Modelling Global Risks of Climate Change

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Pentland Centre for Sustainability in Business

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Research Areas

- Sustainable soils and land use
- Systemic ecosystem risks and the corporate boardroom
- Ethical supply chains
- Scaling up business solutions
- 'Nexus' issues and Business
- Sustainable Lifestyles and Cities

Research Areas

Sustainable soils and land use

Looking at how soils can help shape our societies.

Systemic ecosystem risks and the corporate boardroom

Looking at the consequences of the melting of polar ice caps.

Ethical supply chains

Looking at how businesses can source products responsibly.

Scaling up business solutions

'Nexus' issues and business

Sustainable lifestyles and cities

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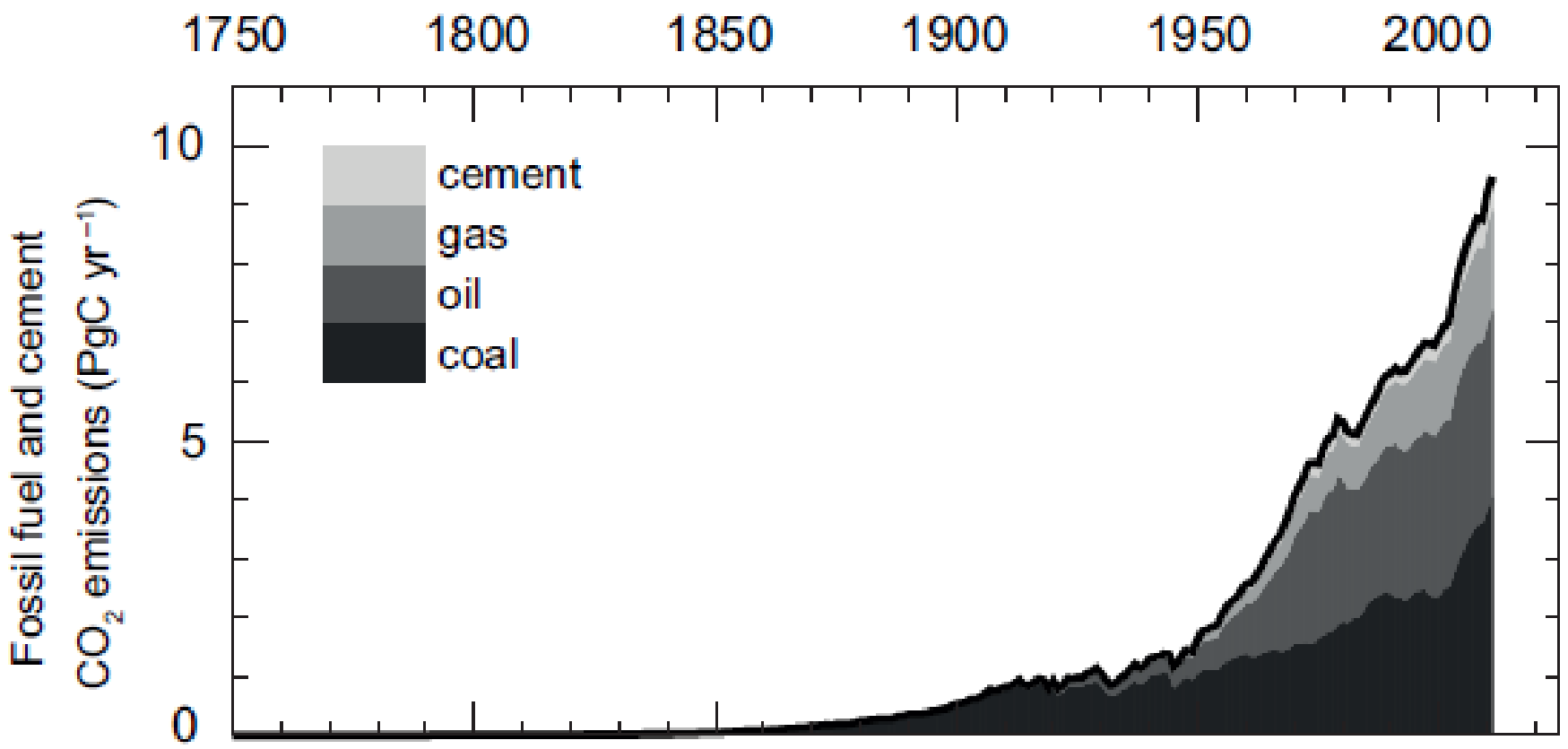
Climate change debate: where do you stand?

- Is the anthropogenic climate change real?
- If so, how does it manifest itself and what are the risks to humanity?
- Will the climate change only cause losses (negative impacts), or will there be gains, too?
- Which parts of the world will benefit / lose? What are the geopolitical risks?
- Which parts of the economy will be affected and how?
- What action could be taken on multiple levels to reduce the risks?

Main contributors to the Earth's climate

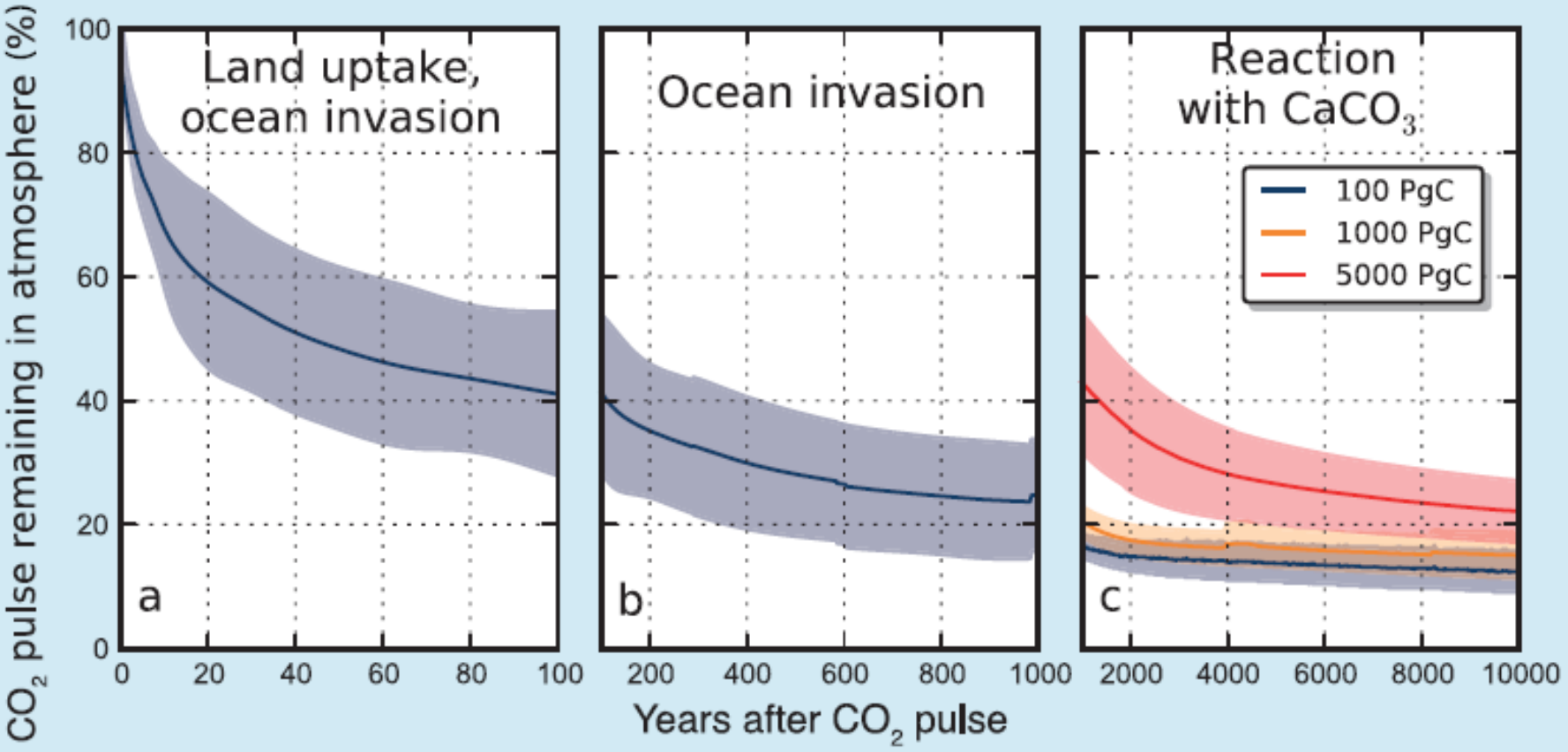
- Solar activity - 11 year cycles, multiple aperiodic changes
- Earth's orbital position - 100 kyr cycles, 40 kyr cycles
- Layout of the continents - millions of years
- **Greenhouse gases** (GHGs) in the atmosphere: CO_2, CH_4, N_2O, soot… These are naturally passive, i.e. they mostly follow other climate drivers
- Exceptional GHGs releases: volcanic eruptions, meteorite impacts and anthropogenic emissions

Anthropogenic CO2 emissions to date



Source: IPCC AR5

Atmospheric lifetime of CO2

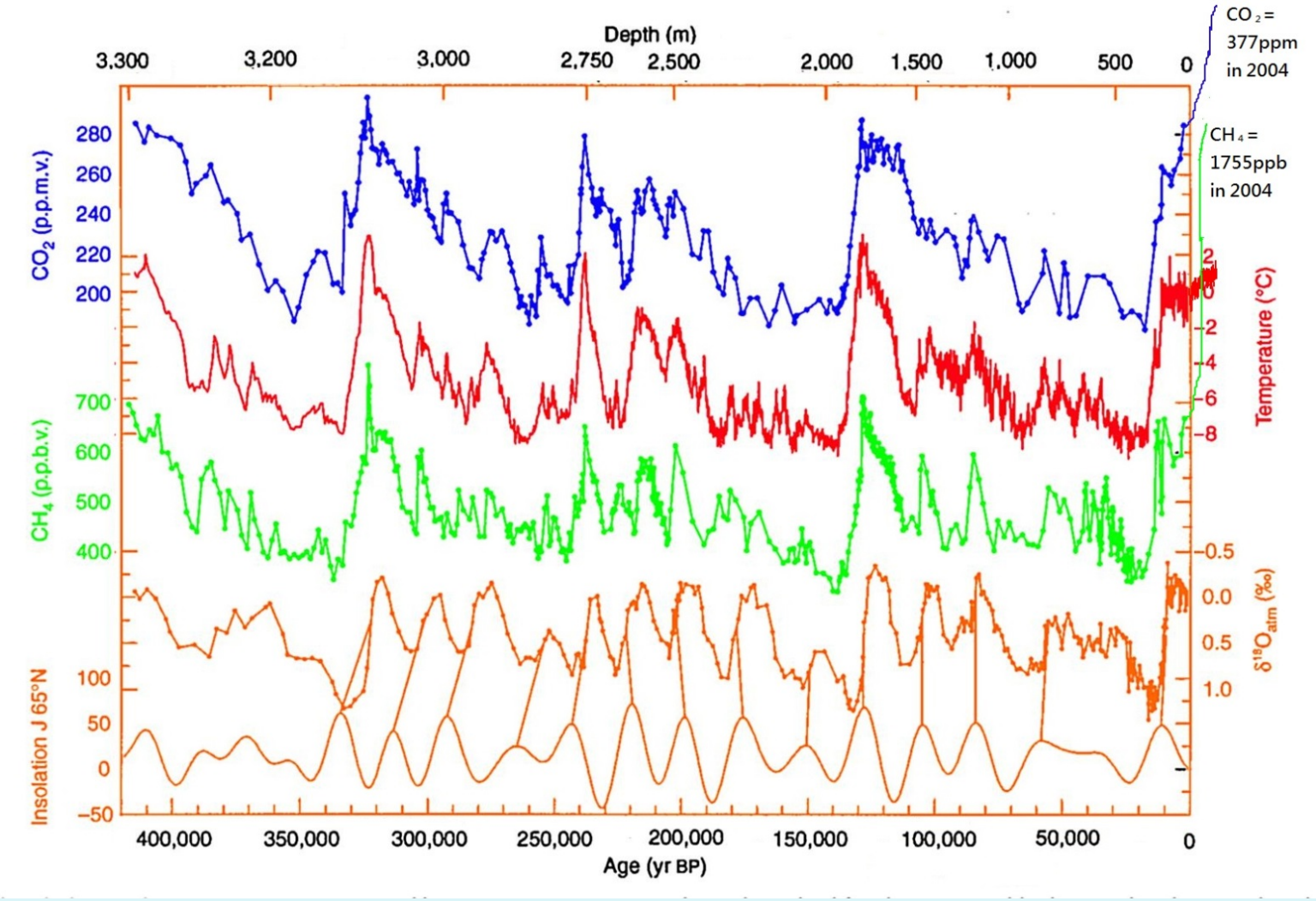


Source: IPCC AR5

Anthropogenic emissions: key figures

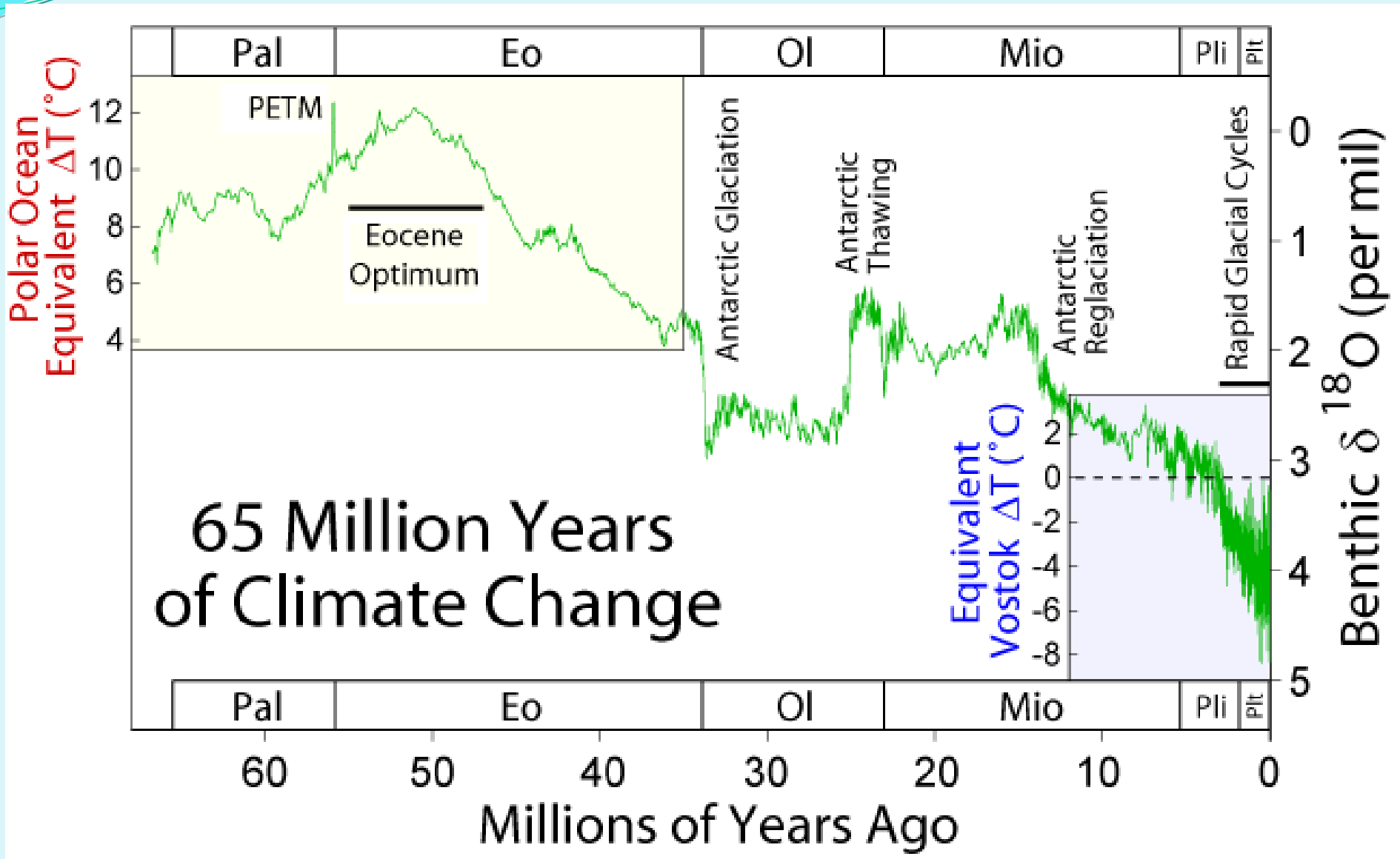
- An estimated 555 Gt of C (2000 Gt CO_2) released to date since 1750 (fossil fuels, cement and land use)
- Currently 9.5 Gt C is emitted per year from burning fossil fuels and cement production, growing at 3.2% per year
- Land use adds another 0.9 Gt C per year
- As a result, the concentration of CO_2 has increased to 400 ppm (2014) from 278 ppm prior to 1750, currently rising by 4 ppm per year
- CH_4, N_2O, soot, aerosols have also grown considerably
- How big is 400 ppm CO_2? Have we been there before?

Paleoclimate: recent glacial cycles



Source: Petit et al (1999)

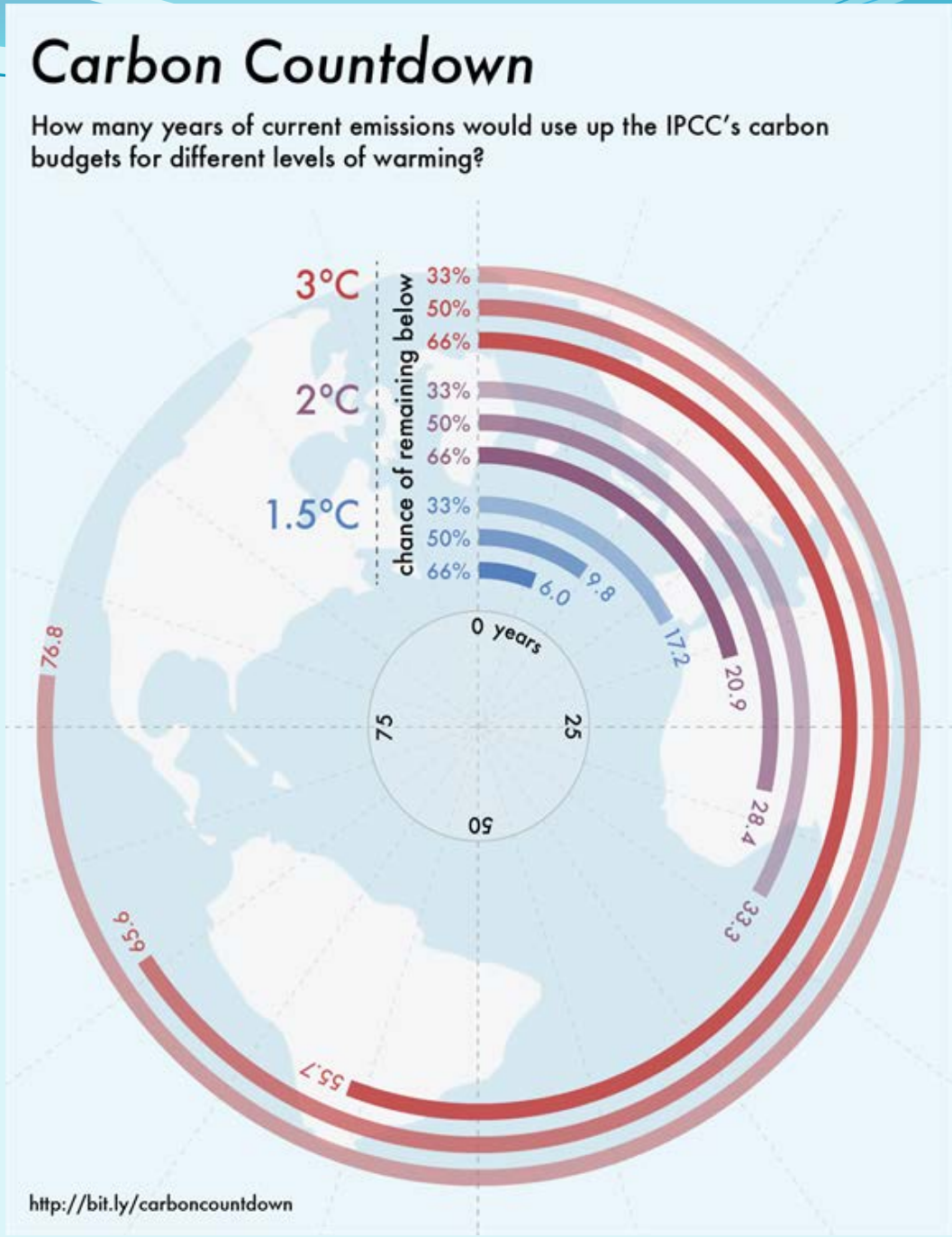
Paleoclimate: last 65 Myr



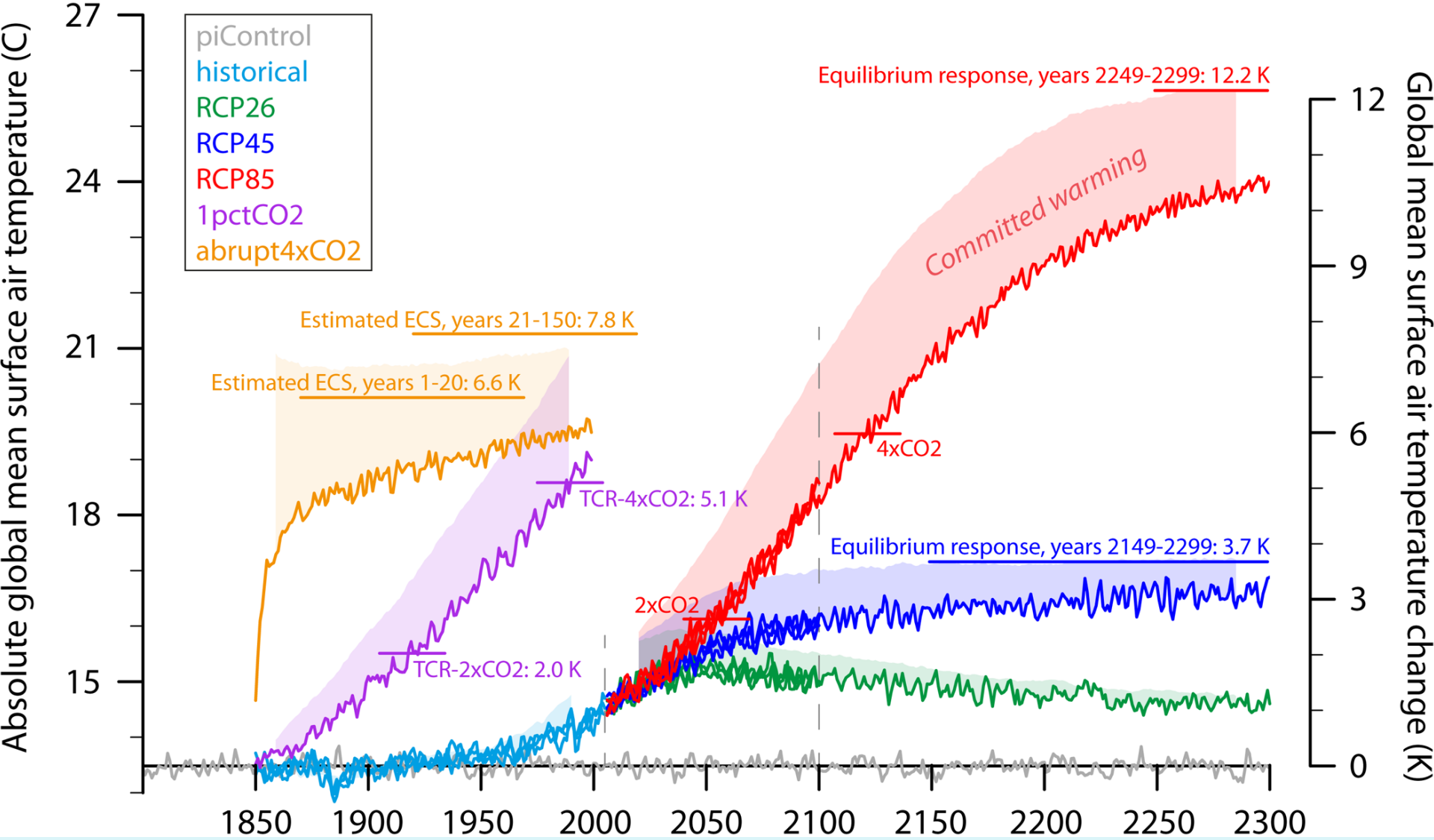
Source: Zachos et al (2001)

- **Carbon budget:** how much CO2 could be released to stay below a certain warming target
- 2 degC budget: 1000 Gt C
- Of it remains as of 2015: around 45%

Source: IPCC AR5, CarbonBrief

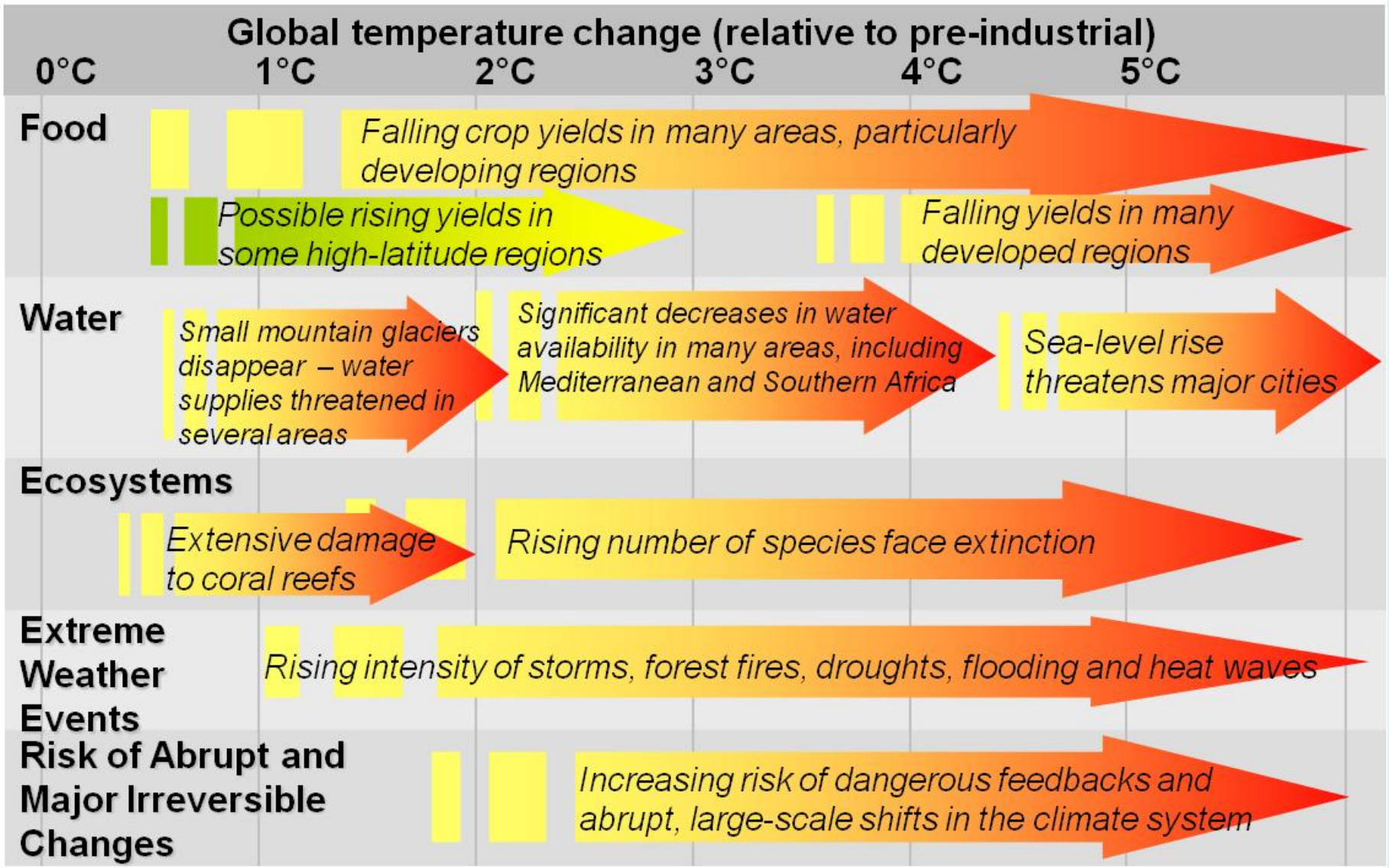


Possible climate futures: RCP Projections



Source: IPCC AR5, Giorgetta et al (2013)

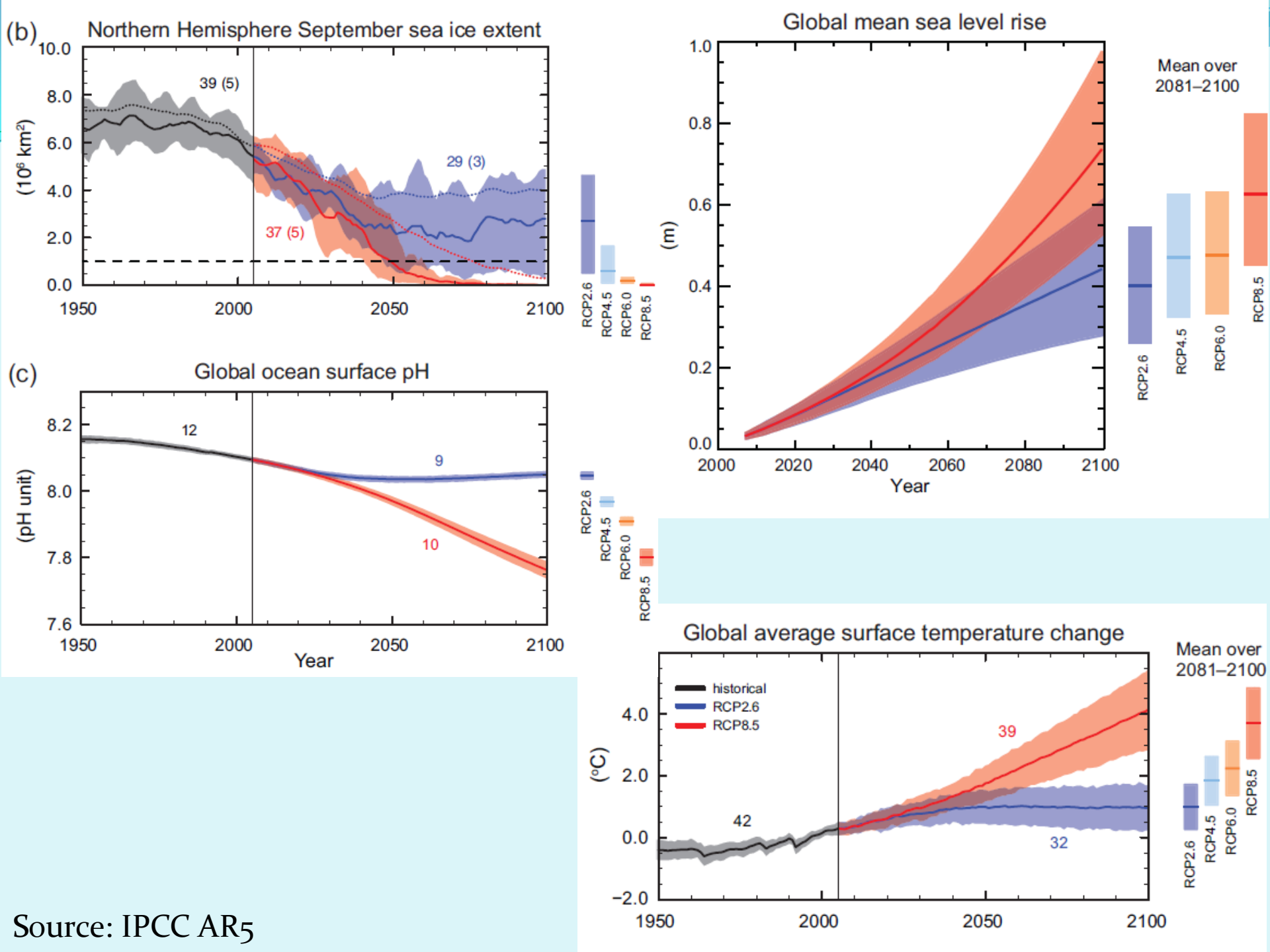
Main risks posed by climate change



Source: Stern (2006)

Planet's "vital signs"

- Arctic sea ice, snow cover, glaciers, ice sheets
- Regional extreme weather events (heatwaves, freezes, storms)
- El Nino - La Nina cycle
- Ocean heat content
- Ocean acidification
- Sea level
- Atmospheric GHGs concentrations
- Global and regional annual temperatures

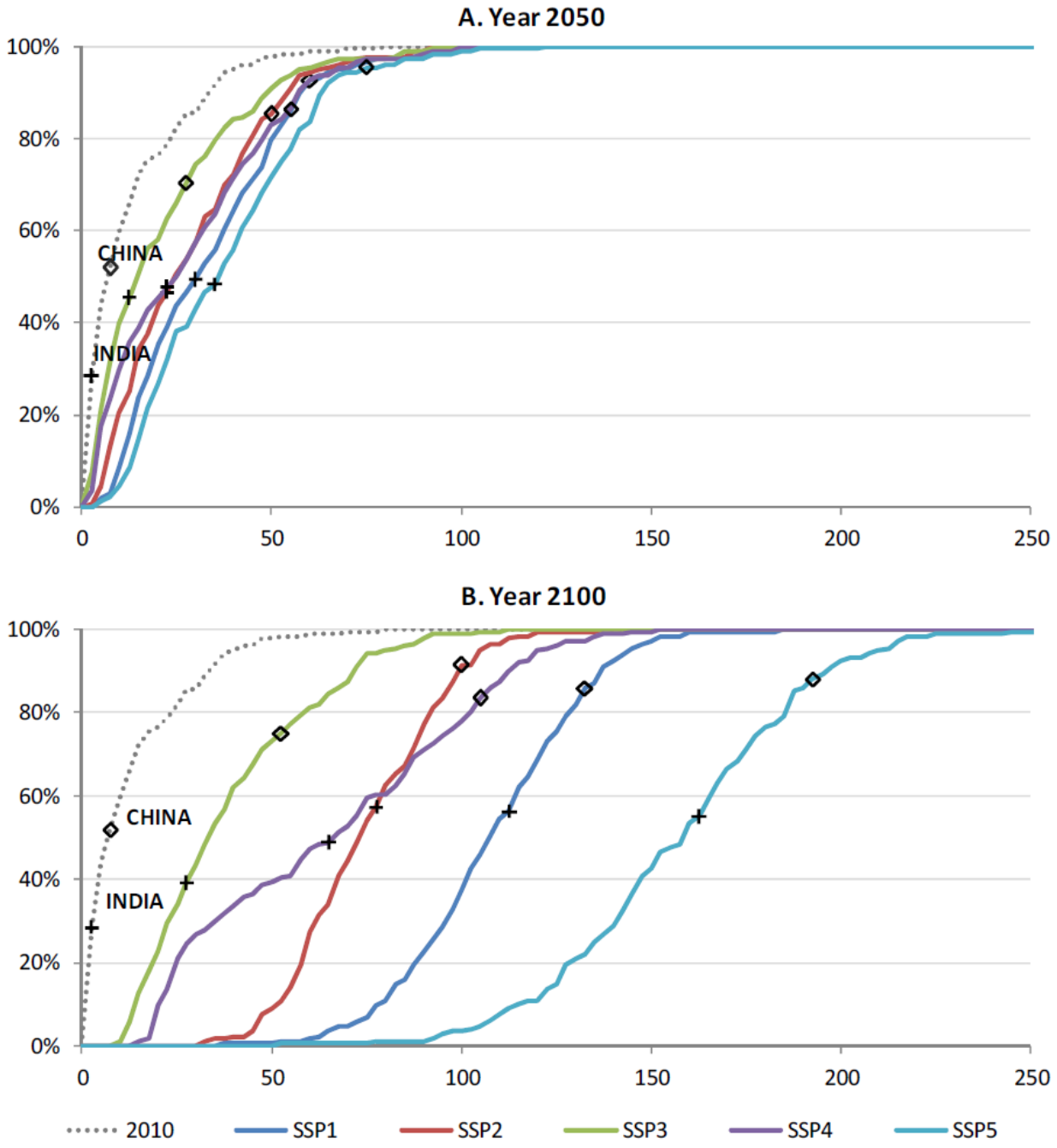


Source: IPCC AR5

Possible Socieconomic Scenarios

Source: O'Neill et al. (2012)

Figure 5. Distribution of income levels (Per capita GDP PPP (thousand USD 2005 per person)

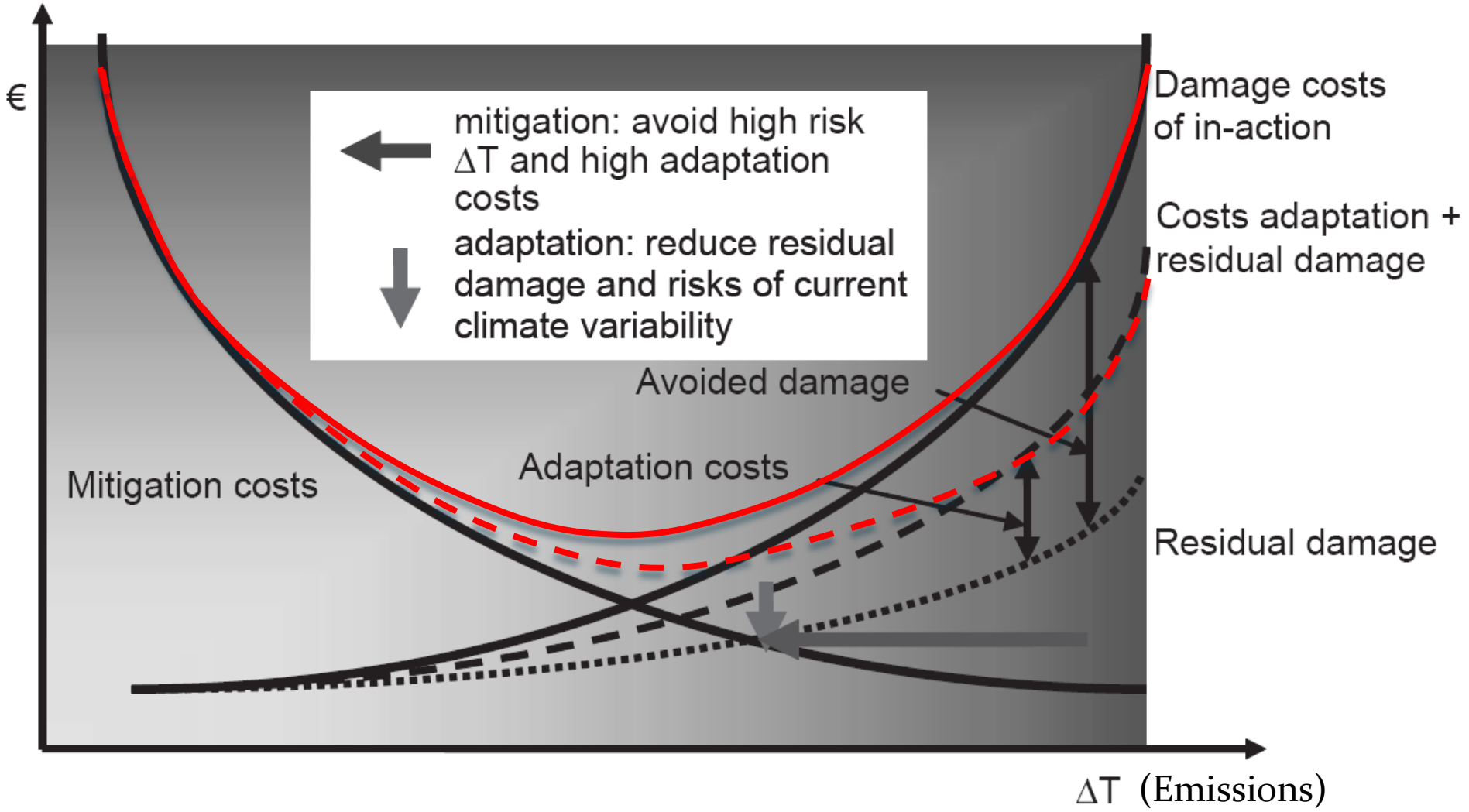


Source: OECD

What options do we have?

- **Do Nothing**: just endure the consequences of a changing climate
- **Mitigation**: curb emissions by moving from fossil fuels to renewables, planting trees, etc. Biggest challenge: allowing poorer countries to develop, industrialize and lift people out of poverty, whilst letting richer nations maintain their living standards
- **Adaptation**: adjust to the inevitable changes in the climate by building flood defenses, improving crop irrigation, relocating people, etc

Optimal Combination of Mitigation & Adaptation



Source: Swart and Raes, 2007

How much control do we have?

- Finding an optimal strategy for dealing with climate change through mitigation and adaptation is very difficult
- Why? (i) too many uncertainties on all levels; (ii) climate change threats are relatively long-term and are not perceived as immediate dangers; (iii) significant vested interests in maintaining business as usual – fossil fuel industry, lobbyists, shareholders, politicians
- Result: growing inequalities on multiple levels – within individual countries, globally and possibly between generations

What are the policy instruments?

- International climate deal to reduce emissions and invest into adaptation – Kyoto 97', Paris 2015'
- Bilateral, trilateral, multilateral agreements to curb emissions without losing short-term competitiveness – recent US-China deal
- Individual government incentives – EU's 20/20/20 agenda
- Financial instruments: carbon tax, emissions trading scheme
- Advanced financial instruments: incorporating climate risks into any investment portfolio evaluation
- **Paris Agreement** (December 2015): (i) long-term goal (2 degC) and (ii) ratcheting-up mechanism (increasing ambitions every 5 years)

How do we asses policy options?

- **Qualitative methods**: analyzing management practices on multiple levels and gradually steering corporate, political and also individual culture
- **Quantitative methods**: using climate models, economic models and integrated assessment models (IAMs) to advise policymakers and general public
- All approaches are required to find constructive and workable solutions

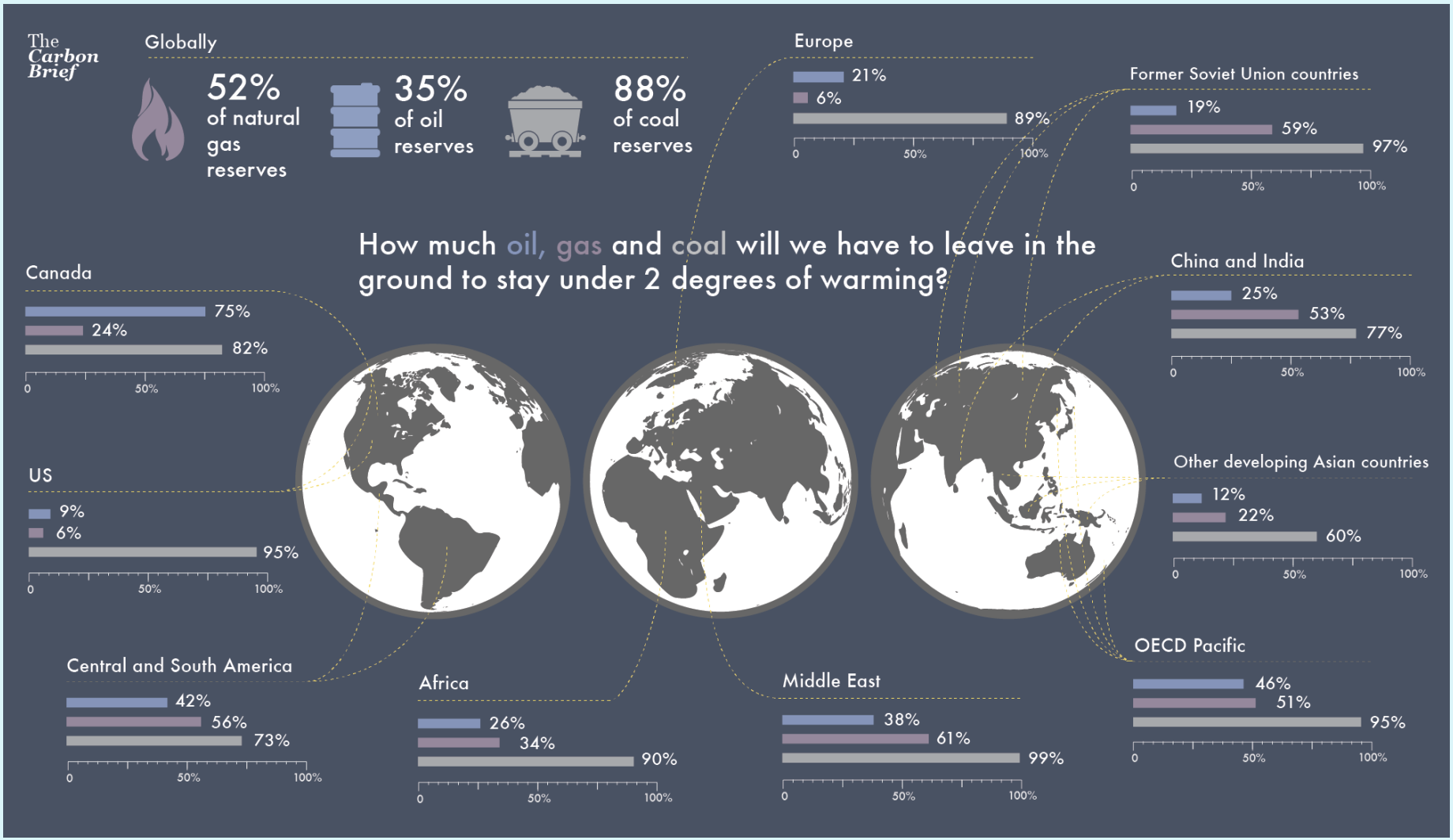
What are IAMs?

- Mathematical models that combine simplified representations of climate, economics and policy, often on the global scale
- Policy = combination of mitigation, adaptation measures for a given socioeconomic pathway
- Use expert climate and macroeconomic models as a source of most parameter values
- Are run under specified policy scenarios for up to 2 to 3 centuries ahead in order to gauge all the essential impact and costs
- Provide initial estimates for the magnitudes of the impacts, SCCO2, cost-effectiveness of the measures / policies and the relevant risks

PAGE09 IAM

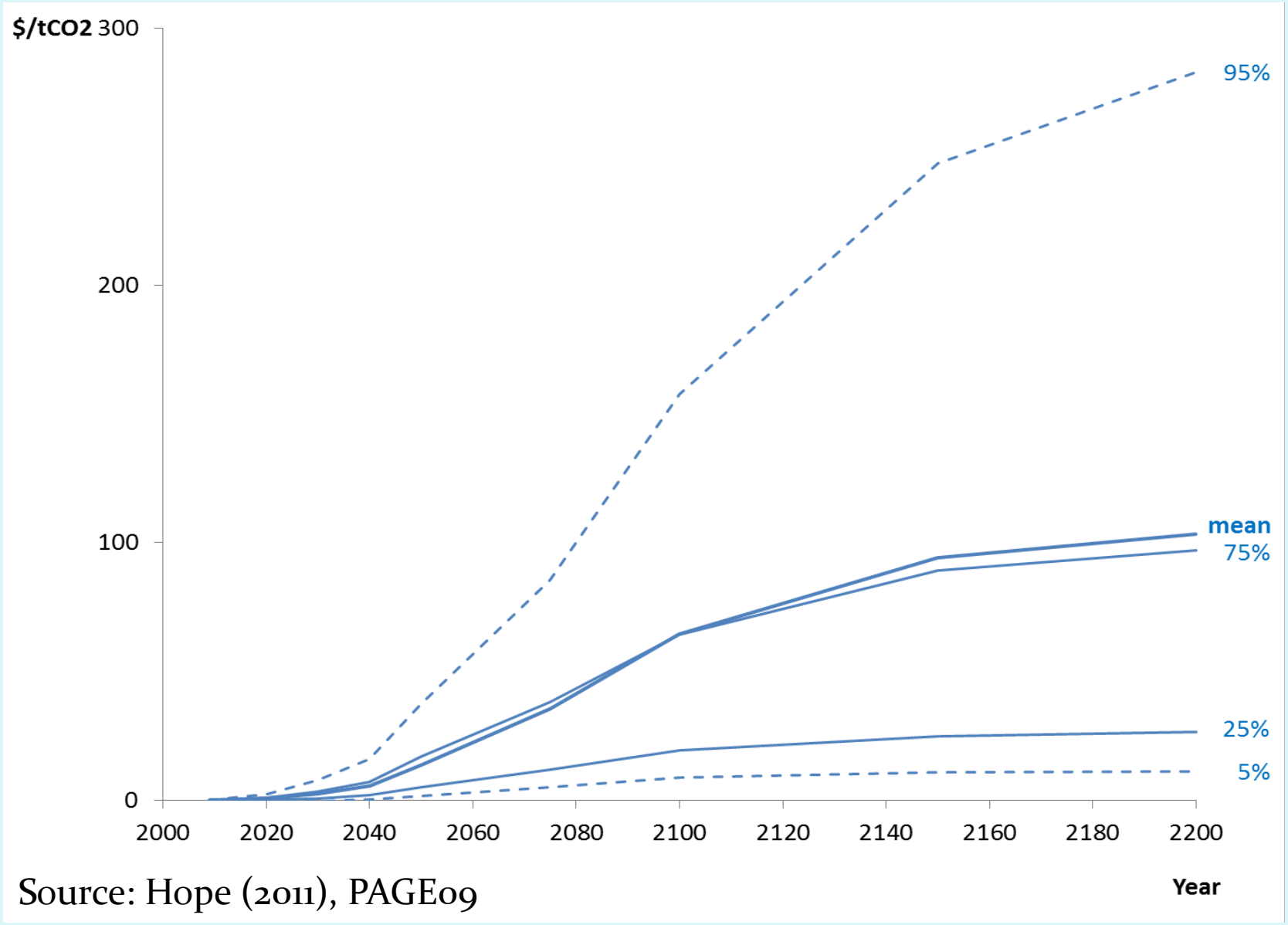
- Excel 2010 workbook with @RISK6 add-in
- Explicit treatment of CO_2, CH_4, N_2O, sulphates
- World split into 8 regions
  - EU, US, other OECD, FSU, China+, India+, Africa+, Latin America
- 10 analysis years
  - increasing step, up to 2200
- 4 impact sectors
  - sea level, economic, non-economic, discontinuity
- 112 uncertain inputs
- 10k or 100k Monte-Carlo runs to calculate distributions of the outputs

Example of IAM's output: regional carbon budgets for the 2 degC target



Source: McGlade & Ekins (2015), adapted by Carbon Brief

Example of IAM's output: cumulative SCCO2



Source: Hope (2011), PAGE09

What is SCCO2?

- Equal to the extra NPV of global impact that would be caused if one more tonne of CO_2 is put up into the atmosphere today
- The polluter pays principle tells us that the SCCO2 is what anyone who puts a tonne of carbon dioxide into the atmosphere this year should have to pay
- Economic theory argues that the best way for the polluters to pay is to charge them a climate change tax (carbon tax) equal to the SCCO2 on *every* tonne of emissions

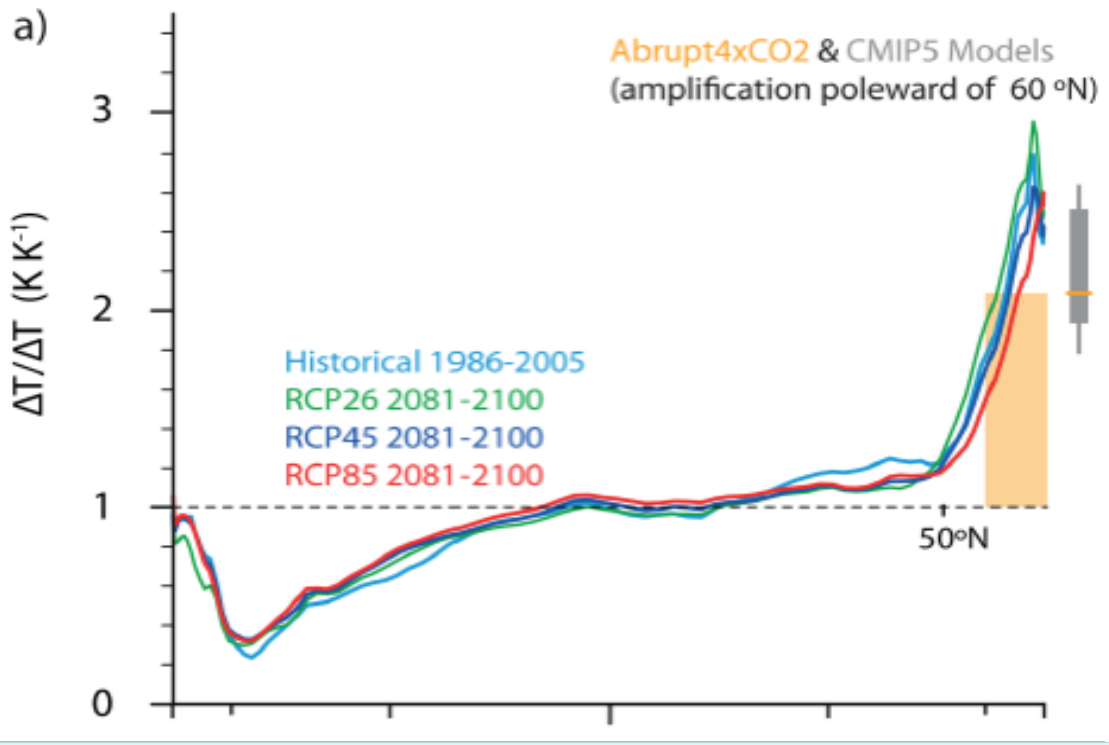
Who will be worst affected / has to pay most?

Relative impact in:

From emissions in:	EU	US	China	India	Africa	Globally
EU	1.0%	0.8%	1.2%	4.0%	2.9%	**11.3%**
US	1.3%	1.1%	1.7%	5.6%	4.0%	**15.9%**
China	1.1%	0.9%	1.4%	4.7%	3.4%	**13.4%**
India	1.9%	1.5%	2.3%	7.7%	5.6%	**22.0%**
Africa	1.0%	0.8%	1.3%	4.3%	3.1%	**12.3%**
Globally	**8.5%**	**6.8%**	**10.5%**	**35.1%**	**25.5%**	

Source: Hope (2011), PAGE09

Arctic amplification under climate change



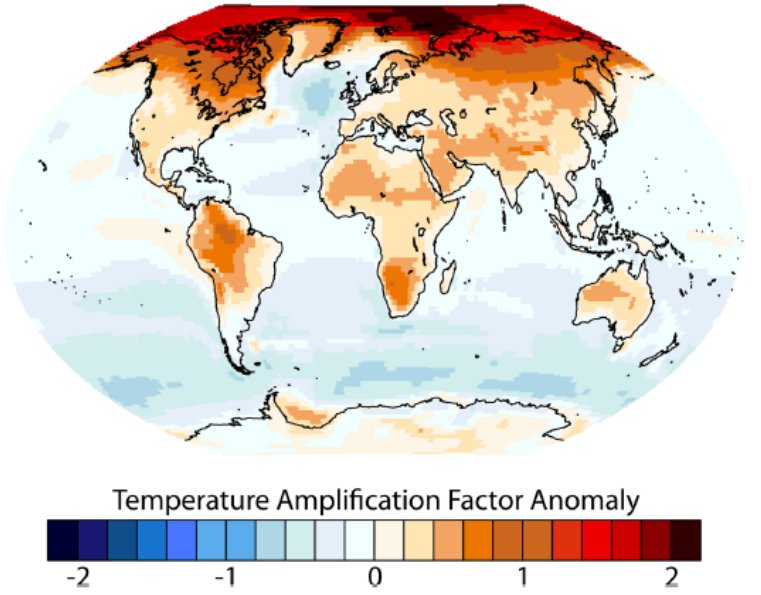
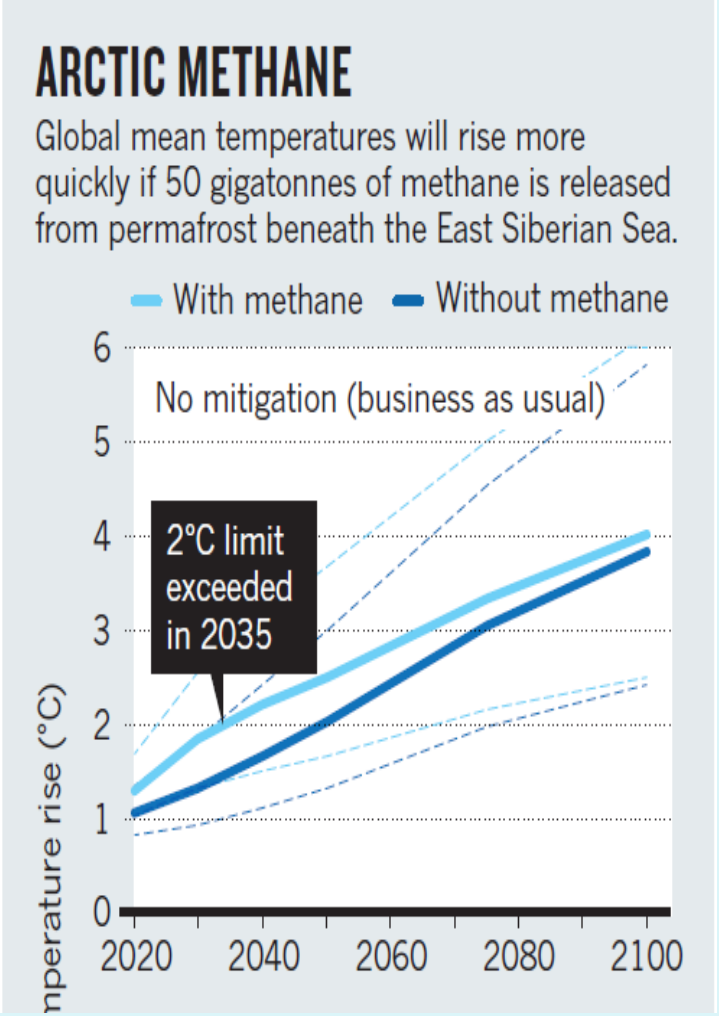


Figure 13. Normalized deviation from global mean warming ($\Delta T/\Delta T_{global} - 1$) from years 100–150 of *abrupt4xCO2*, positive/negative values indicating more/less warming than the global average.

Source: MPI-ESM-LR model runs (*Giorgetta et al., 2013*)

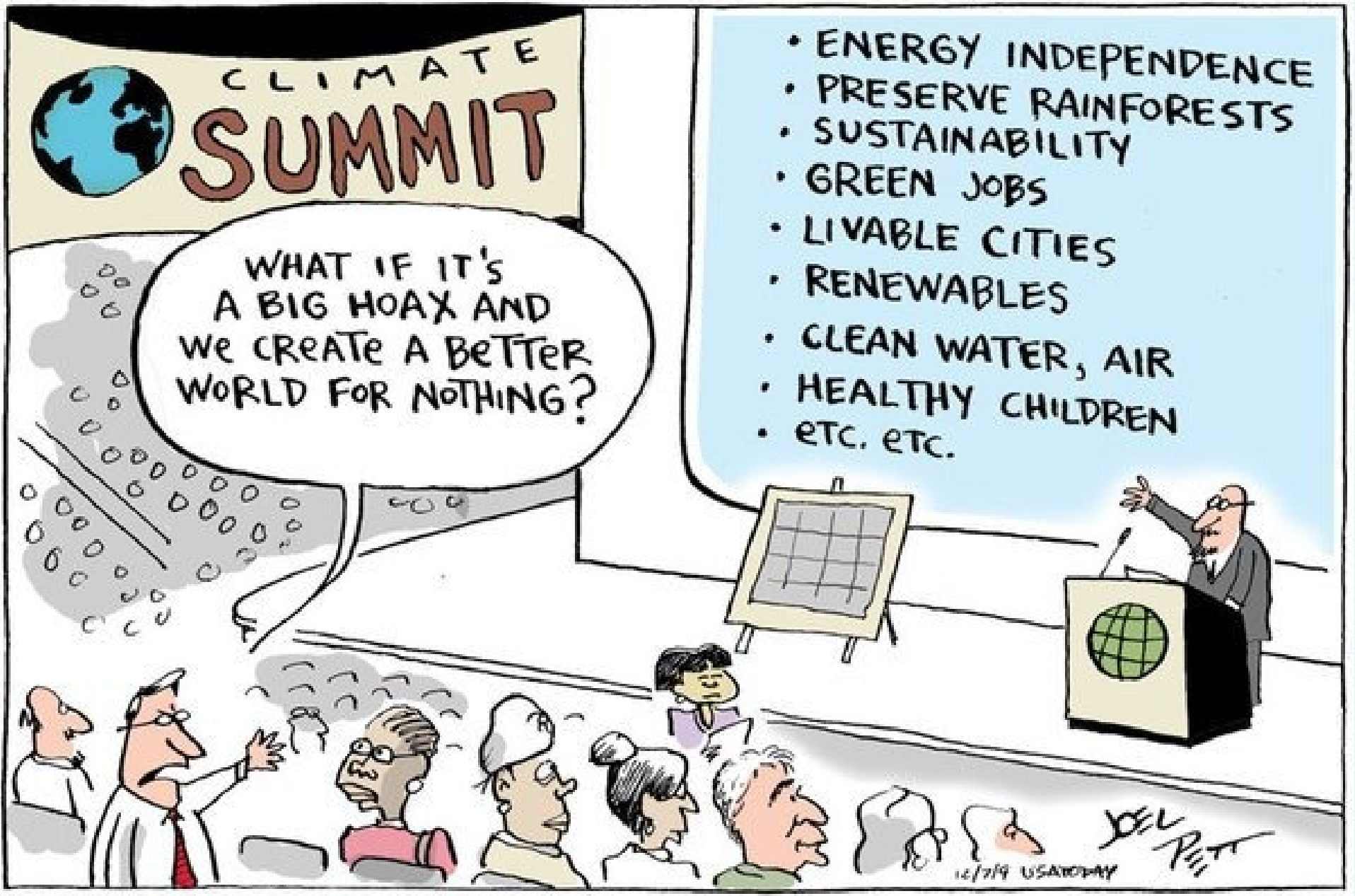
Recent study: global economic impacts from thawing permafrost feedbacks

- Whiteman et al (2013) – methane emissions from hydrates on Arctic shelf (sub-sea permafrost)
- 50 Gt of released within 10 years – **one of the most extreme scenarios** (Shakhova et al, 2010)
- Used PAGE09 integrated assessment model to estimate global economic impacts
- Extra warming from the methane emissions caused USD 60 trillion impacts globally (mean NPV), which is around 15% of the total cost of climate change in the model setting used
- Ongoing work to dynamically link methane emissions with Arctic temperature projections



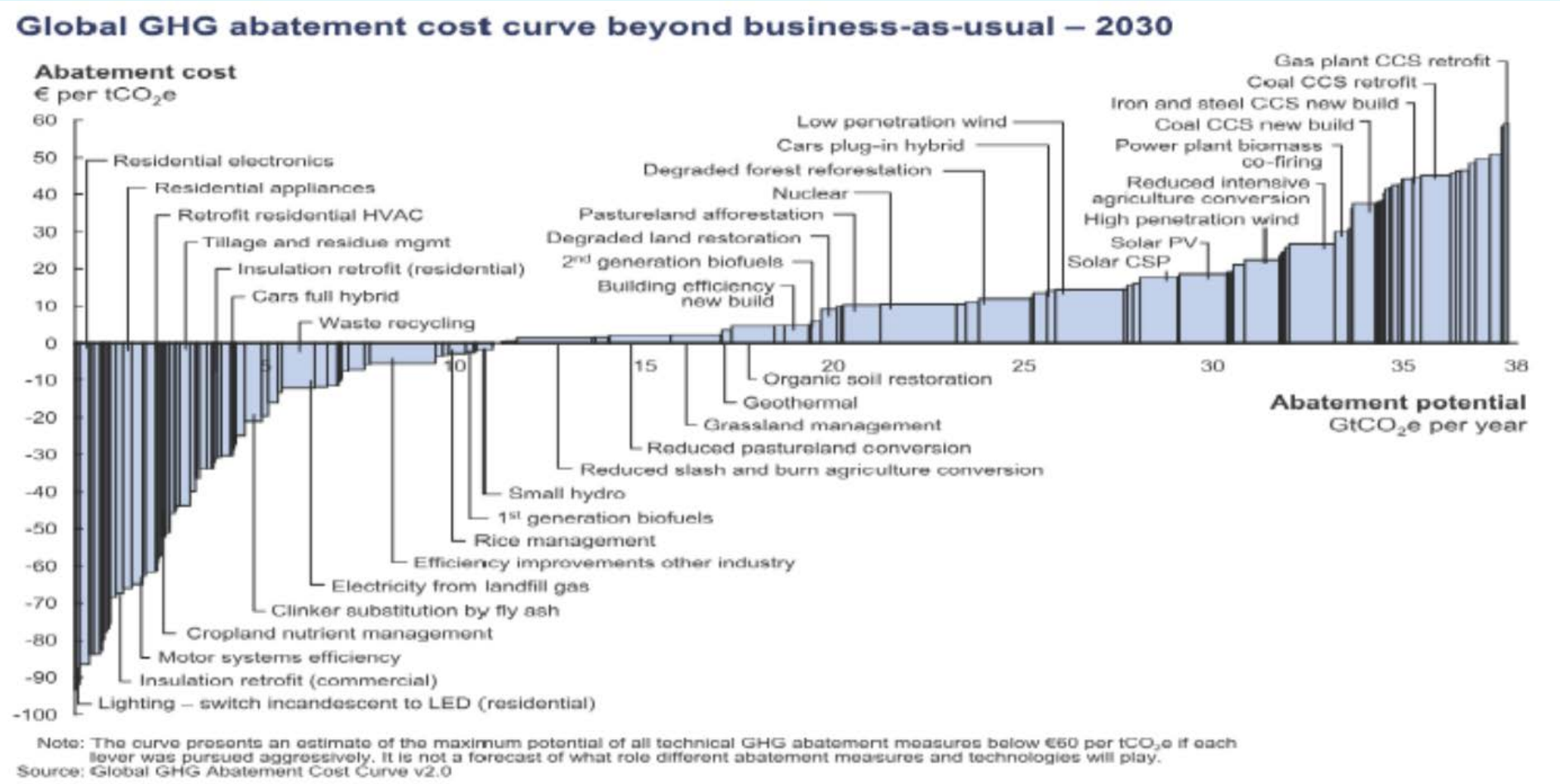
Source: Whiteman G, Hope C & Wadhams P, 2013, "Climate science: Vast costs of Arctic change", Nature 499, 401–403 (25 July 2013) doi:10.1038/499401a

Thank you!



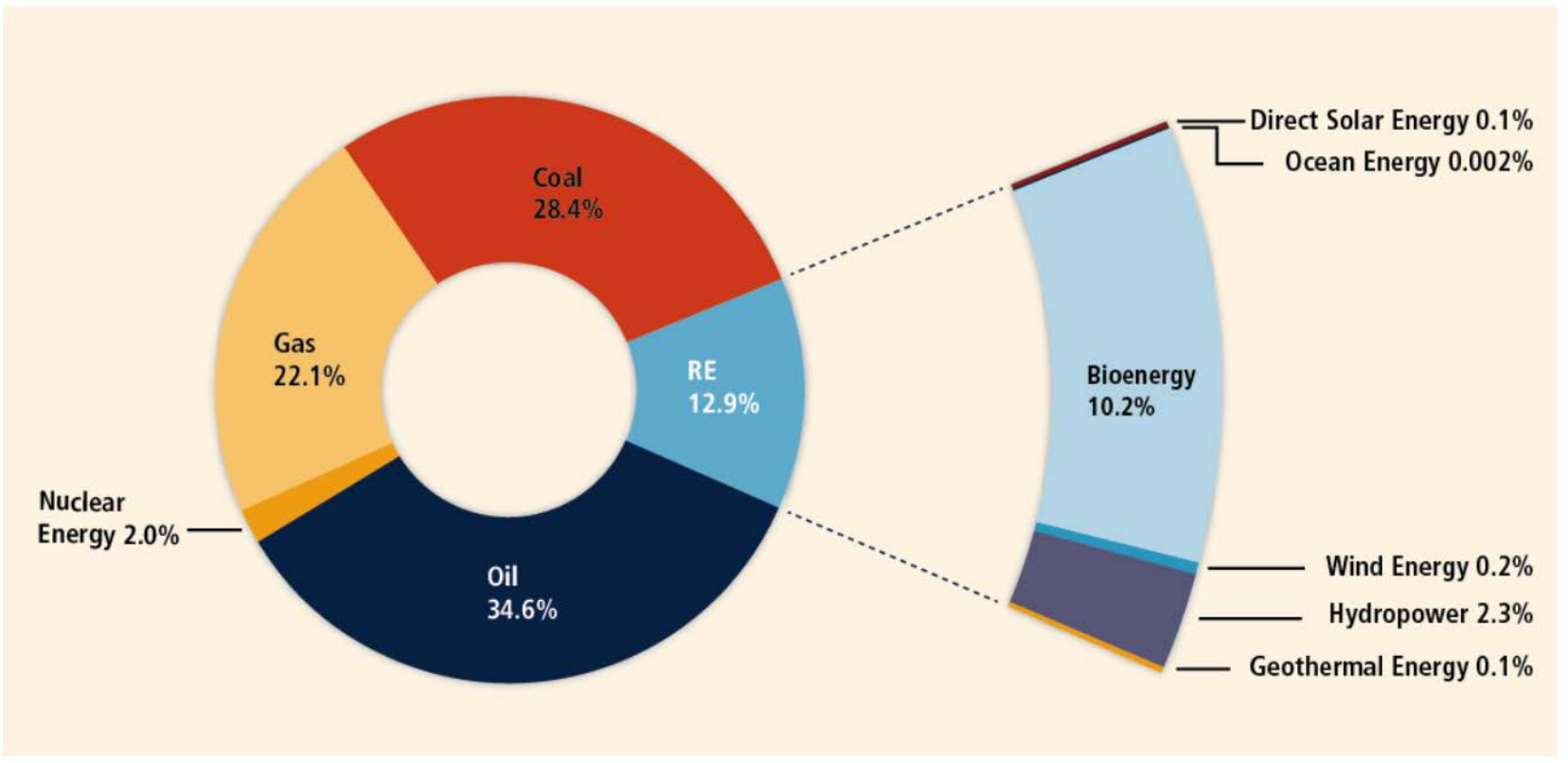
Source: Joel Pett, USA Today (December 2009

Marginal Abatement (Mitigation) Cost Curve



Source: McKinsey 2007

Current Global Energy Mix



Shares of energy sources in total global primary energy supply in 2008

SRREN (IPCC,2011)

What can we all do?

- Many mitigation efforts are dependent upon the everyday citizens' behaviour
- Why? We are:

- Householders (e.g. PV installation, building insolation)
- Consumers (e.g. energy company, carpets, cars)
- Investors (e.g. banking, pension funds)
- Activists (e.g. membership of Greenpeace)
- Employees (e.g. creating change in the workplace)
- Political voters (e.g. Green party?)