Climate Change and Economics
Selected insights & critical appraisal

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Lectures for Future
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Content

- Climate Change
  - Observed Changes
  - Drivers
  - Possible future impacts

- Climate Change (and) Economics
  - What is it about?
  - What can we learn from it?
  - What are its shortcomings?
  - Mitigation options

Climate change – A hot topic

Donald J. Trump @realDonaldTrump

Folgen

The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive.

20:15 - 6 Nov 2012

104.158 66.332

Treibhausgasemissionen steigen in Österreich weiter

29. Jänner 2019, 13.12 Uhr

Die Treibhausgasemissionen (THG-Emissionen) sind in Österreich 2017 zum dritten Mal infolge gestiegen. Mit 51,7 Millionen Tonnen CO2-

Austrian GHG emissions are increasing (again and again and again)

Regierung beschließt Dürre-Hilfe

Payments for Austrian farmers affected by droughts

Kurier 2013-08-13

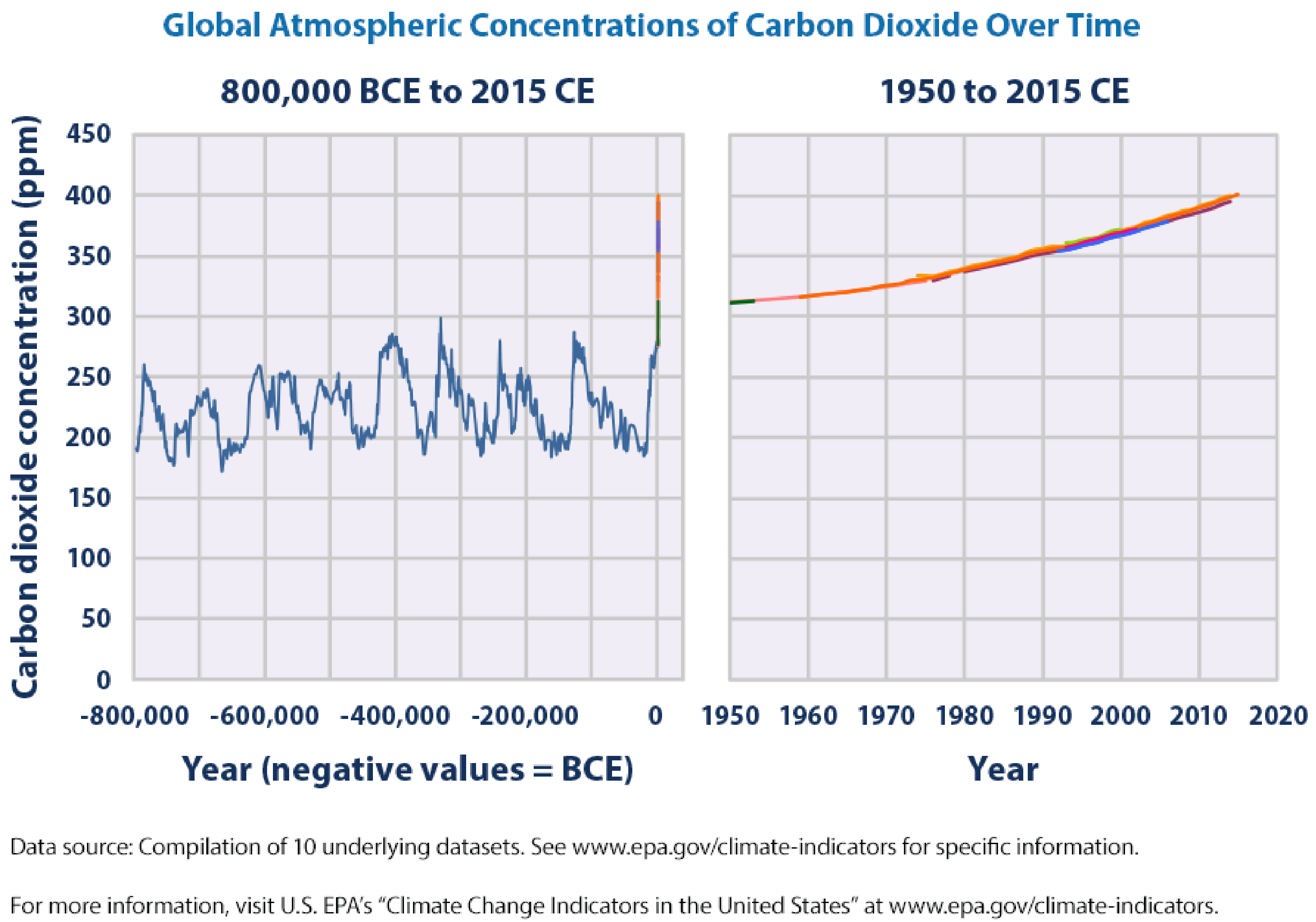
ENVIRONMENT SEPTEMBER 19, 2019 / 7:55 AM / A MONTH AGO

China plans 226 GW of new coal power projects: environmental groups

Climate change – A hot topic

CLIMATE CHANGE
OBSERVED CHANGES

EPA Climate Indicators



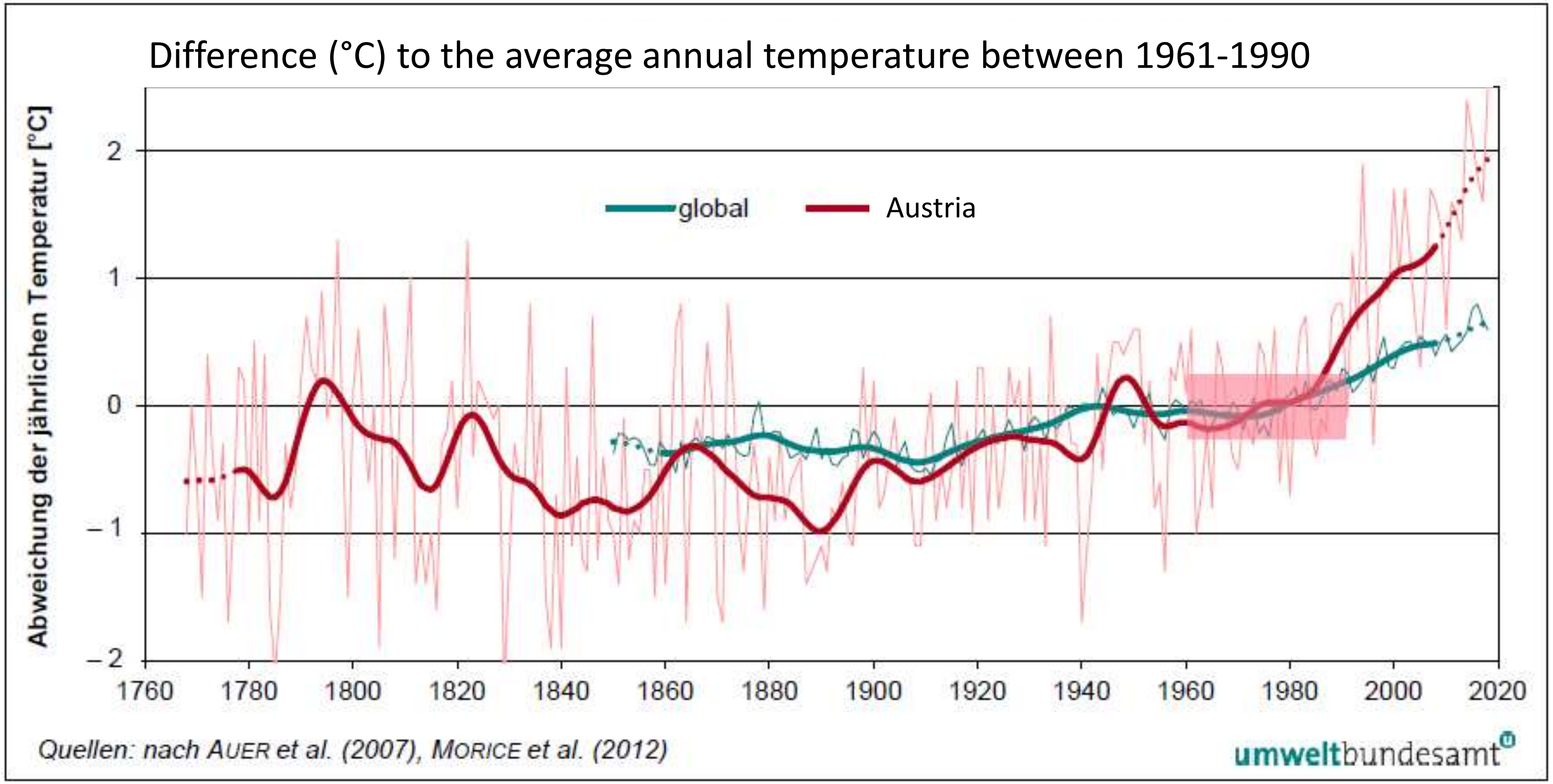
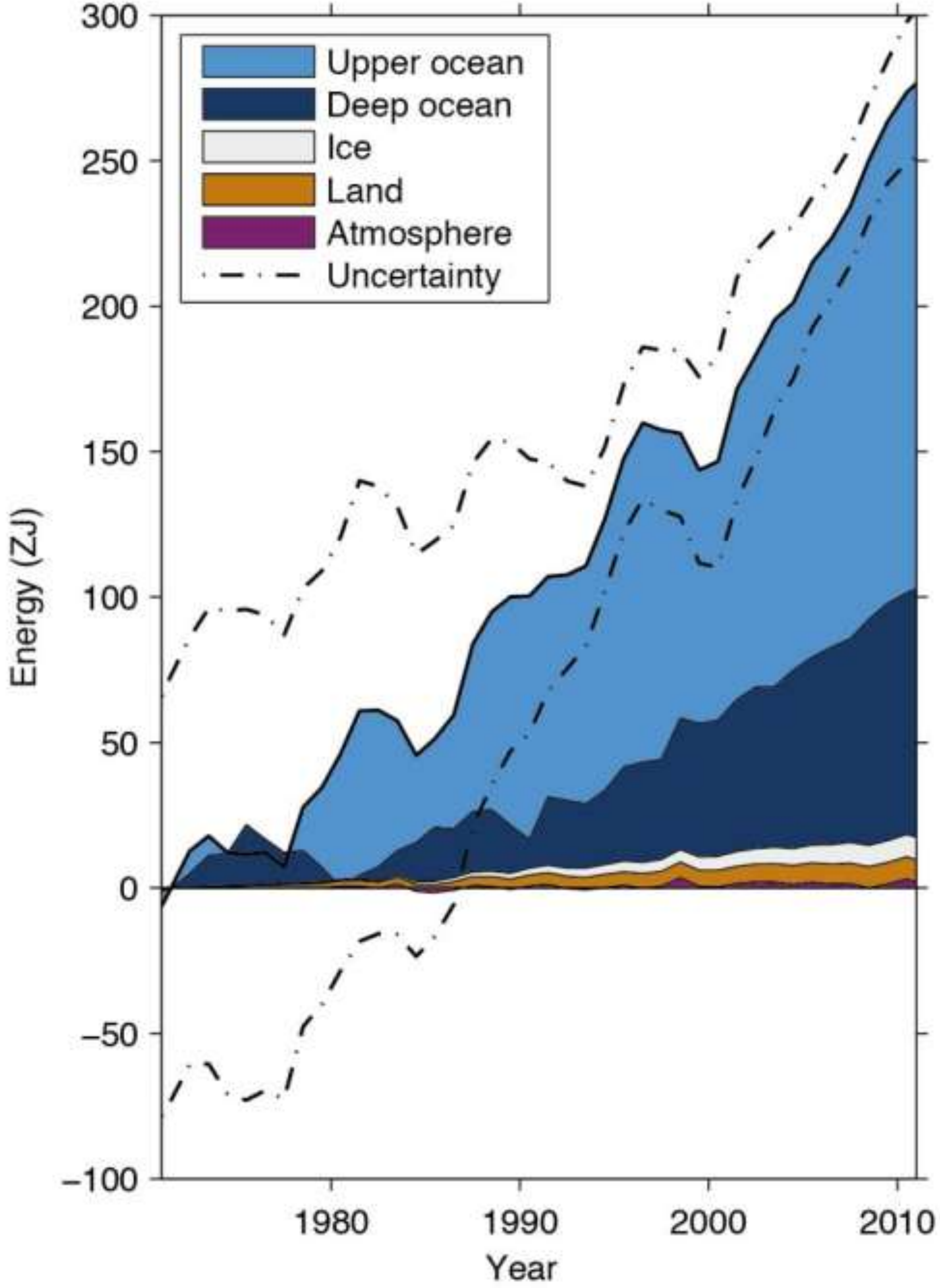


Abbildung 3: Jährliche Abweichung zur mittleren Temperatur der Jahre 1961–1990 für Österreich und global.

Source: EAA (2019): Climate Protection Report 2019

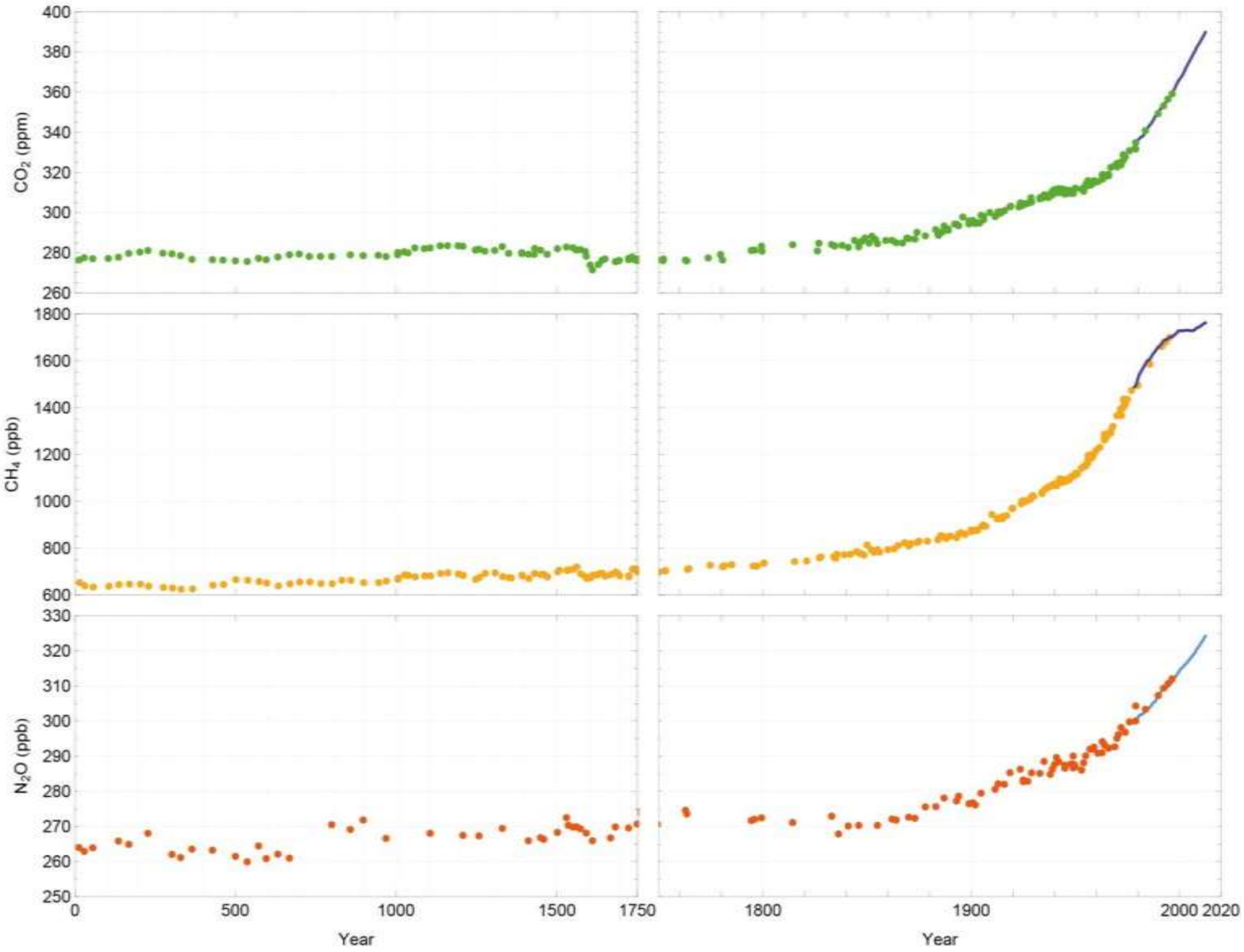
Source: IPCC (2014) AR5 – WGI Box 3.1, Fig. 1



CLIMATE CHANGE
DRIVERS

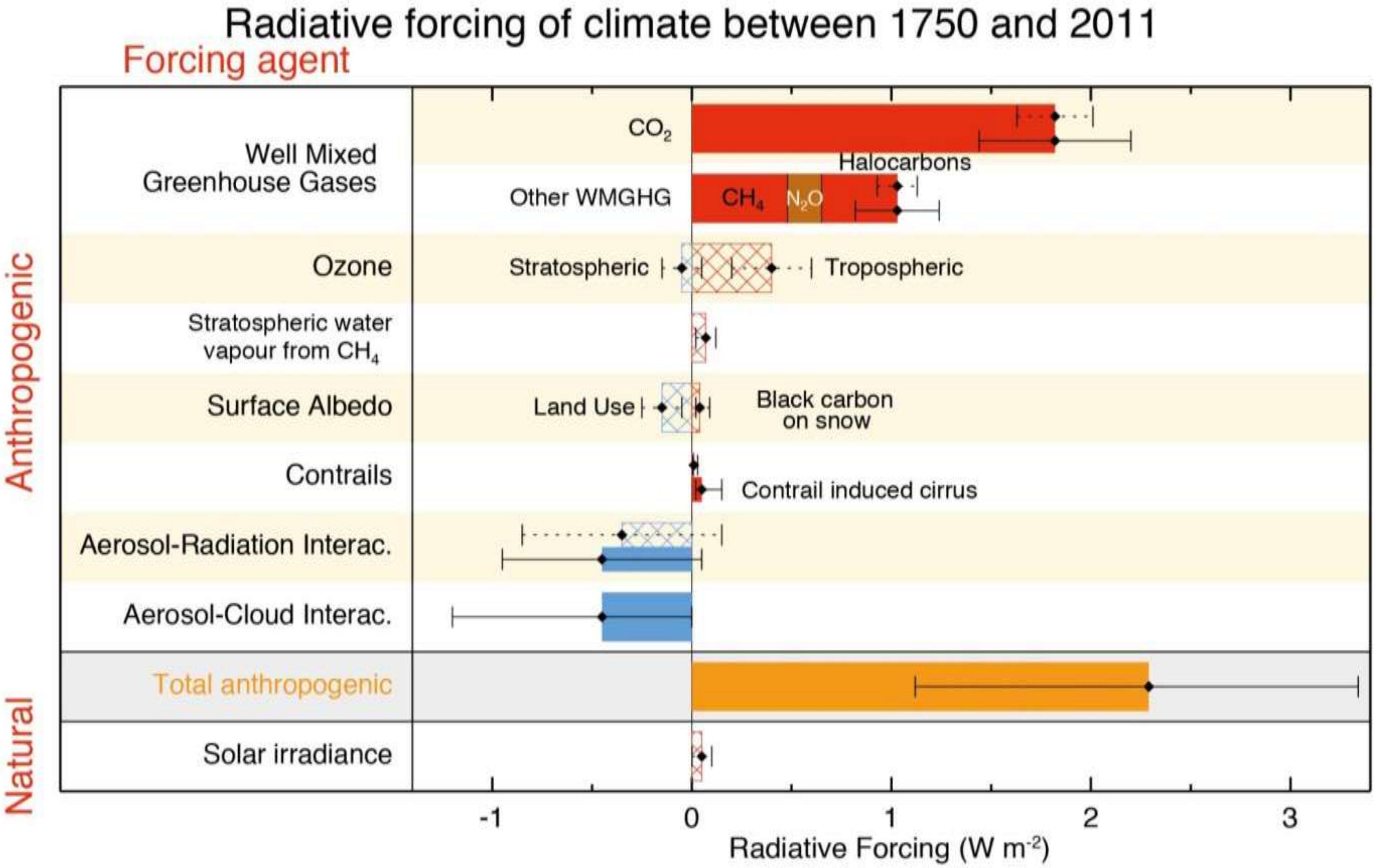
(Physical) Drivers of CC

Source: IPCC (2014) AR5 WGI Fig. 6.11



(Physical) Drivers of CC

Source: IPCC (2014) AR5 WGI Fig. 8.15

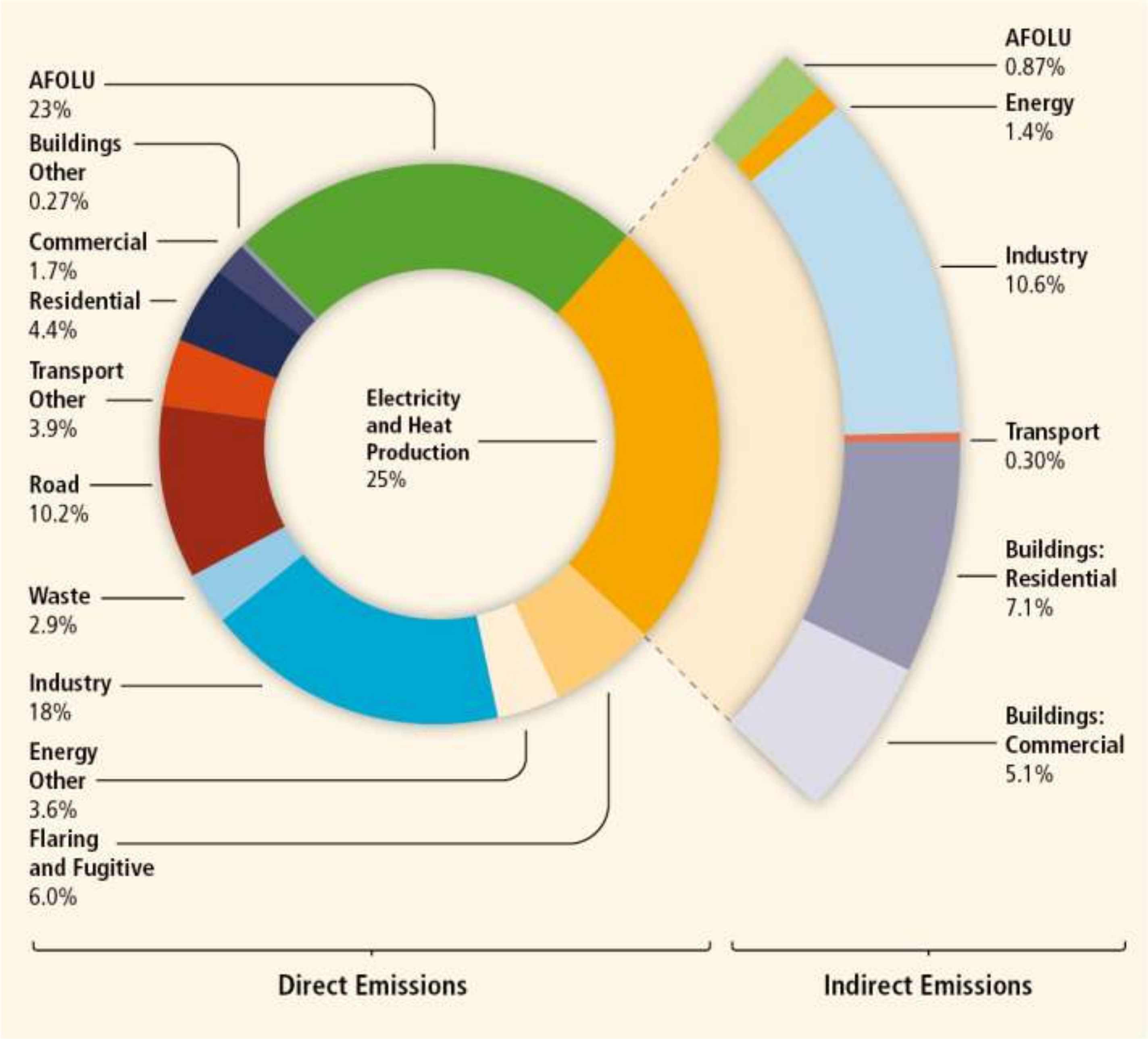


Drivers of the drivers

- Human (economic) activity
  - CO_2:
    - Fossil fuel combustion (transport, energy, industry, housing)
  - CH_4:
    - Agriculture (enteric fermentation)
    - Waste Disposal
  - N_2O:
    - Agricultural soils (mineral fertilizer)
    - Manure management
    - Fossil fuel combustion
  - Others (HFC, PFC, SF6,NF3)
    - e.g. aluminium production, semiconductor manufacturing

(Economic) Drivers of CC

Source: IPCC (2014) AR5 WGIII Figure 1.3



IPAT / KYAT Identity

IPAT Identity

- I → (Resource) Impact
- P → Population
- A → Affluence
- T → Technology
- For example: Footprint = Population x GDP per capita x footprint per GDP

$$I = P * A * T$$

KYAT Identity

- F → CO2 emissions
- P → population
- G → GDP
- E → energy

$$F = P * \frac{G}{P} * \frac{E}{G} * \frac{F}{E}$$

I=PAT developed by Commoner, Ehrlich and Holdren in the 1970ies

KYAT identity developed by Yoichi Kaya especially for CO2-Emissions (1993)

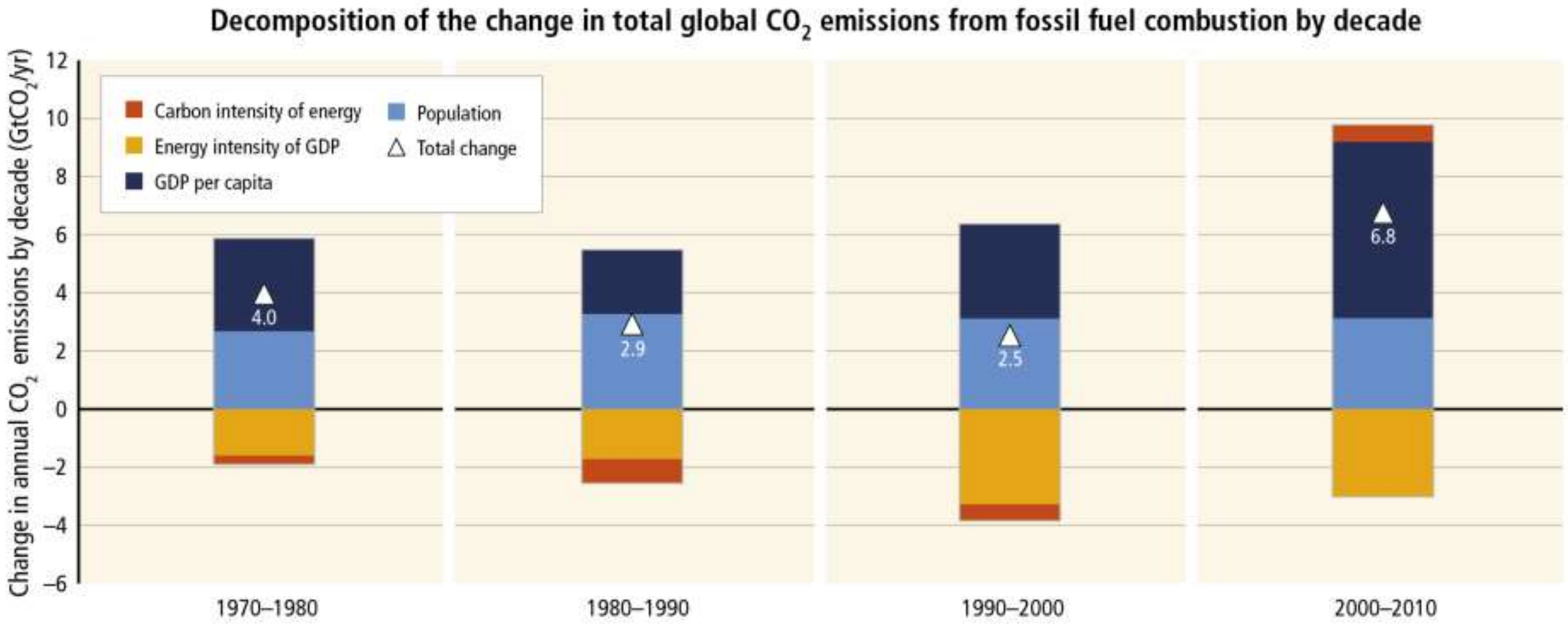
IPAT Equation

- Can be approximated in % changes as:

$$\frac{\Delta I}{I} = \frac{\Delta P}{P} + \frac{\Delta A}{A} + \frac{\Delta T}{T}$$

- 2000-2012 Data from World Bank:
- I / GHG emissions = +2.3% / yr
- P / population = +1.2% / yr
- A / GDP per capita = +1.6% / yr
- T / GHG per GDP = -0.5% / yr

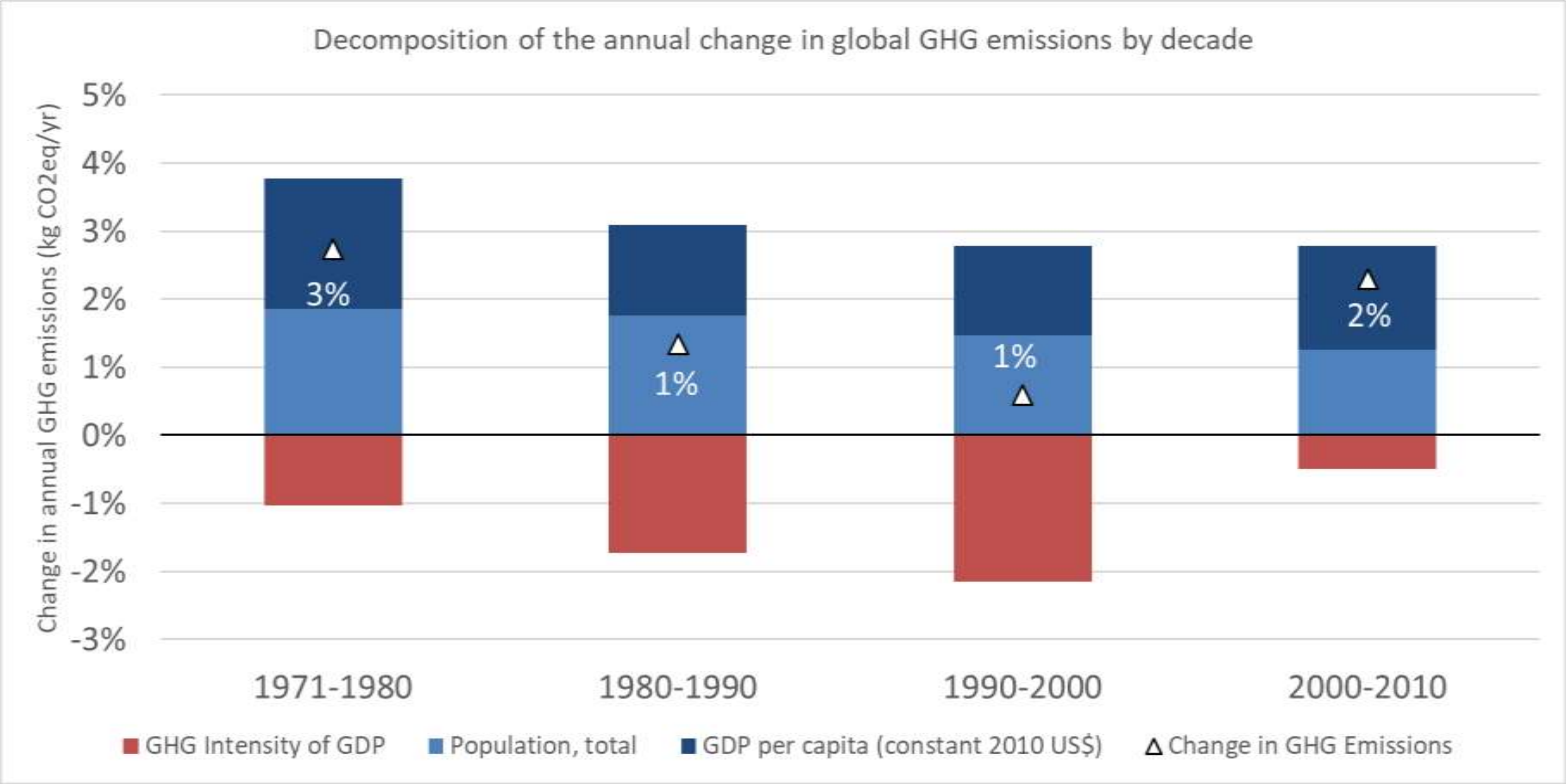
(Economic) Drivers of CC



Source: IPCC (2014) AR5 – Synthesis Report. Fig. 1.8

(Economic) Drivers of CC

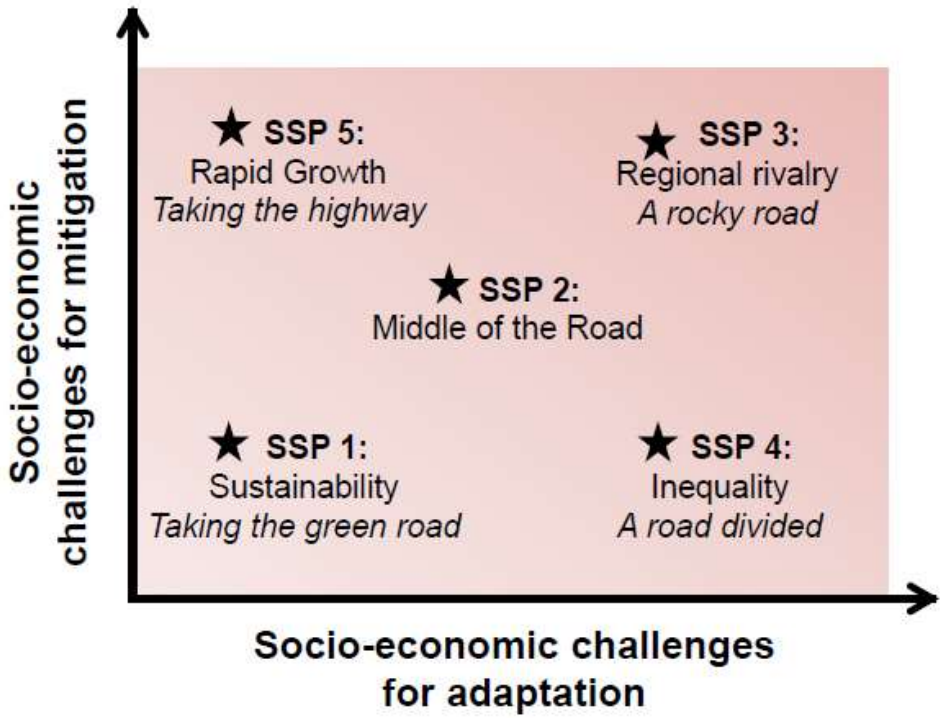
Source: World Bank Development Indicators

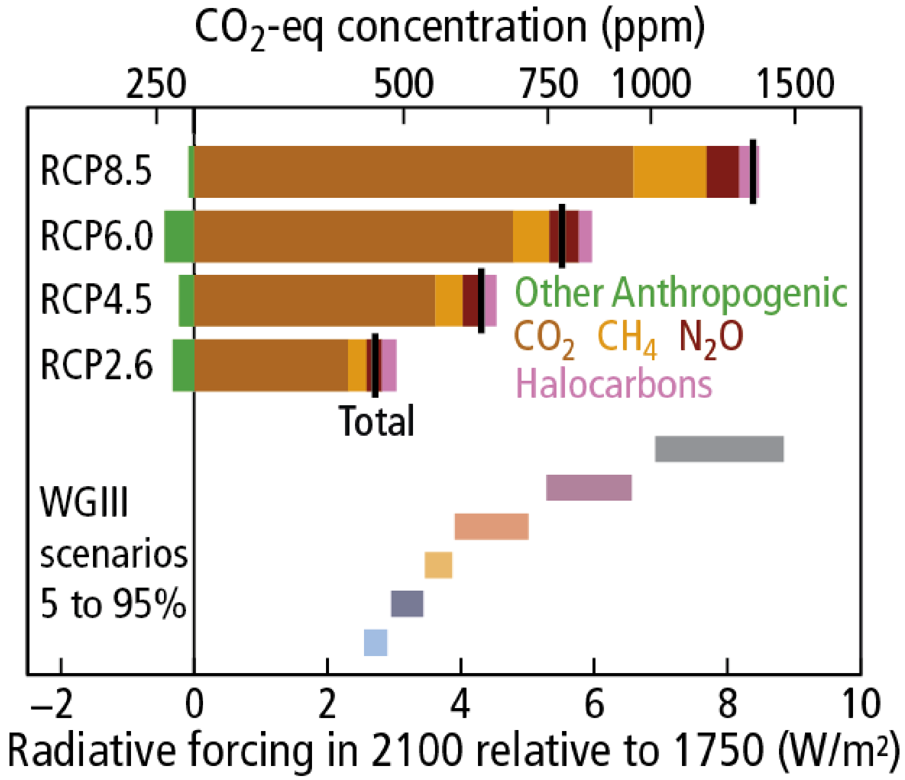


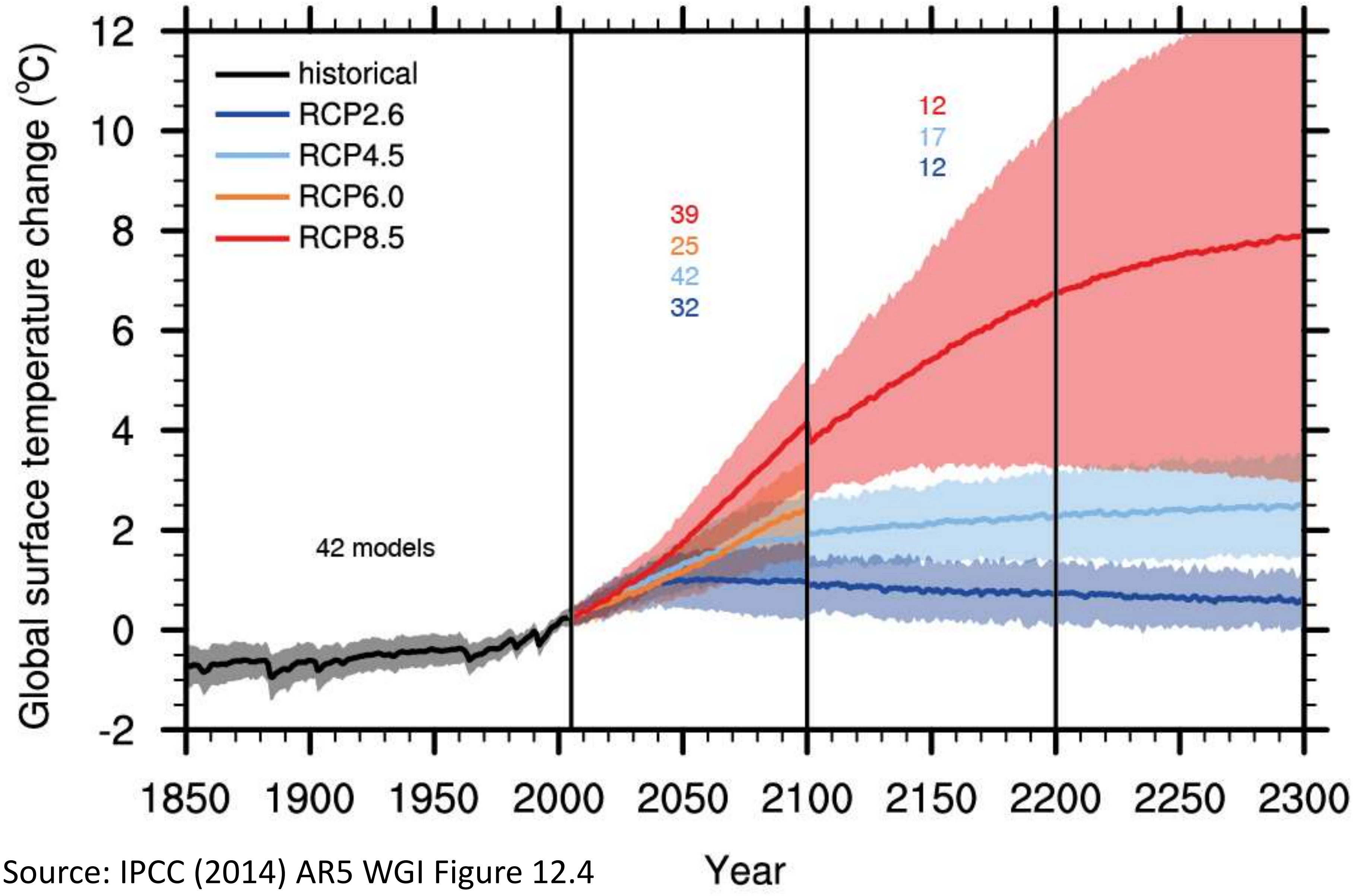
CLIMATE CHANGE
WHAT'S GOING TO HAPPEN?

IPCC Approach

- RCPs – Representative Concentration Pathways
- SSPs – Shared Socio-Economic Pathways

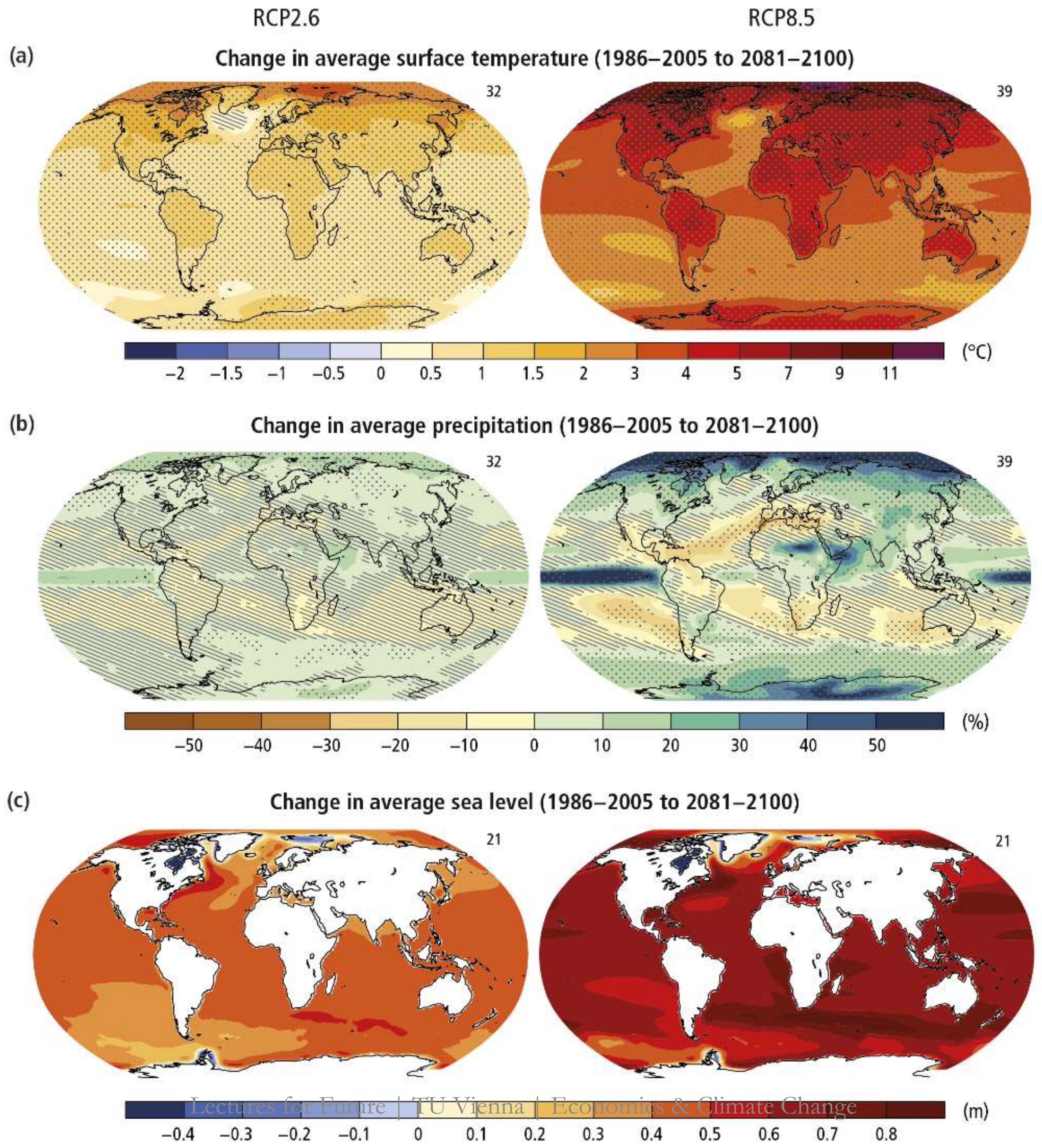






Source: IPCC (2014) AR5 WGI Figure 12.4

Source: IPCC (2014) AR5 – Synthesis Report. Fig. 2.2



COP 21 – Paris Agreement

- Article 2:
  1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:
     a. Holding the increase in the global average temperature to **well below 2 °C** above pre-industrial levels and to **pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels**, recognizing that this would significantly reduce the risks and impacts of climate change;
     b. Increasing the **ability to adapt** to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;
     c. Making finance flows consistent with a pathway towards low greenhouse gas emissions and **climate-resilient development**.
  2. This Agreement will be implemented to reflect equity and the principle of **common but differentiated responsibilities and respective capabilities**, in the light of different national circumstances.

- National pledges currently not enough…
  - https://climateactiontracker.org/ (→ +2.6°C bis +4.7C°)

Why stay below 1.5°C?

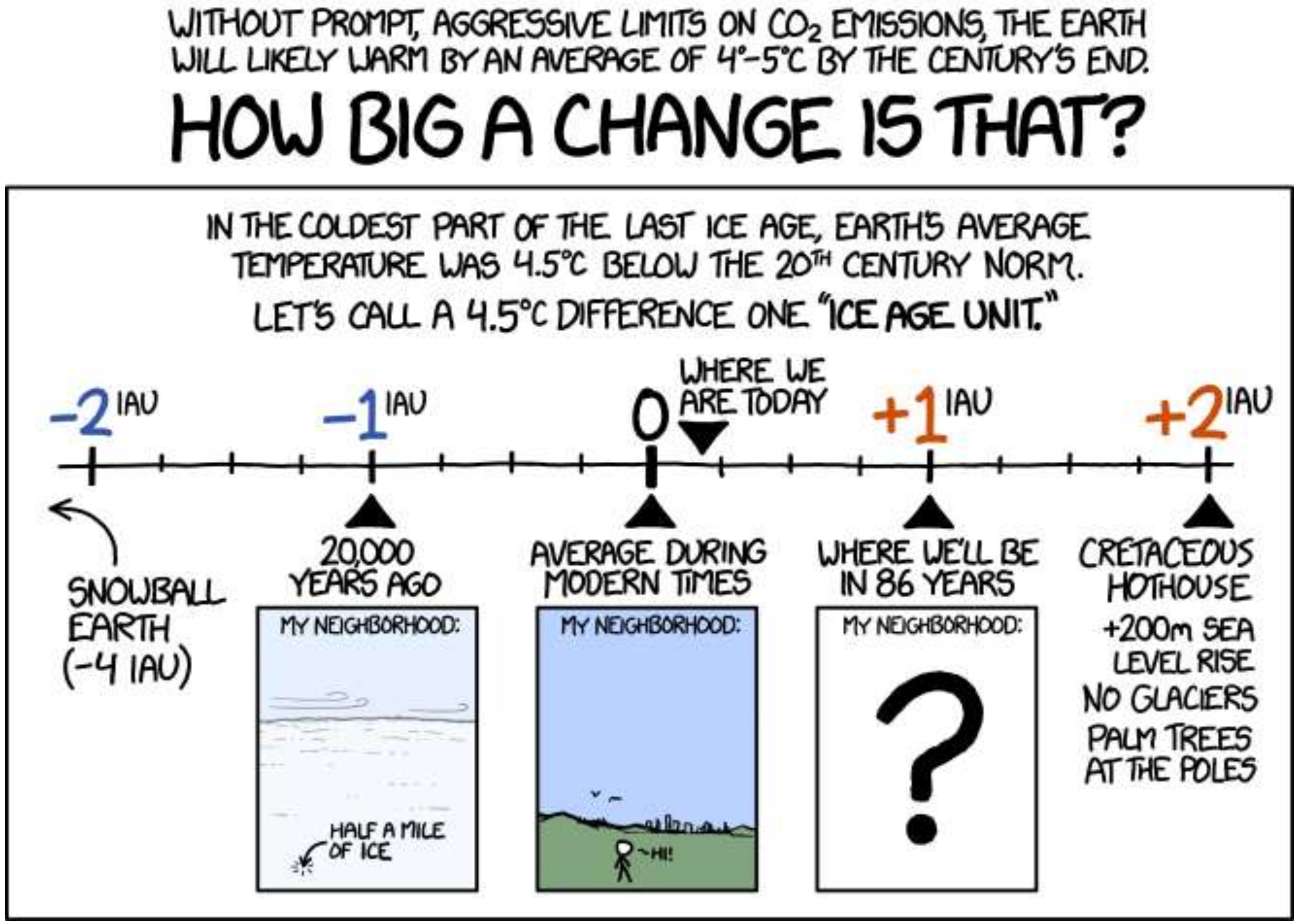
- Avoid critical tresholds (positive feedback loops), e.g.:
  - Methane trapped in permafrosts and oceans
  - Albedo changes (loss of ice/snow covers)

- Avoid catastrophic events, e.g.:
  - Extreme weather events
  - Food and water security
  - Loss of ecosystems and biodiversity
  - Diseases

Why stay below 1.5°C?
The imperative (Hoegh-Guldberg et al., 2019)

Tipping Point (a few examples)	< 1.5°C	1.5°C to 2°C	up to 3°C
Arctic sea ice in summer	Likely to be maintained	50% chance to be ice-free	Very likely to be ice-free
Permafrost	17 to 44% reduction	28 to 53% reduction	Potential for collapse
Rainforests – forest dieback	Uncertain risks	Larger uncertain risks	Potential tipping point
Coral reefs	Decline to 10 to 30% of present day values at 1.0°C	Decline to < 1% (!)	Irreversible changes around 2°C to 2.5°C
Key staple crops	Global maize crop reductions of ca. 10%	Reductions increase to ca. 15%	Drastic reductions globally and in Africa; potential for collapse in some regions

Source: Hoegh-Guldberg et al. (2019). The human imperative of stabilizing global climate change at 1.5°C. Science 365. https://doi.org/10.1126/science.aaw6974



Source: XKCD https://xkcd.com/1379/

Also: A timeline of earth's average temperature; https://xkcd.com/1732/

Did the IPCC AR5 understimate risk?

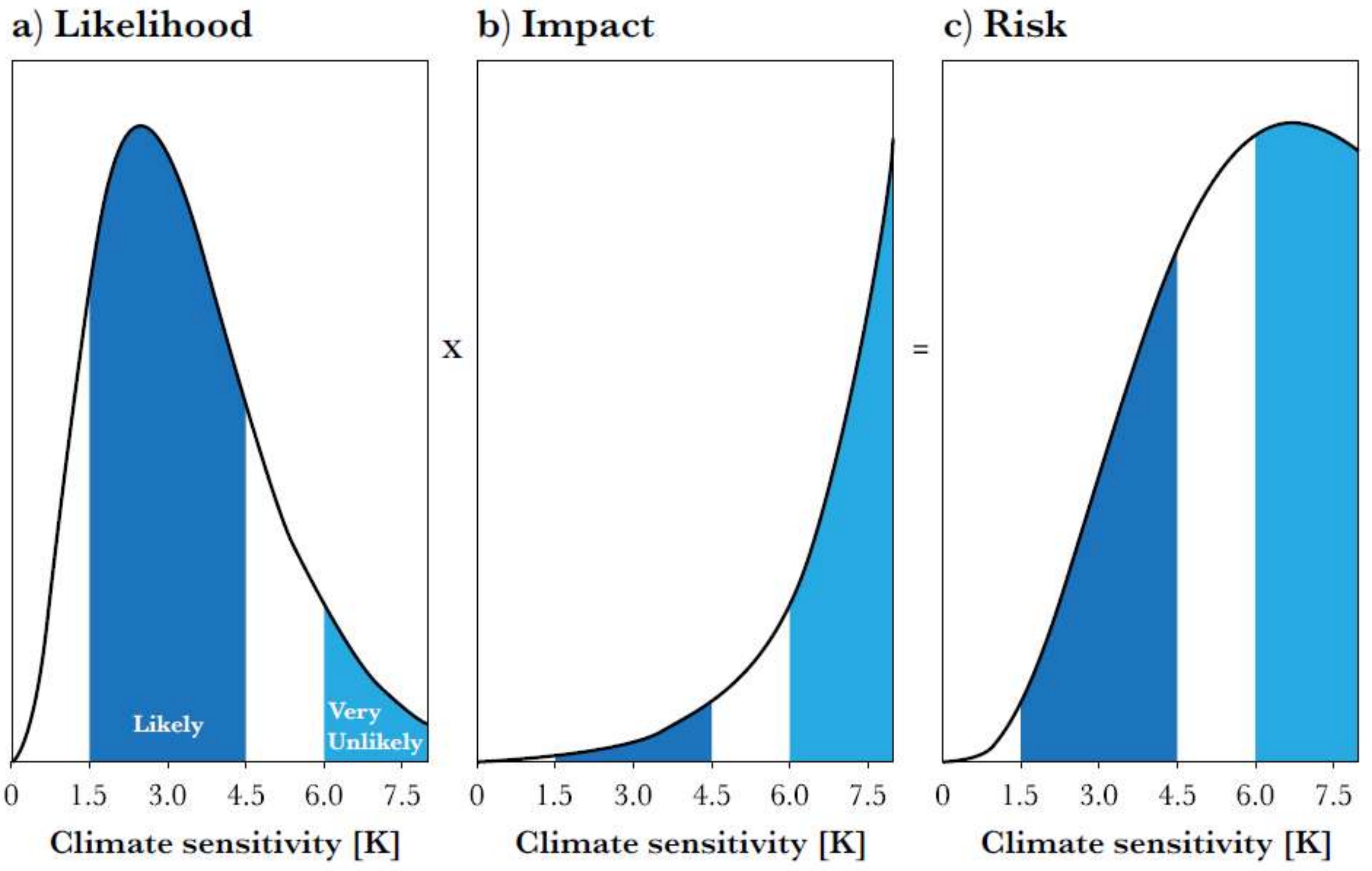


Figure 2: Schema of climate-related risk. (a) Event likelihood and (b) Impacts produce (c) Risk. Lower likelihood events at the high end of the probability distribution have the highest risk (Credit: RT Sutton/E Hawkins).

Spratt and Dunlop, 2018

Did the IPCC AR5 understimate risk? (Spratt and Dunlop, 2018)

- Climate models
  - Conservative (low climate sensitivity)
  - Often omit many large-scale events (tipping-points), e.g.:
    - Permafrost warming
    - Carbon sink efficiencies
    - Melting of polar ice sheets (sea-level rise)
    - Understimation of albedo effects

(…besides the obvious economic activities that drive GHG emissions…)

WHERE DOES ECONOMICS COME IN?

Climate change economics

- Two main aspects:
  1. What are the **costs** of climate change?
  2. How can resources best be **allocated** to:
     - **a) Mitigate** climate change
     - **b) Adapt** to climate change

→ Identify policies that
- increase social welfare; or
- reach a mitigation target at least cost

→ Methods: generally called „Integrated Assessment Modelling" (IAM)
→ quite diverse

Climate change economics

- Two (main) approaches:
  1. Cost-effectiveness analysis (CEA)
     - Find the least-cost mitigation pathway
     - Process-Based IAM (bottom-up)
       - E.g. Energy-Land Use models (e.g. MESSAGE-GLOBIOM)
  2. Cost-benefit analysis (CBA)
     - Maximize welfare
     - Top-down stylized IAMs
       - E.g. Macroeconomic models integrated with climate change models (e.g. DICE/RICE, PAGE)

Climate change economics

- Two viewpoints:
  1. Positive Economics
     - → looks at empricial evidence (e.g. econometric studies)
     - Is theory based, but empirically founded
     - Process-based IAMs are rather like this
  2. Normative Economics
     - Makes a value judgement → maximizes social welfare!
     - Social welfare function is at the heart of top-down macroeconomic IAMs

ATTEMPTS TO ESTIMATE THE COSTS OF CLIMATE CHANGE

How to estimate the cost of climate change

- Monetarize **physical** impacts
  - e.g. human health, ecosystem services, destroyed infrastructure

- Assume a (arbitrary) **damage function**
  - No empirical and theoretical foundations, but…
  - … it can provide you with a Nobel Prize (Nordhaus)

$$L(T) = 1/(1 + \pi_1 T + \pi_2 T^2)$$

- Both are **fed into top down IAMs** → connect climate models with macroeconomic models

Economic Impacts (IPCC 5th AR)

- Aggregate losses increase with temperature *(limited evidence, high agreement)*
- At +2.5°C → -0.2 to -2% GDP *(medium evidence, medium agreement)*
- Probably much higher *(limited evidence/high agreement)*
- Other factors are likely to have larger impact on GDP
  - Demography, Income, Technology, Life Style, Regulation, Government …
- Risks due to natural disasters

Economic Impacts (IPCC 5th AR)

- 5th AR also includes critical remarks on economic impacts:
  - No consideration of
    - Great singular events and irreversibility
    - Tipping points
    - Loss of biodiversity …
  - Aggregation problem (ethical issues)
  - Only few studies that consider > 3°C
  - Scenarios with low probability but high consequences have to be considered (risk!)

- *"… it is outside the scope of science to identify a single best climate change target and climate policy"* (Synthesis Report, Box 3.1, p. 79)

Economic Impacts (IPCC 1.5°C SR)

- Growth impacts until 2100 lower with 1.5°C than 2.0°C *(medium confidence)*
- Energy investments 12% higher than compared to 2.0°C
- Not much known about total/marginal mitigation/abatement cost for 1.5°C
- "Knowledge gaps remain"

Stern Review (2006)

- Climate change „is the greatest and widest-ranging market failure ever seen“.

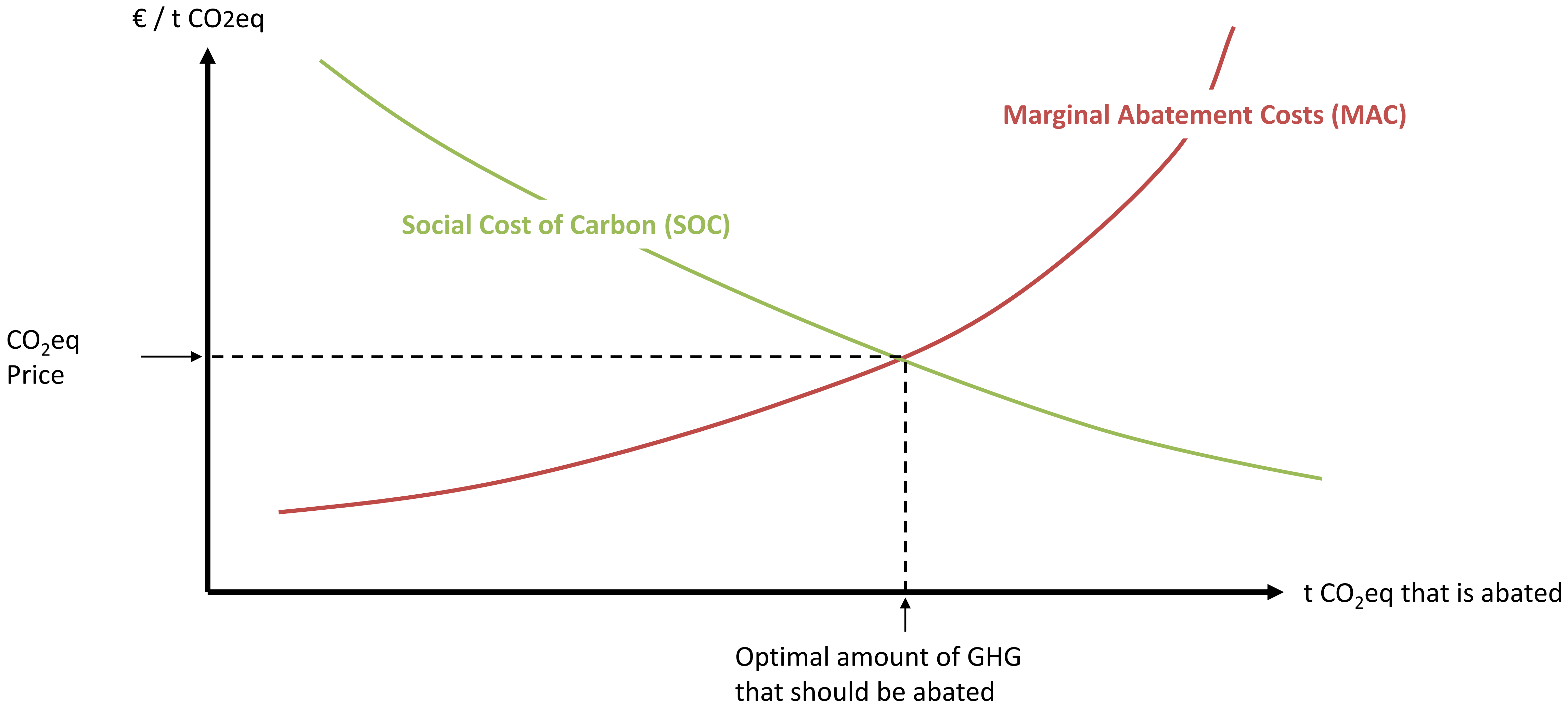
- Look at the economic **costs** of CC in three ways:
  1. **Physical** impacts on the economy, humans and environment
  2. **Integrated Assessment Models (IAM)**
     - Quantification of economic impacts of climate change
     - Macroeconomic models to account for transition costs towards a low-carbon energy system (i.e. mitigation)
  3. Comparison o the „**social cost of carbon**“ with the „**marginal costs of mitigation**“

Stern Review

- Conclusions:
  - Early mitigation efforts are less costly and increase welfare
  - Adaptation is necessary, but more costly (if no mitigation takes place)
  - CC-mitigation is the „pro-growth strategy for the longer term“

- Criticism
  - Choice of discount rate (Nordhaus!)
  - Underestimation of damages

Social cost of carbon vs. Marginal costs of mitigation



Social Cost of Carbon

- Marginal damage costs of (one additional amount of) CO_2
- Net present value
- Pigouvian tax (→ internalise externality)

- Based on total costs and depends on:
  - Discount rate
  - Projections of CO_2 emissions
  - Climate sensitivity
  - Economic and demographic development
  - Uncertainties
  - Aggregation of regional impacts

Choic of discount rate is essential

- Discount Rate
  - Ramsey equation (1928):
  - $\rho = \eta * g + \delta$
  - η → elasticity of marginal utility of consumption
  - g → growth in consumption
  - δ → pure time preference

Choice of discount rate is essential

Stern Review

- Social cost of carbon estimated to be \$85/tC (higher than usual at that time)
- Higher than most abatement/mitigation cost options

- Monetarize physical impacts
- Discount rate of ca. 1.4%

Nordhaus

- His model (DICE) assumed a SCC/carbon tax of \$10-15/tC at
- Questioned many mitigation options at that time

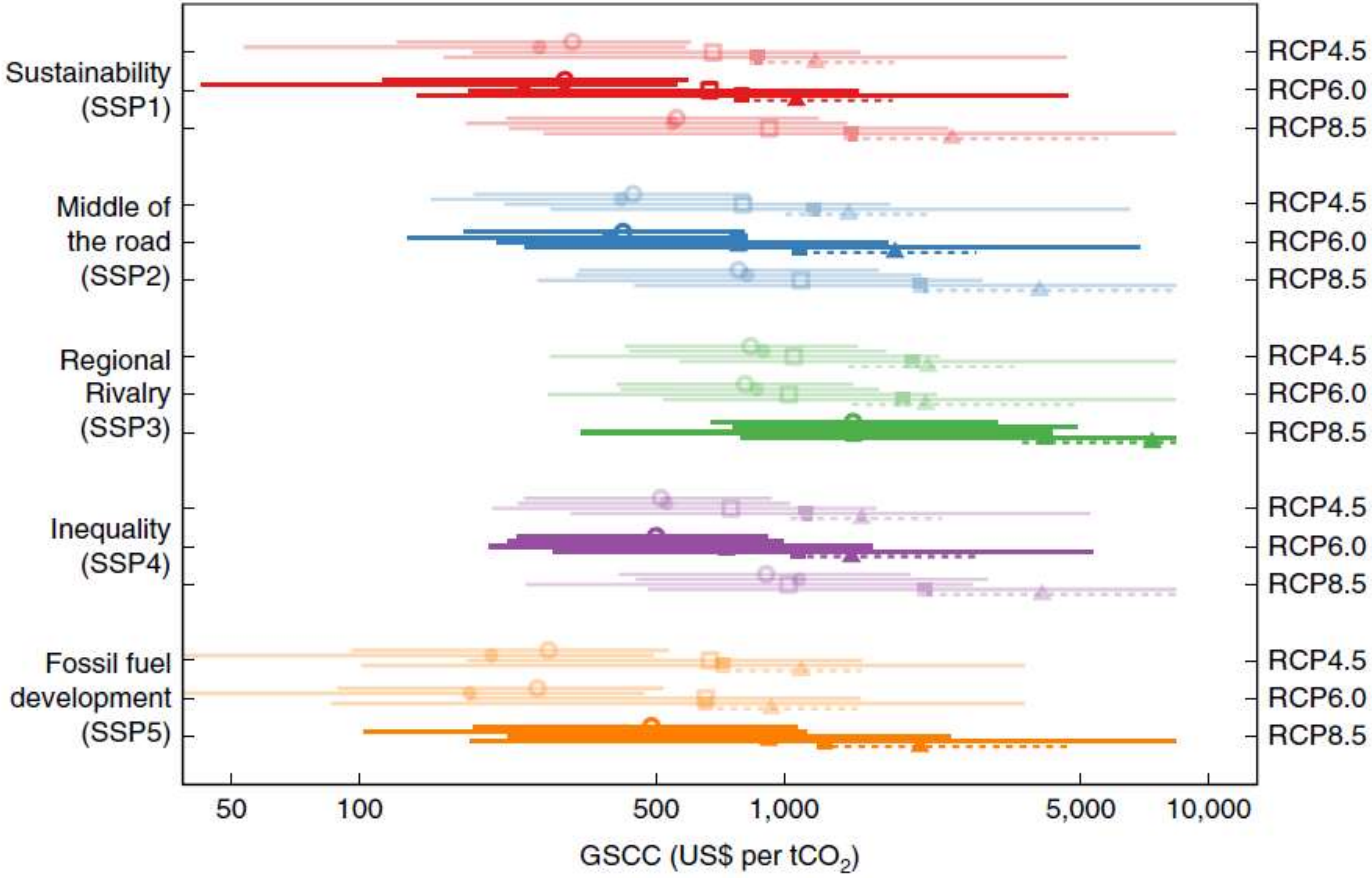
- Damage function
- Discount rate of ca. 5.0%

Current estimations of the social cost of carbon

- Bandwith in the IPCC-AR5:
  - $270 /tC (not time preference)
  - $181 /tC (1% time preference)
  - $33 / tC (3% time preference)

- Ricke et al. (2018): Country-level social cost of carbon. *Nature Climate Change 8(10)*, 895-900
  - Median: **$417** t/$CO_2$ (between $10 & $1000) → $\rho \sim 3\%$
  - Values are used for policy making → EPA!
  - Most costs occur in: India, China, Saudi-Arabia & USA

Ricke et al. (2018): Country-level social cost of carbon. *Nature Climate Change 8(10)*, 895-900



Social Cost of Carbon

- Social values (e.g. welfare function, discount rate)
  - Matter much more in top-down stylized IAMs than in process based IAMs
  - Process based IAMs
    - GHG target is set and reached at least-cost
  - Top-down stylized IAMs
    - Maximizes social welfare

Are top-down IAMs totally useless?

- Crucial flaws:
  - Discount rate is arbitrary (and has huge effect)
  - Climate senstivity has large uncertainties
  - CC impact function has no theoretical or empirical foundation
  - Models do not tell as what happens if catastrophe strikes
- Other options?:
  - Focus on extreme events
  - Make use of expert opinions

Pindyck (2013) Climate Change Policy: What Do the Models Tell Us? (NBER Working Paper No. 19244) + (2017) The Use and Misues of Models for Climate Policy (Review of Environmental Economics and Policy) 11(1), 100-114

My own two cents

- Results from (top-down) IAMs need to looked at very carefully and should not be interpreted as facts – especially any SCC estimations
- However:
  - These models still help us to understand systems, how things interact with each other and what needs to be considered → „pedagogical devices“
  - Useful argument? → „Even these very stylised models argue for the need to tackle climate change!“

My own two cents

- IAMs have now become very diverse, especially those that are process based:
  - Energy models (PRIMES)
  - Land use/agricultural models (GLOBIOM)
- Good tools to find cost-efficient technical solutions
- Rest on fewer dubious assumptions (still plenty though)
- Still need macroeconomic models → integration of both types is high on the research agenda

MITIGATION

Mitigation

- Overall Aim:
  - Allow a maximum amount of GHG in the atmosphere (GHG budget)
  - For 1.5°C target → -50% by 2030; carbon neutrality by 2050

- So many ways…
  - CO_2 markets (taxes, cap & trade), Subsidies, Standards, Regulations
  - What is most efficient? effective? ethical? just?

- Ethical issue / Justice:
  - Who should contribute how much?

Mitigation options

Technological & societal options

- Renewable energy
- Energy efficiency
  - Sector coupling / Energy-Hubs
- Zero emission technologies (R&D)
- Circular economy
- Infrastructure & investments
- Carbon capture & sequestration / utilization ?
- Social-ecological transformation

Policy (instrument) options

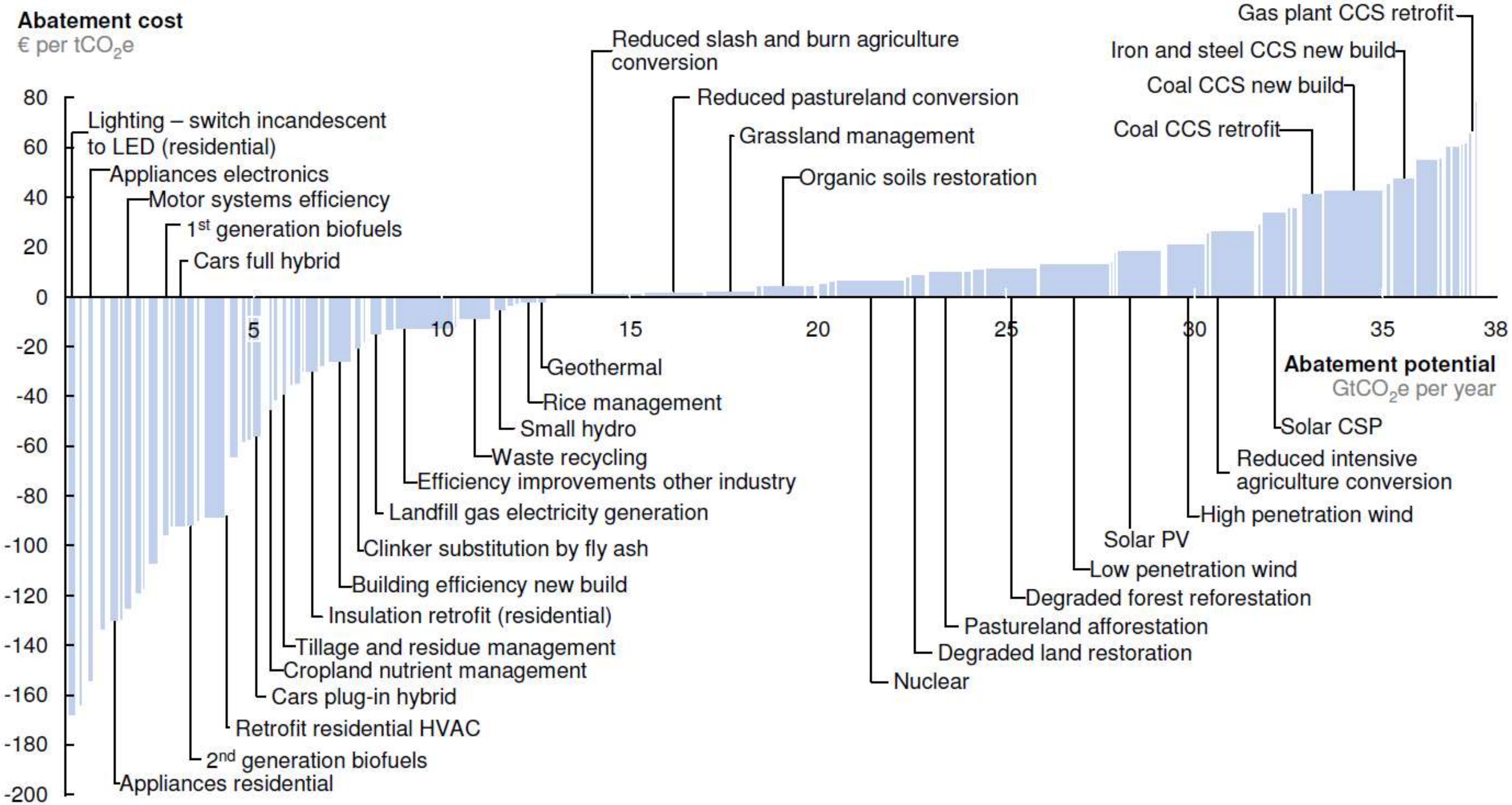
- Economic
  - Carbon pricing
  - Subsidies
- Regulation
  - Efficiency standards
  - Ban on fossil fuel technology
- Information & eduction
  - Labelling
  - Curricula
- Citizen juries

Mitigation options - Austria

- Ref-NECP
  - S4F Reference National Energy and Climate Plan information about the necessary emission reduction path (1.5°C Paris-Goal)
  - Illustration of possible climate protection pathways (for Paris Goal)
  - List of indispensable basic measures
  - Detailed catalogue of effective measures

https://ccca.ac.at/refnekp

Examples of marginal abatement/mitigation costs



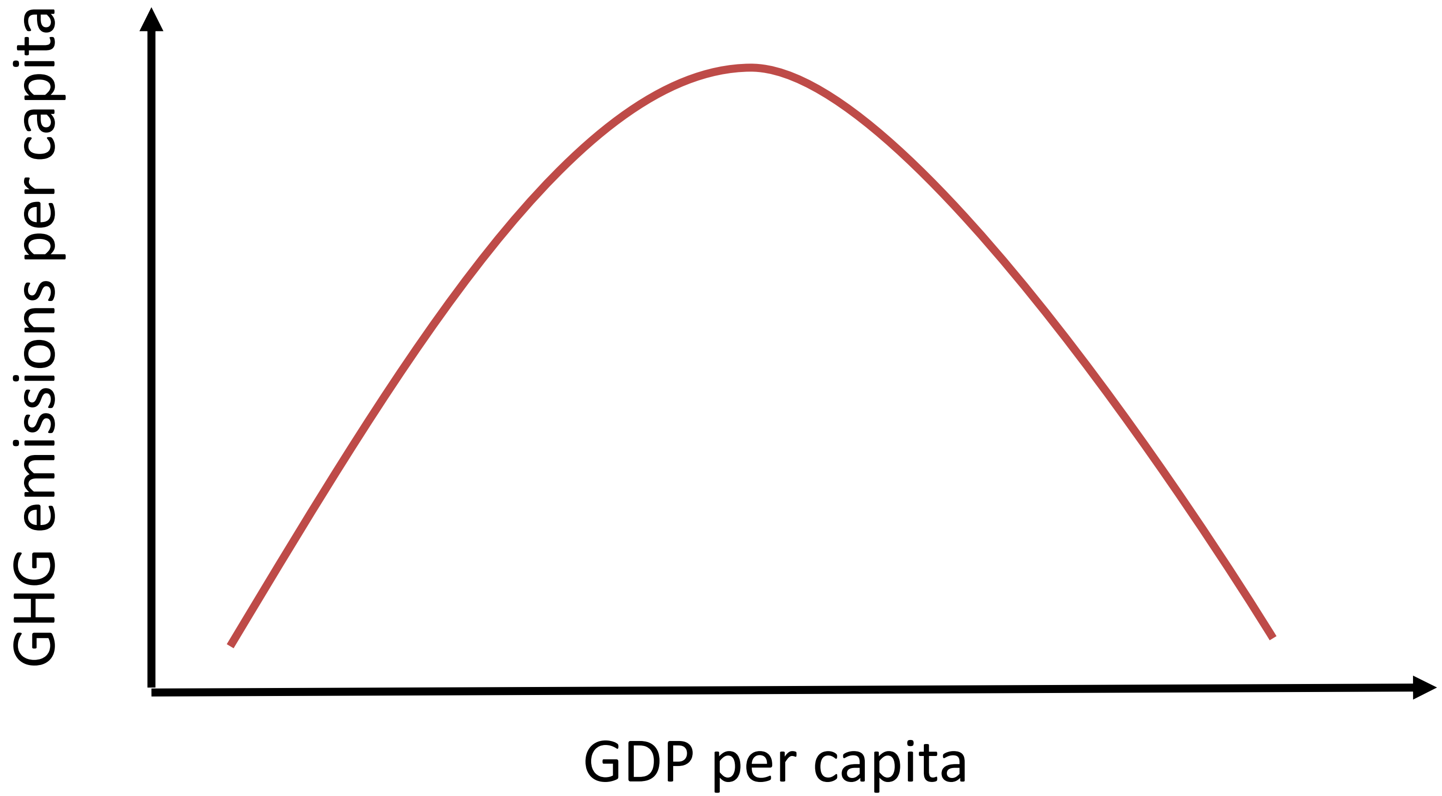
McKinsey&Company (2010) Version 2.1 of the Global Greenhouse Gas Abatement Cost Curve

Notes on the marginal abatement cost curve

- Negative costs → probably not implemented due to misperceptions, insitutional barriers, cultural behavior
- Static assumption (e.g. oil prices)
- Static technology (curves will change with time)
- Supply → only available if investments are possible

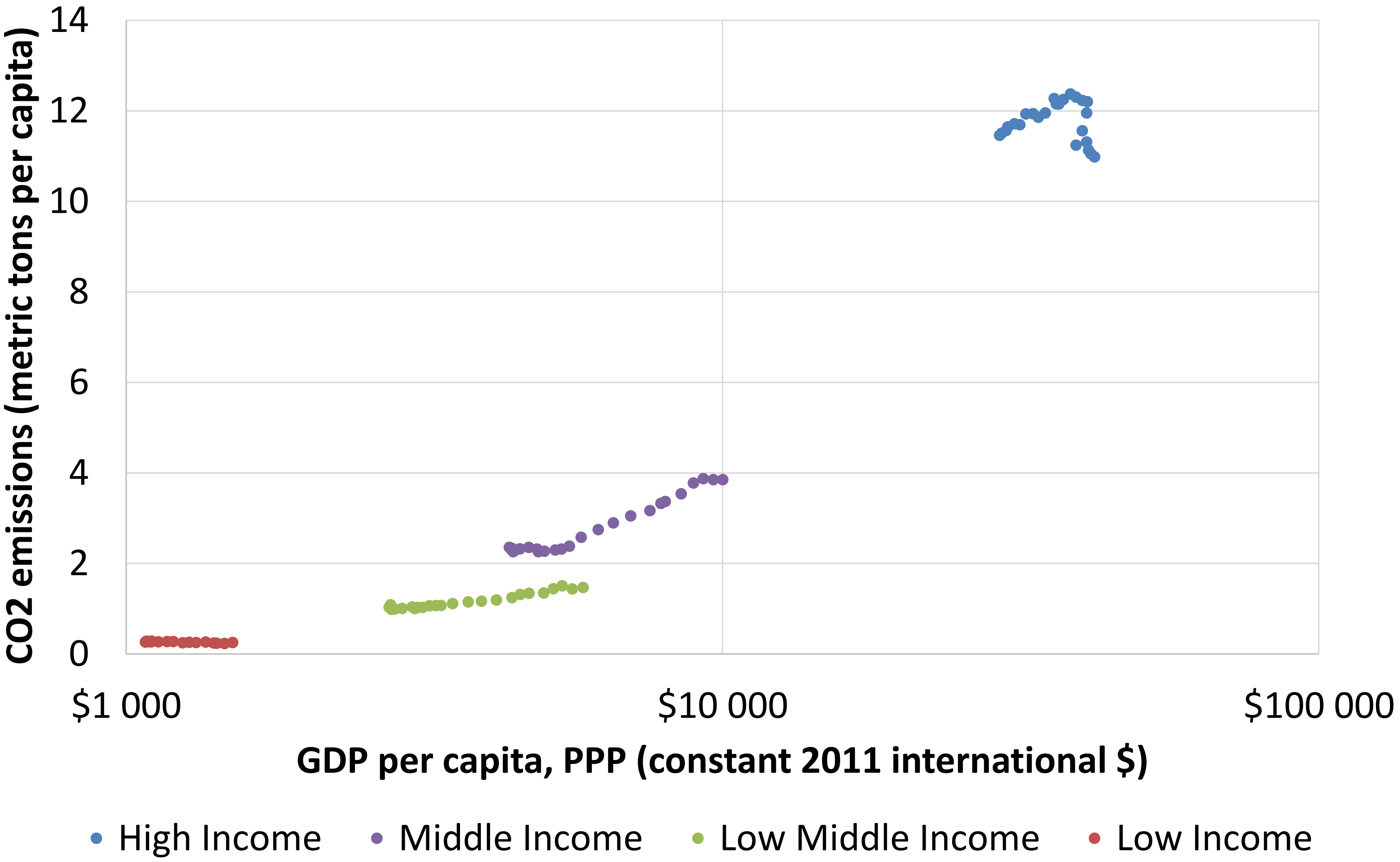
Mitigation

- The economists (naive) hope: the Environmental Kuznet‘s Curve (EKC)

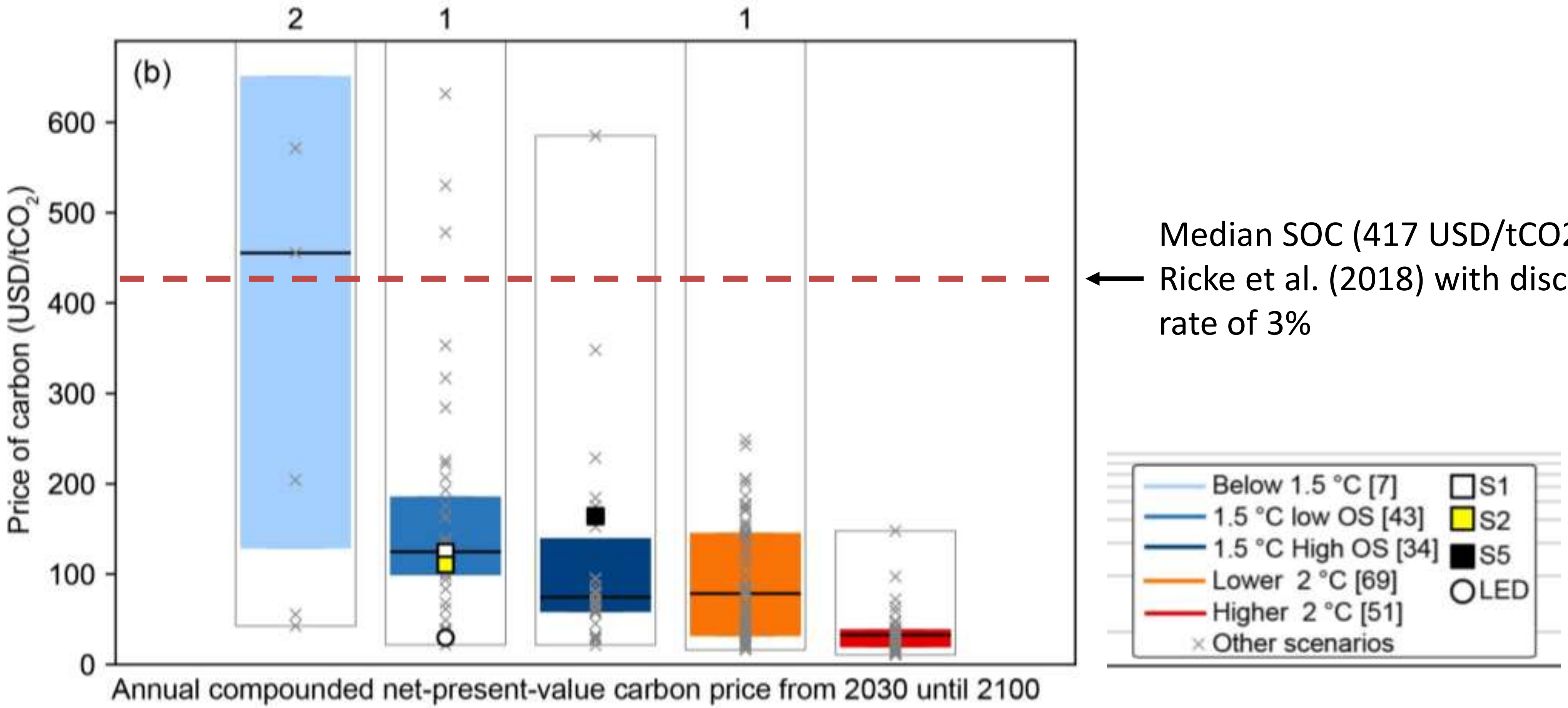


Mitigation

Source: http://databank.worldbank.org (1990-2016)



Mitigation – MAC in the IPCC 1.5°C SR



Median SOC (417 USD/tCO2) from Ricke et al. (2018) with discount rate of 3%

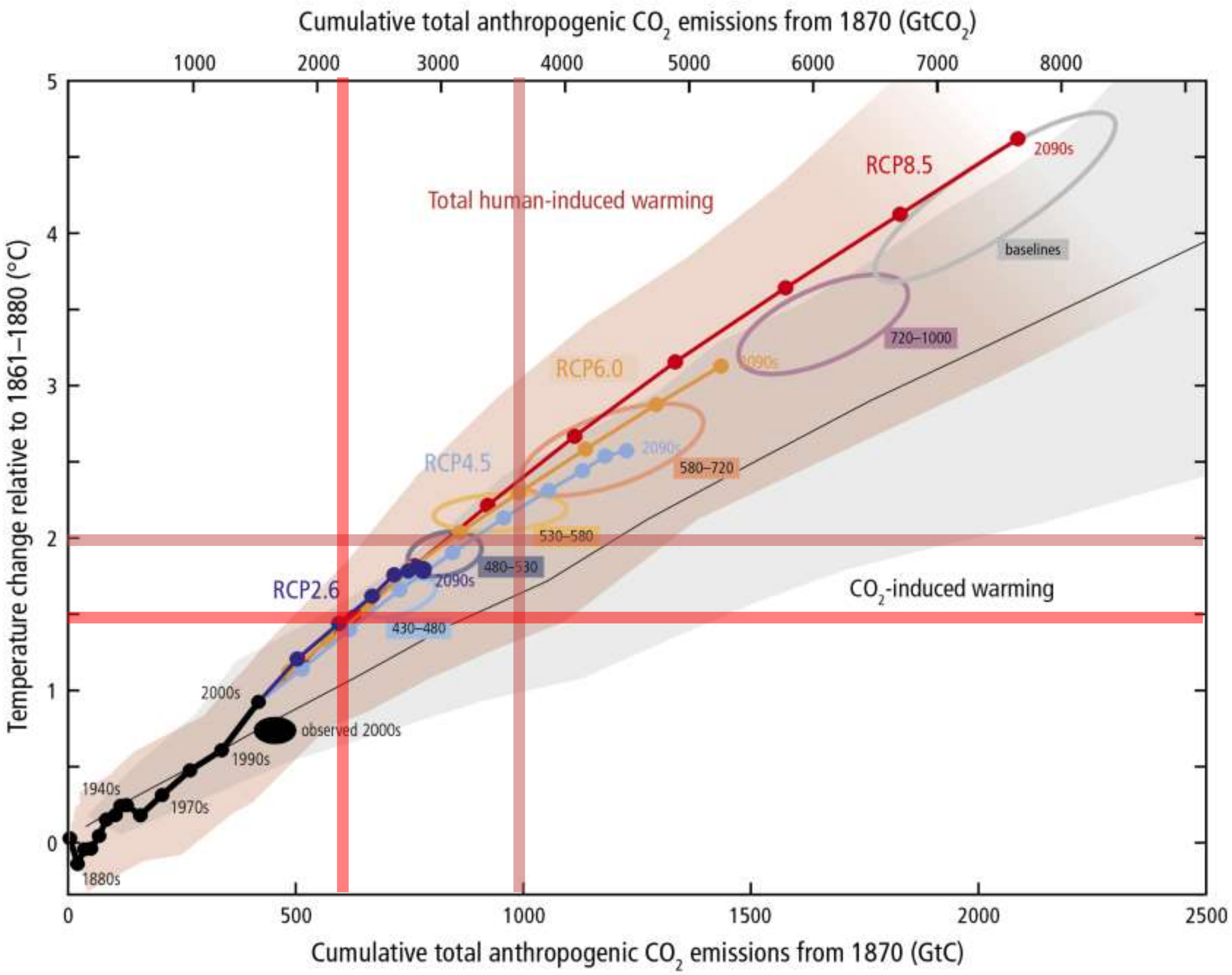
IPCC 1.5°C Special Report - Figure 2.26 - Process-based IAMs - Discount rate: 5%!

CO2/Carbon Budget

- Cumulative CO2 emissions determine land surface temperature changes in the 21st century

- Warming via CO2 is a process that is irreversible for centuries

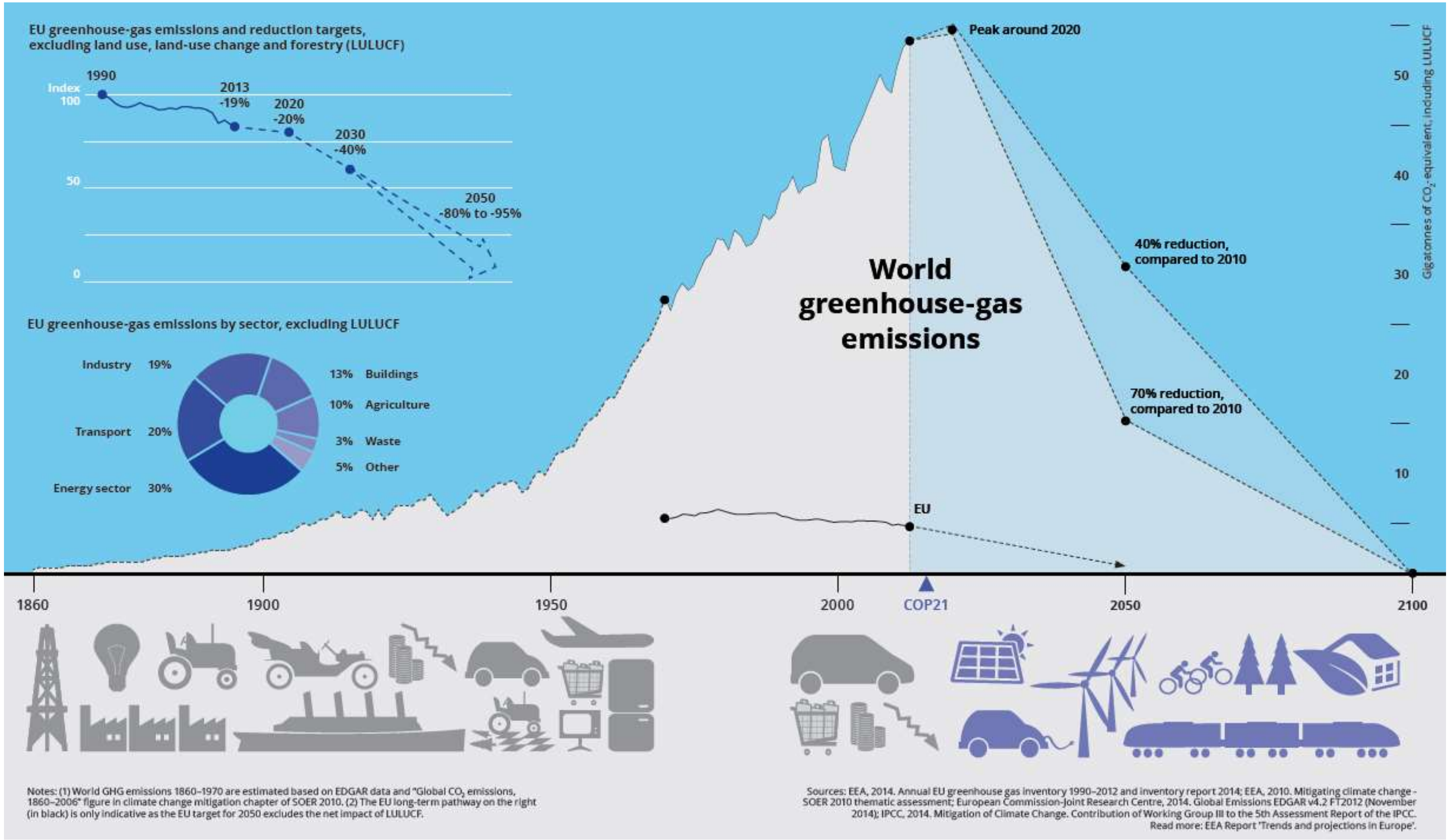
- To keep changes below 2°C the cumulative emissions need to stay at least below 3650 GtCO2 (1000 GtC)
  - 2011: reached 500 GtC!



Source: IPCC (2014) AR5 – Synthesis Report. Fig. 2.3

GHG-Budget

Source: EEA Signals 2015: Living in a changing climate



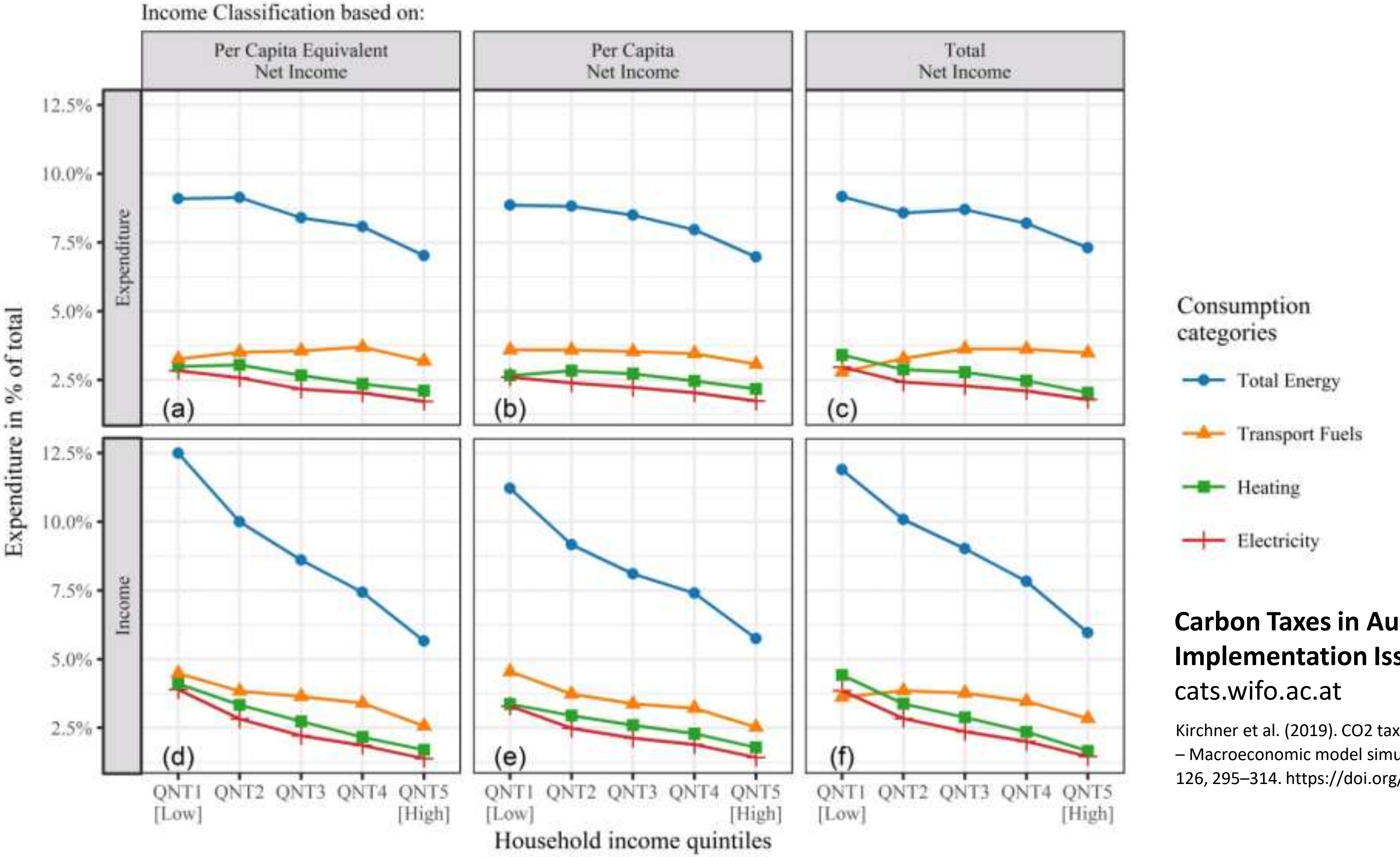
Does mitigation have to hurt?

- Yellow vest protests in France → impossible to implement carbon pricing without hurting the poor?

- Gagnebin et al. (2019):
  - Reform in France not only increased carbon price but came with a change in welfare politics:
    - Electricity subsidies for poor households was abandoned
    - Green check was introduced instead
    - Net effect was an income loss for poor households (not taken into account the increase in the carbon price!)

Gagnebin, M., Graichen, P., Lenck, T., 2019. Die Gelbwesten-Proteste: Eine (Fehler-)Analyse der französischen CO2-Preispolitik. Agora Energiewende, Berlin.

Household Income Quintiles – Austria
Income and Consumption Patterns



Carbon Taxes in Austria: Implementation Issues and Impacts
cats.wifo.ac.at

Kirchner et al. (2019). CO2 taxes, equity and the double dividend – Macroeconomic model simulations for Austria. Energy Policy 126, 295–314. https://doi.org/10.1016/j.enpol.2018.11.030

Socially acceptable carbon pricing

- Carbon pricing alone will hurt lower income households more
- However: the impact will depend on the use of the tax revenues
  → „revenue recylcing"
- Possible options:
  - Pay off government debts
  - Lower other taxes (VAT, labor taxes)
  - Pay a climate dividend to households
  - Invest in climate mitigaiton projects and research

Mattauch et al. (2019). Antworten auf zentrale Fragen zur Einführung von CO2-Preisen. Gestaltungsoptionen und ihre Auswirkungen für den schnellen Übergang in die klimafreundliche Gesellschaft. Diskuss. Sci. Future. https://doi.org/10.5281/zenodo.3371150

May do the trick
Necessary requirements:
- transparency
- earmarking

Potential social impacts in Austria

Households	CO2 tax burden	Climate dividend	Net burden
	All values in € per capita per year		
Low income	249	308	-59
Low-middle income	272	308	-36
Middle income	303	308	-5
Middle-high income	341	308	33
High income	368	308	60

Tax Rate:
+120 € / t CO_2 on top of existing energy taxes

Recycling:
Divindend to households
Lower labor taxes for businesses

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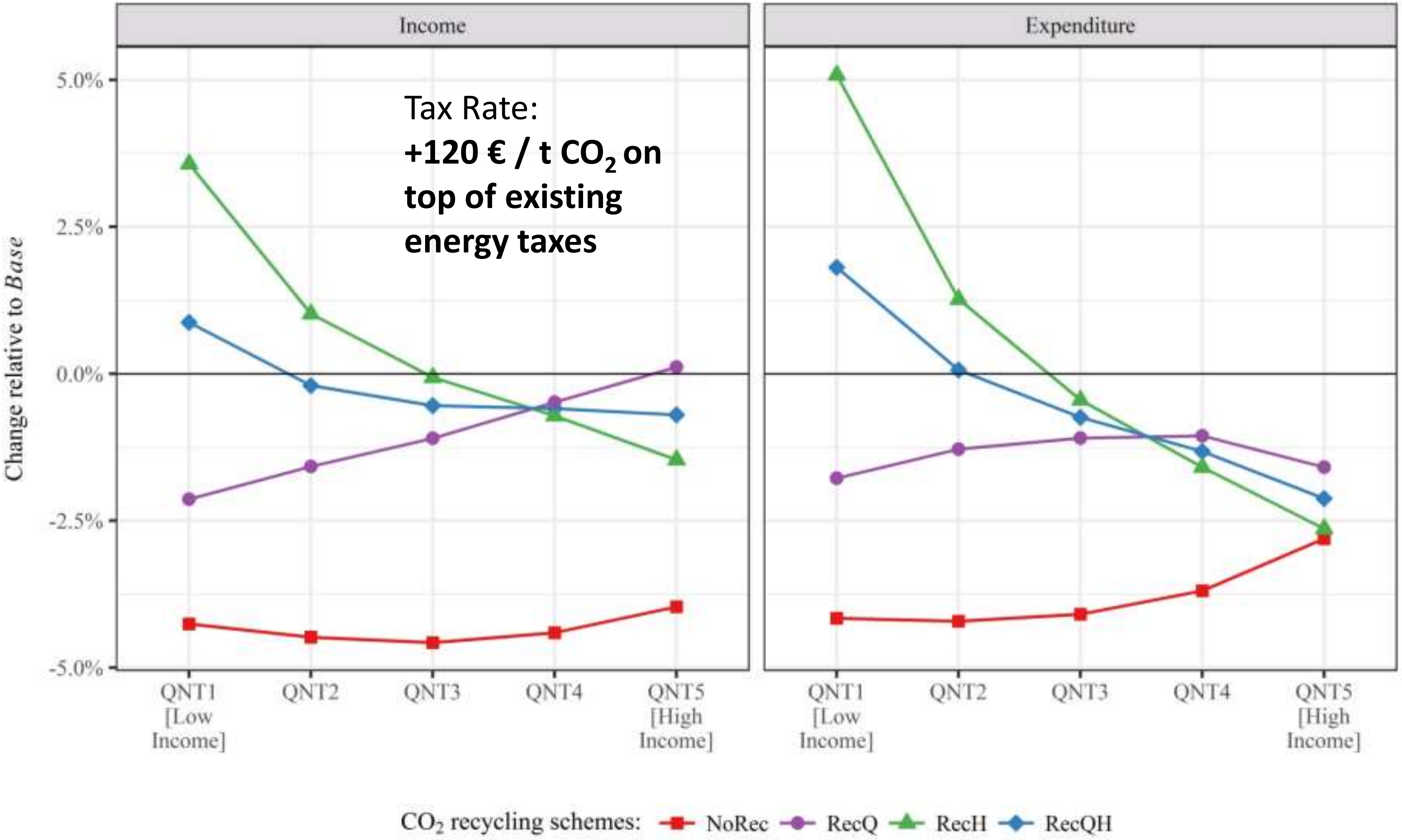
Potential impacts in Austria



Recycling:
NoRec → No Recycling

RecH → Climate dividend to households

RecQH → Climate dividend to households and lower labor tax for businesses

RecQ → Only lower labor taxes for businesses

Carbon Taxes in Austria: Implementation Issues and Impacts
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TAKE HOME MESSAGES

Climate change

- Unprecedented changes

  … driven by human (economic) activity

- Current trajectories pose existential risk

  … imperative to stay below 1.5°C

Climate change economics

- Economic assessments have many drawbacks…
  - value judgements, uncertainties, unknown unkowns…
- …but they provide useful information on:
  - economic dynamics
  - viable and efficient (short-term) mitigation options (→ bottom-up models)
  - how to design socially acceptable policies (climate dividend)
- And even the most crude assessments conclude:
  - mitigation is better than adaptation
  - taking action now is less costly than later

Climate change and economics

- Tackling climate change will require a major transformation of our economic and social systems
- We're in the midst of deciding what we want and how we want to get there
- Science can only provide options → value judgements and decision are made by society & policy makers

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THANKS!