

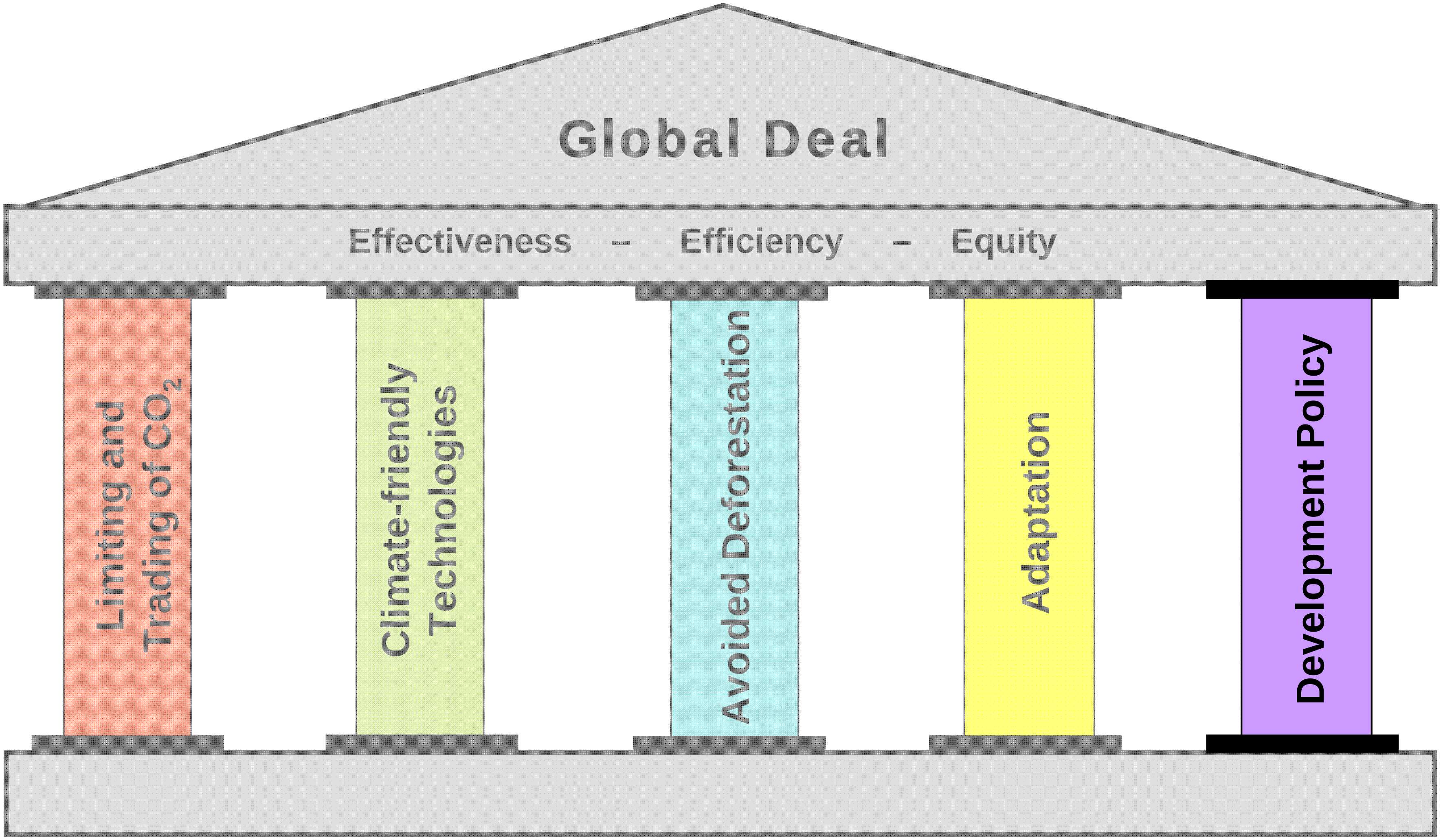
Emissions per year from fossil fuel combustion and cement production

Emissions per year from land use change


Global Deal
Effectiveness – Efficiency – Equity
Limiting and Trading of CO2
Climate-friendly Technologies
Avoided Deforestation
Adaptation
Development Policy

Mitigation and Adaptation

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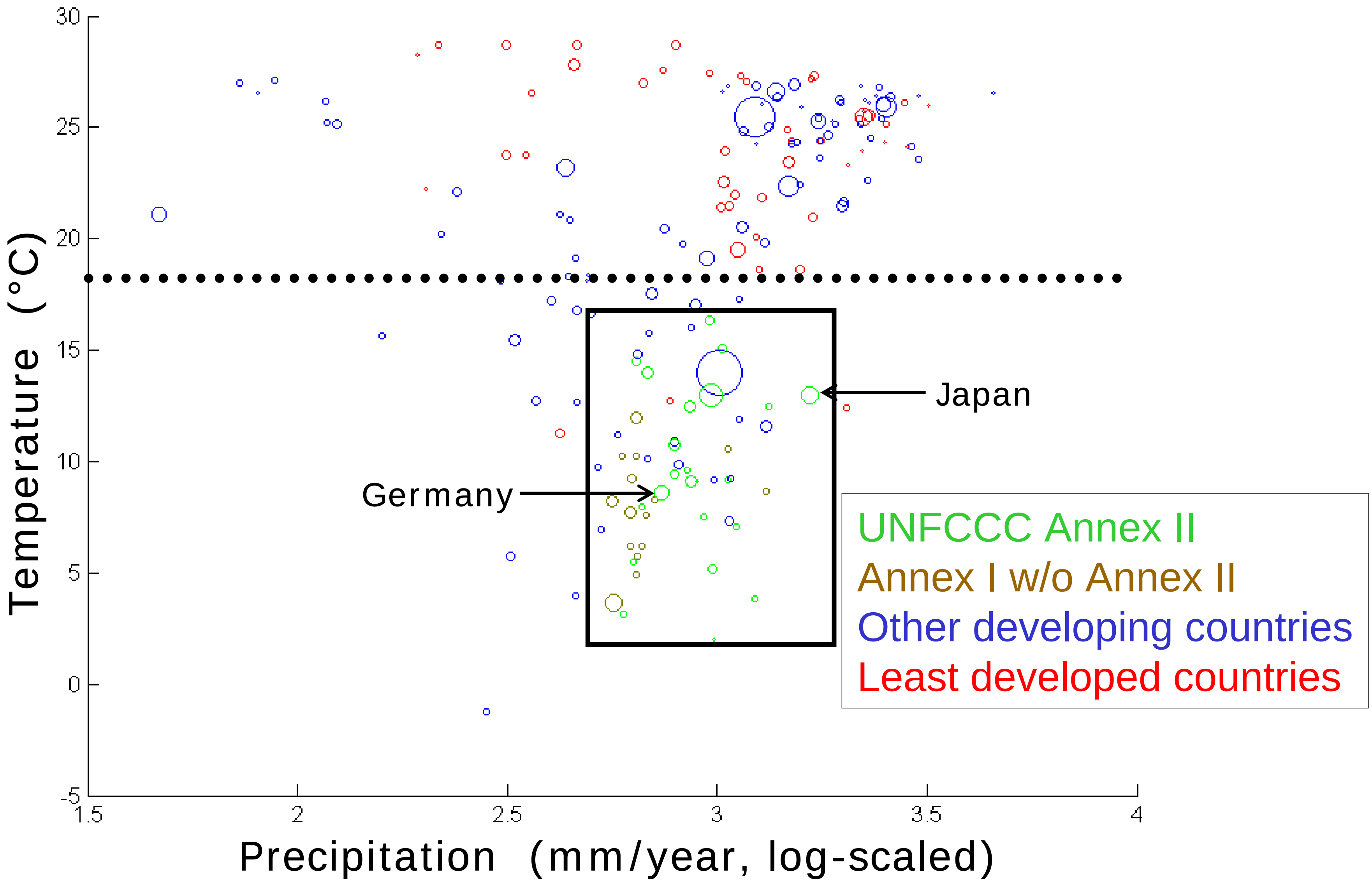
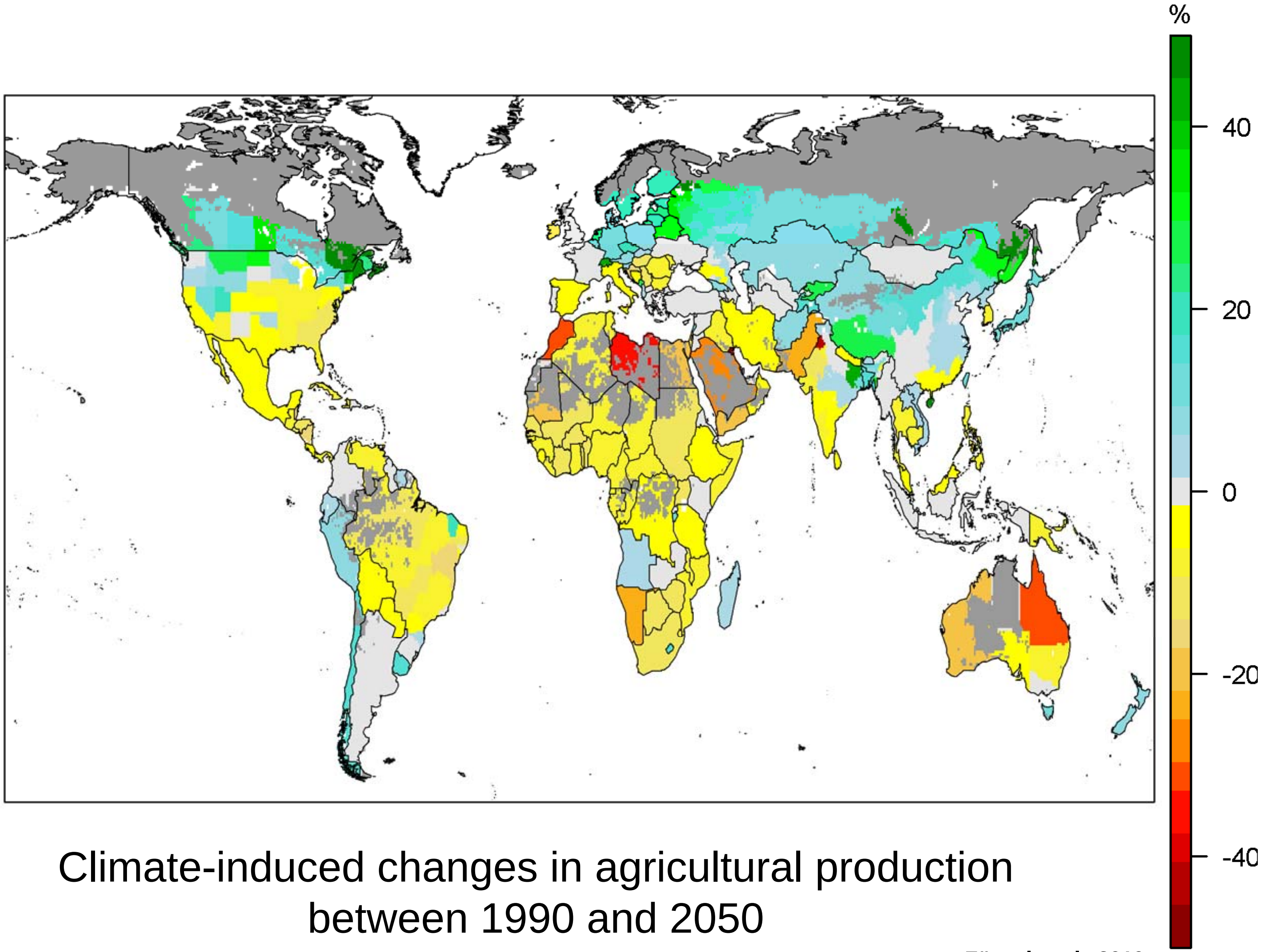
Climate and socio-economic development



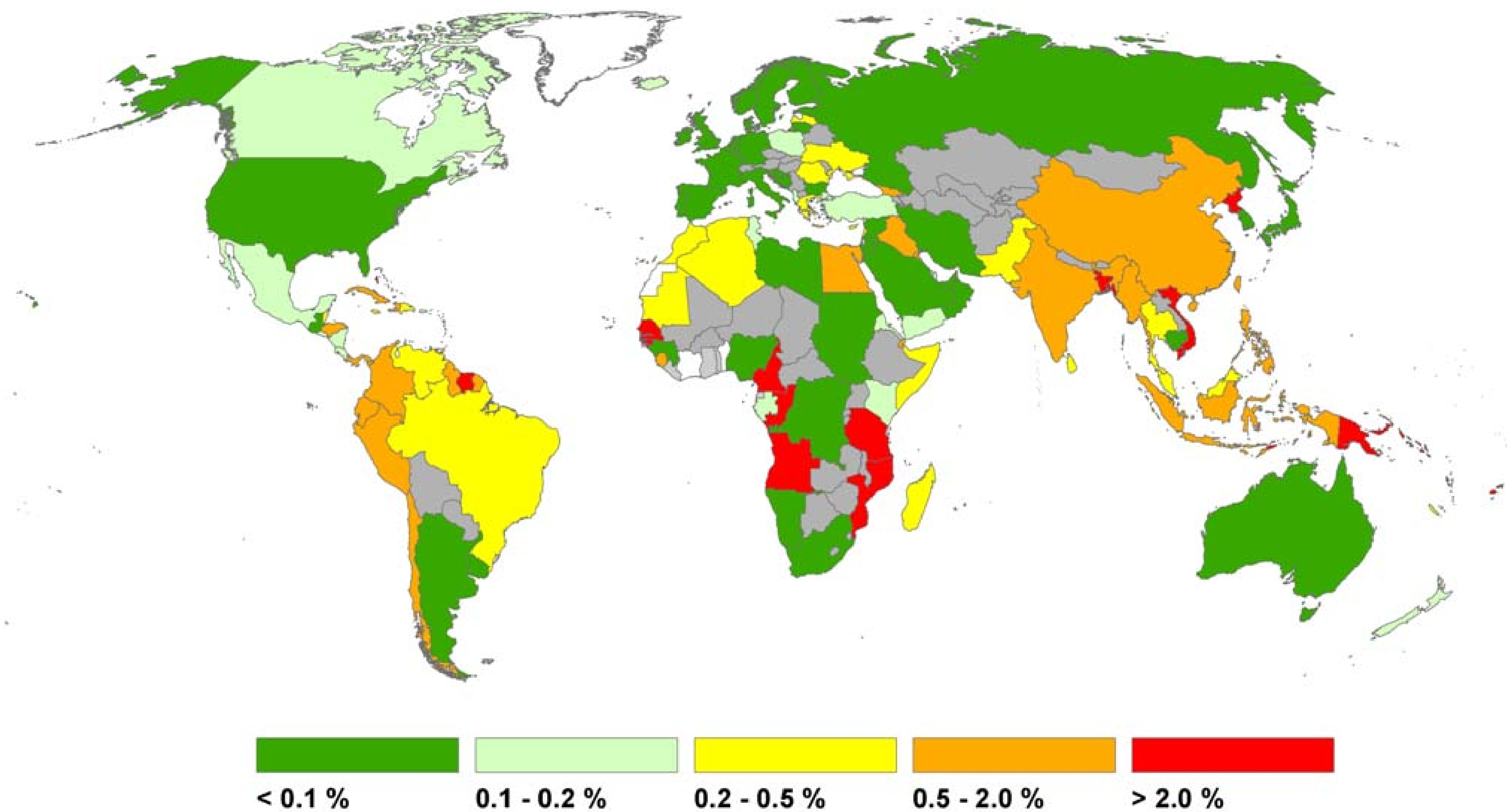
Change in Agricultural Production



Climate-induced changes in agricultural production between 1990 and 2050

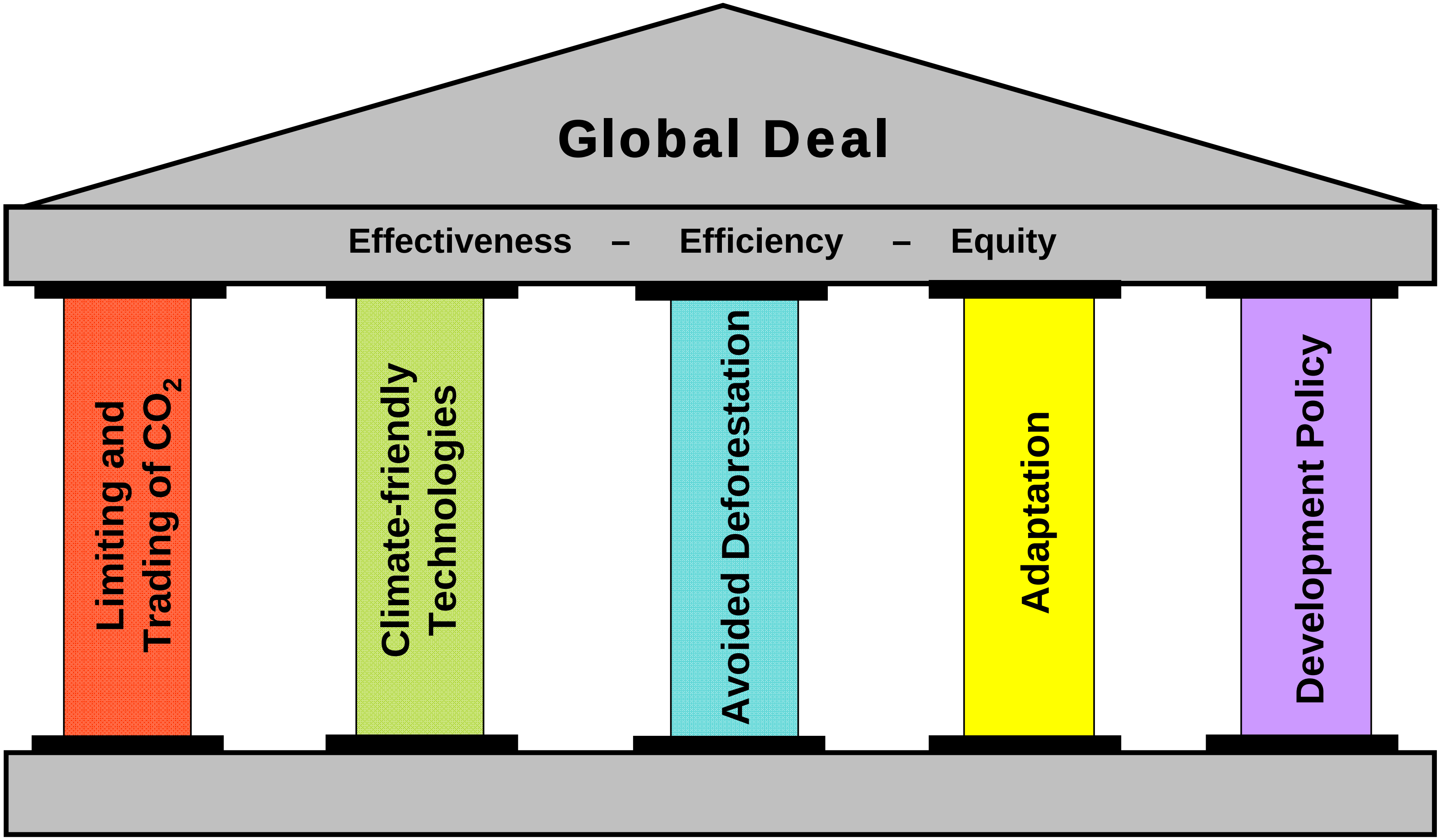
Füssel et al., 2010

Flood Risk by Sea Level Rise



Füssel et al., 2010

Increase of population share threatend by sea level rise on an annual basis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