Potsdam Institute for Climate Impact Research

Climate Economics: Macro-fiscal risks and opportunities

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PIK's Science &Pretzels
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Leibniz Gemeinschaft

MCC
Mercator Research Institute on Global Commons and Climate Change

Technische Universität Berlin

Outline

1. Macroeconomic Implications of the Paris Agreement
2. The Social Costs of Carbon – Guiding Principle for Climate Policies
3. Implementation Challenges for National Governments

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1. **Macroeconomic Implications of the Paris Agreement**
2. The Social Costs of Carbon – Guiding Principle for Climate Policies
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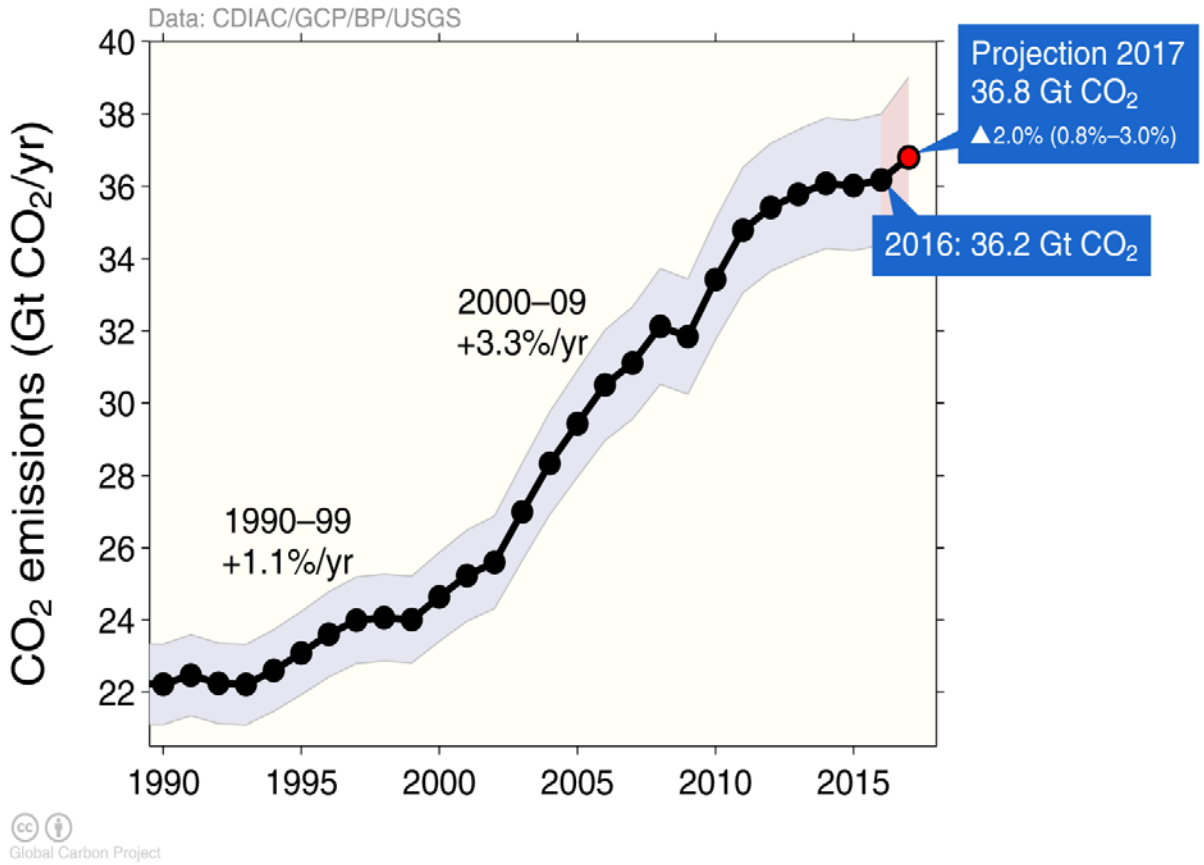
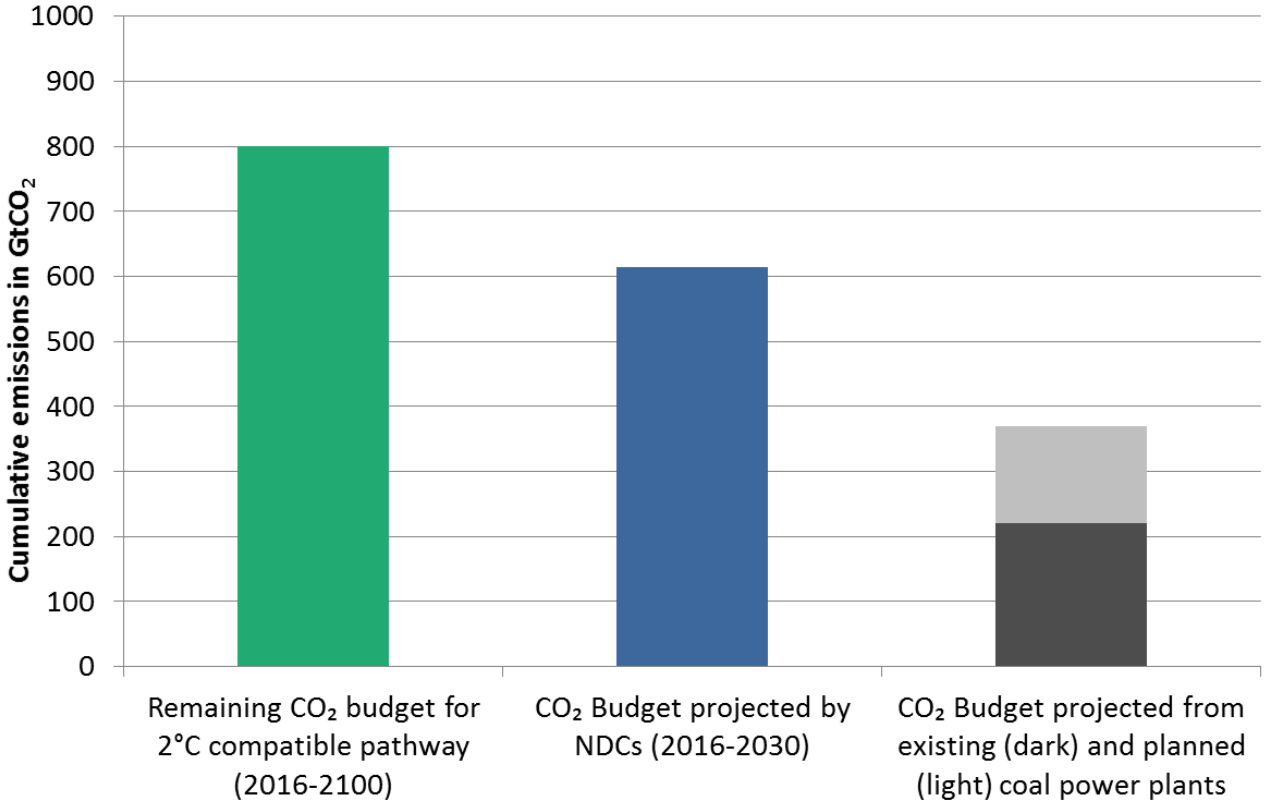
Emissions are rising



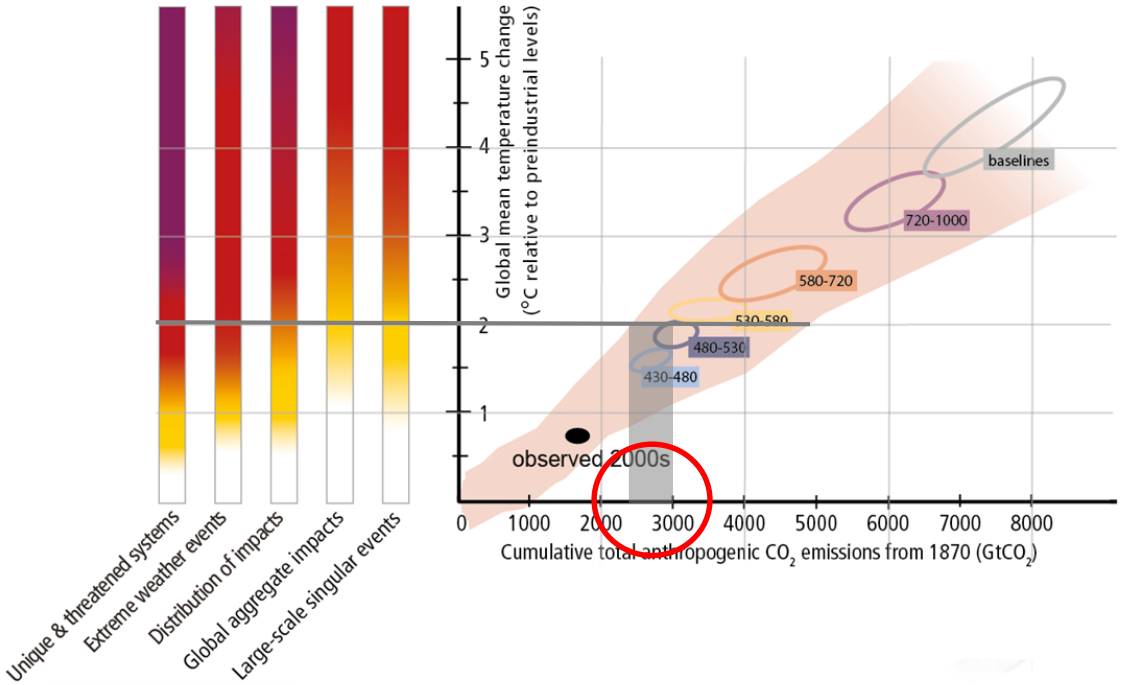
The 2°C budget does not leave any leeway

Cheap and abundant coal is the driver of a „re-carbonisation“ of the energy system in some parts of the world



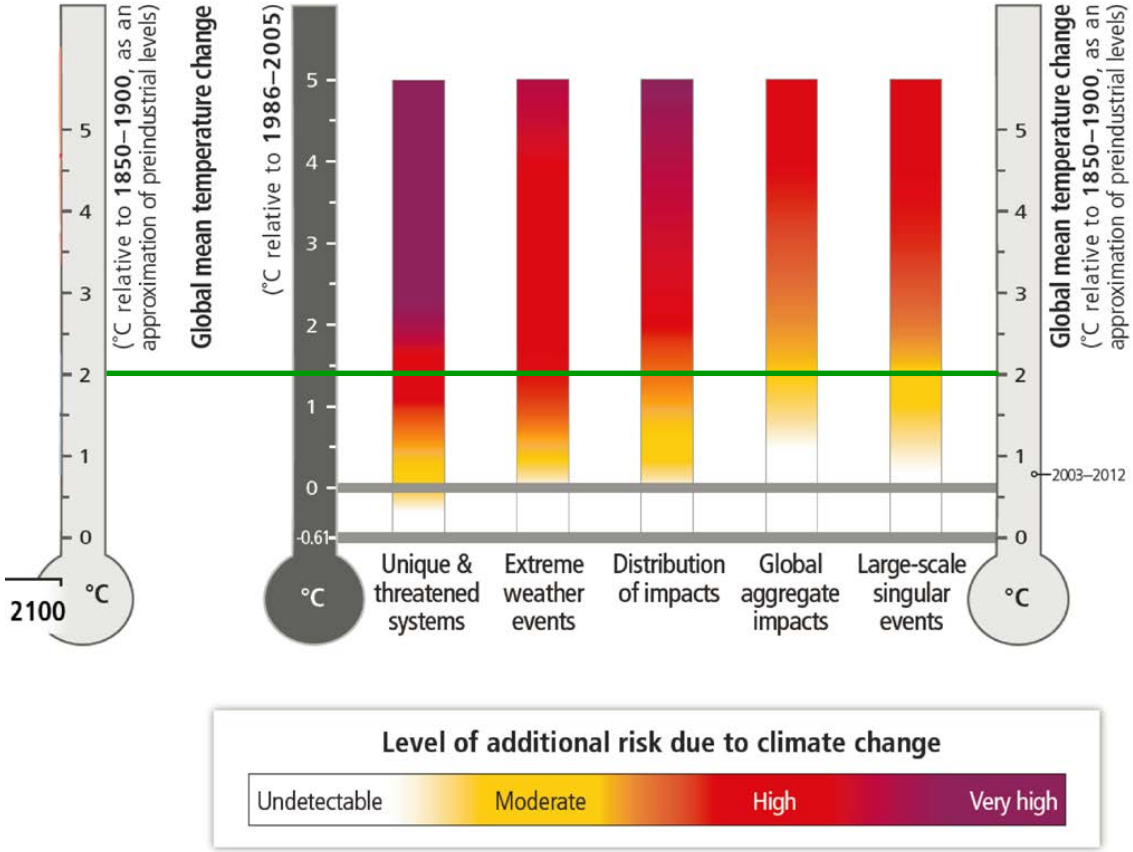
*All budgets are are subject to considerable uncertainty, see Edenhofer et al. (2016)

Risks from climate change depend on cumulative CO_2 emissions...



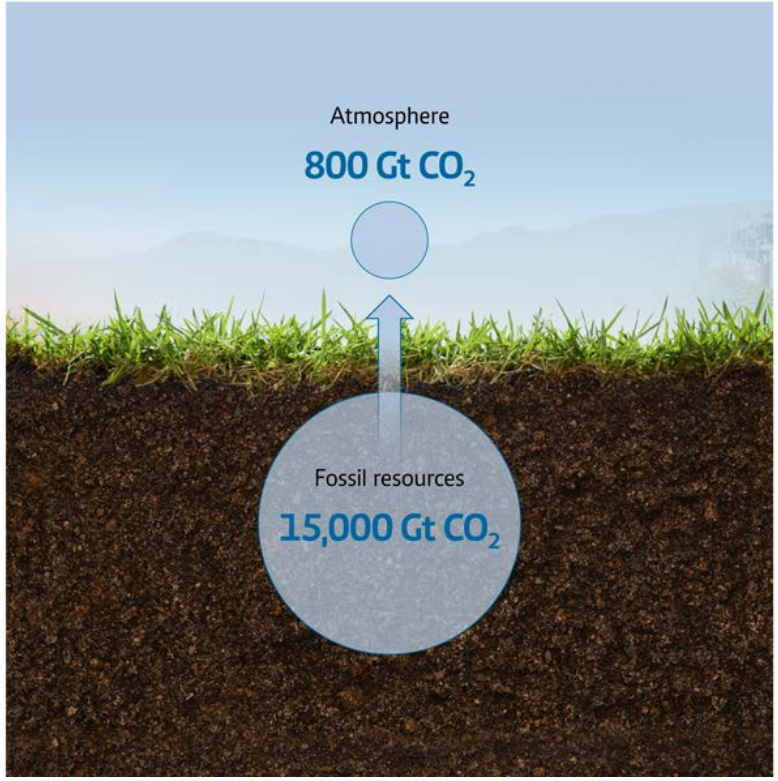
Based on SYR Figure SPM.10

Climate Projections and Associated Risks



Slide by H. J. Schellnhuber

The climate problem at a glance.

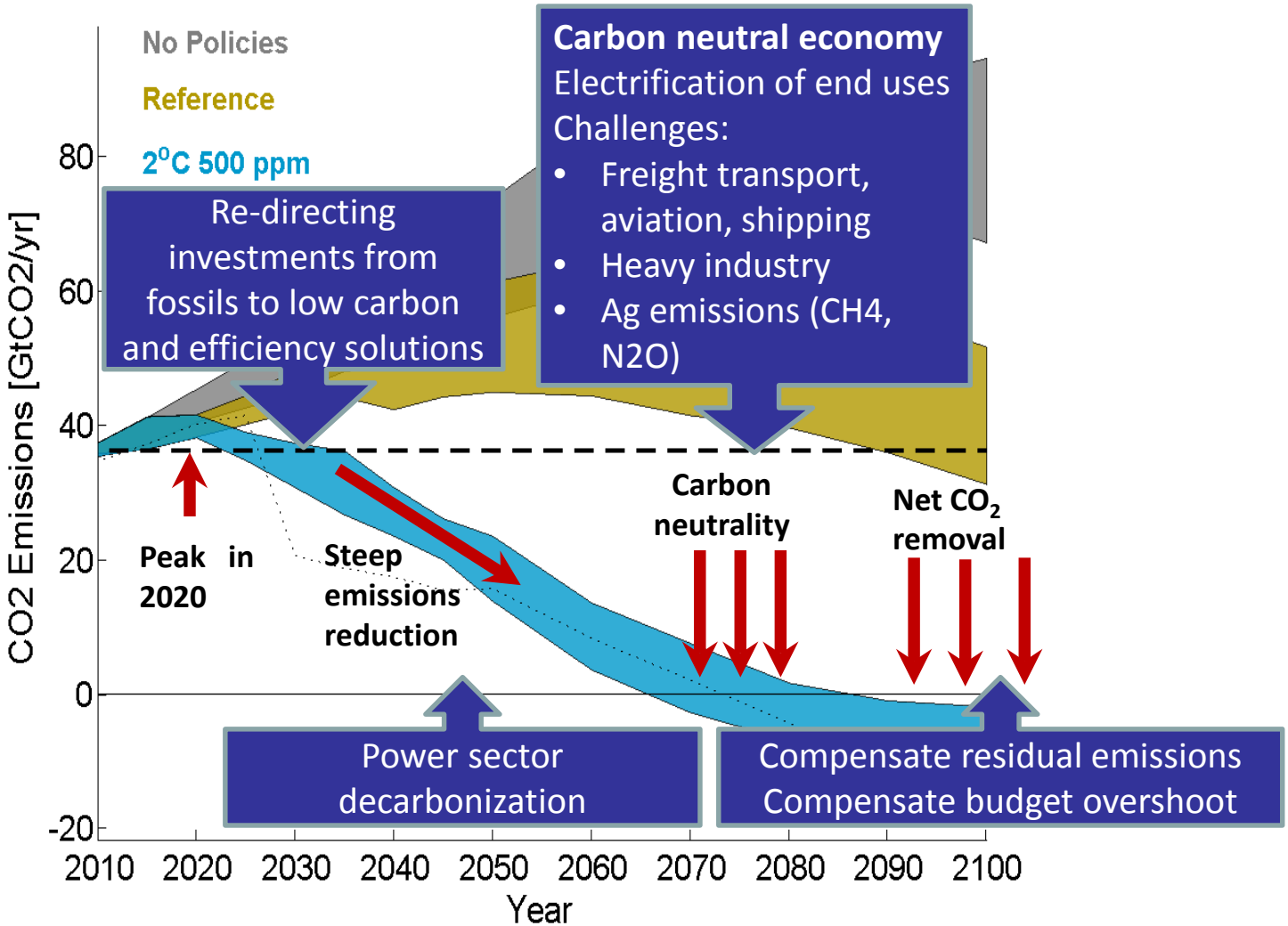


Resources and reserves to remain underground until 2100 (median values compared to BAU, AR5 Database)

Until 2100	With CCS [%]	No CCS [%]
Coal	70	89
Oil	35	63
Gas	32	64

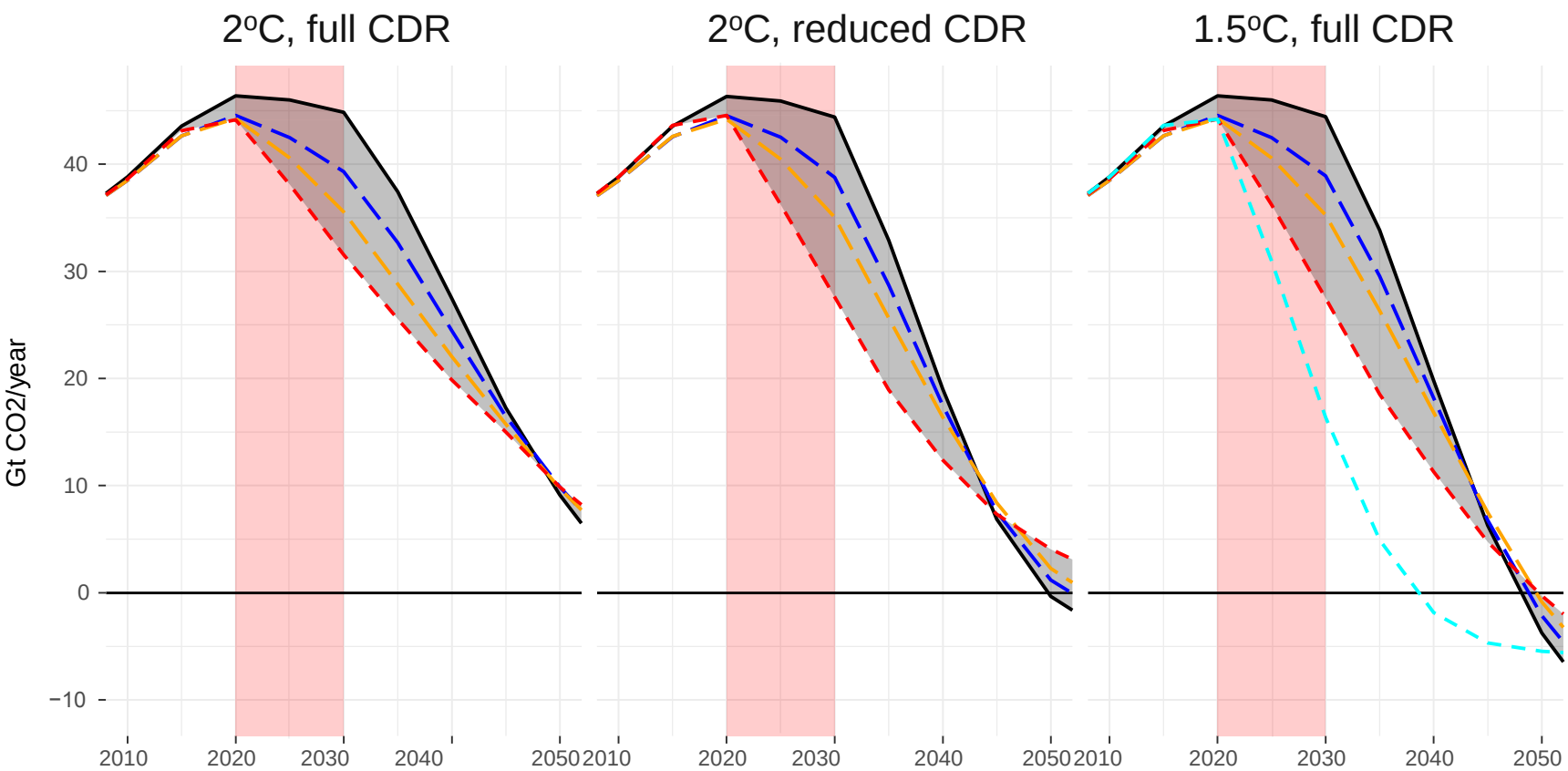
Bauer et al. (2014); Jakob, Hilaire (2015)

The Paris Agreement & the general structure of mitigation pathways

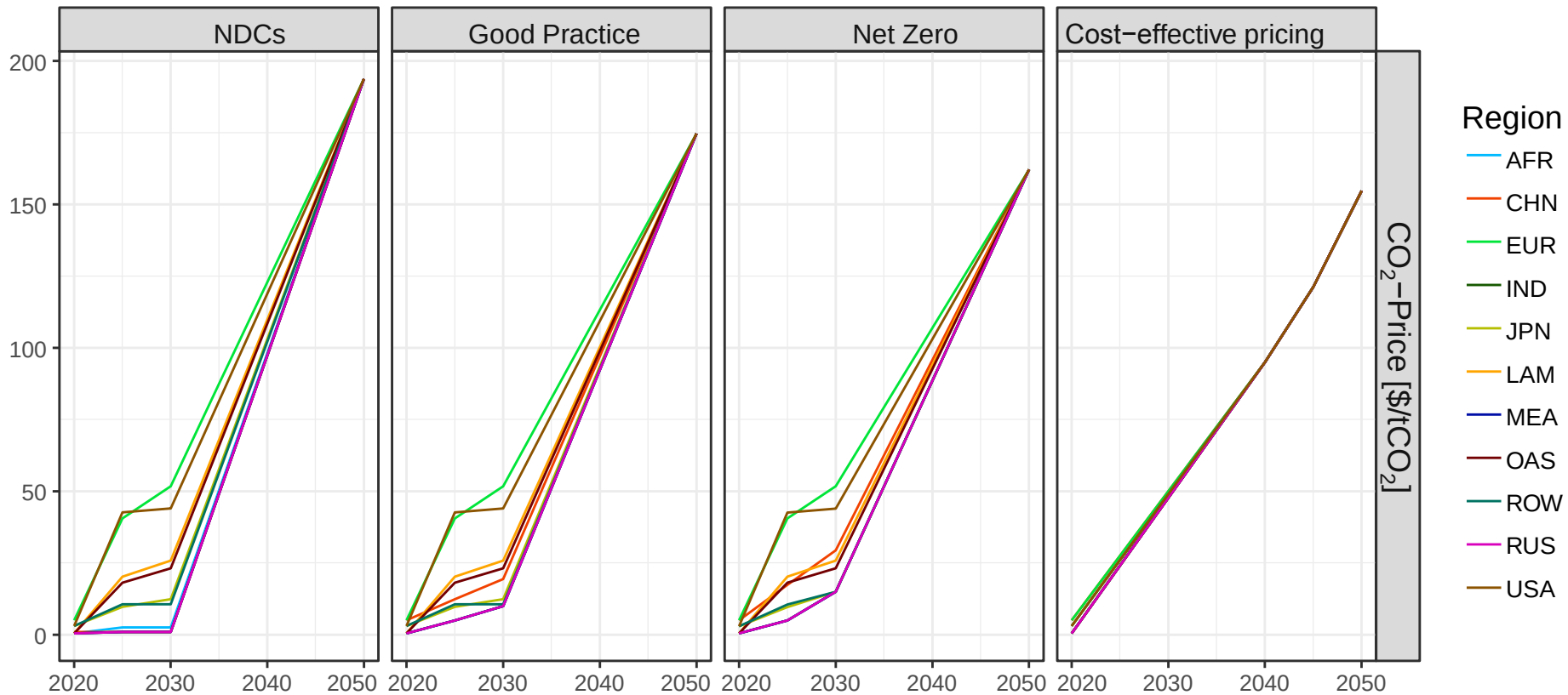


LIMITS Study: Kriegler, Tavoni et al. (2013) Clim Change Econ 04:1340008

Global CO_2 emissions



Regional carbon price convergence



Kriegler et al. (in review)

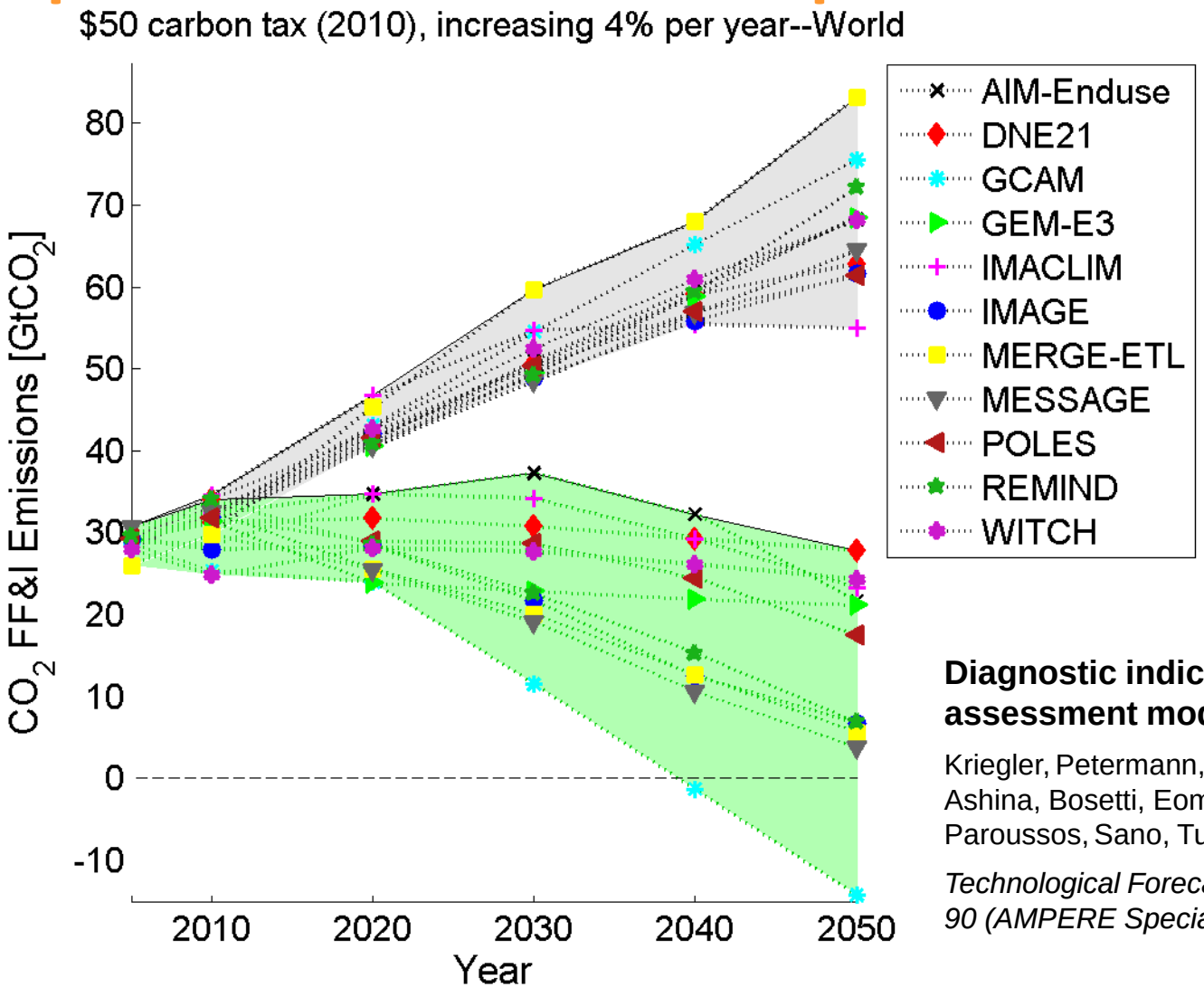
Cumulated consumption loss

Model diagnostics - Experiment

- Carbon price / emissions cap response is a key feature of energy-economy and integrated assessment models for climate policy
- (Global) carbon tax scenarios for diagnostic purposes, not intended to be policy-relevant.

Model name	Equilibrium type	Modeling approach	Time horizon	Low-carbon tech. variety
AIM-Enduse	Partial Equilibrium	Recursive dynamic	Until 2050	High
DNE21+	Partial Equilibrium	Intertemporal optimization	Until 2050	High
GCAM	Partial Equilibrium	Recursive dynamic	Until 2100	High
GEM-E3	General equilibrium	Recursive dynamic	Until 2050	Low
IMACLIM	General equilibrium	Recursive dynamic	Until 2100	Medium
IMAGE/TIMER	Partial Equilibrium	Recursive dynamic	Until 2100	High
MERGE-ETL	General equilibrium	Intertemporal optimization	Until 2100	High
MESSAGE-M	General equilibrium	Intertemporal optimization	Until 2100	High
POLES	Partial Equilibrium	Recursive dynamic	Until 2100	High
REMIND	General equilibrium	Intertemporal optimization	Until 2100	High
WITCH	General equilibrium	Intertemporal optimization	Until 2100	Low

Experiment: Emissions response to carbon tax

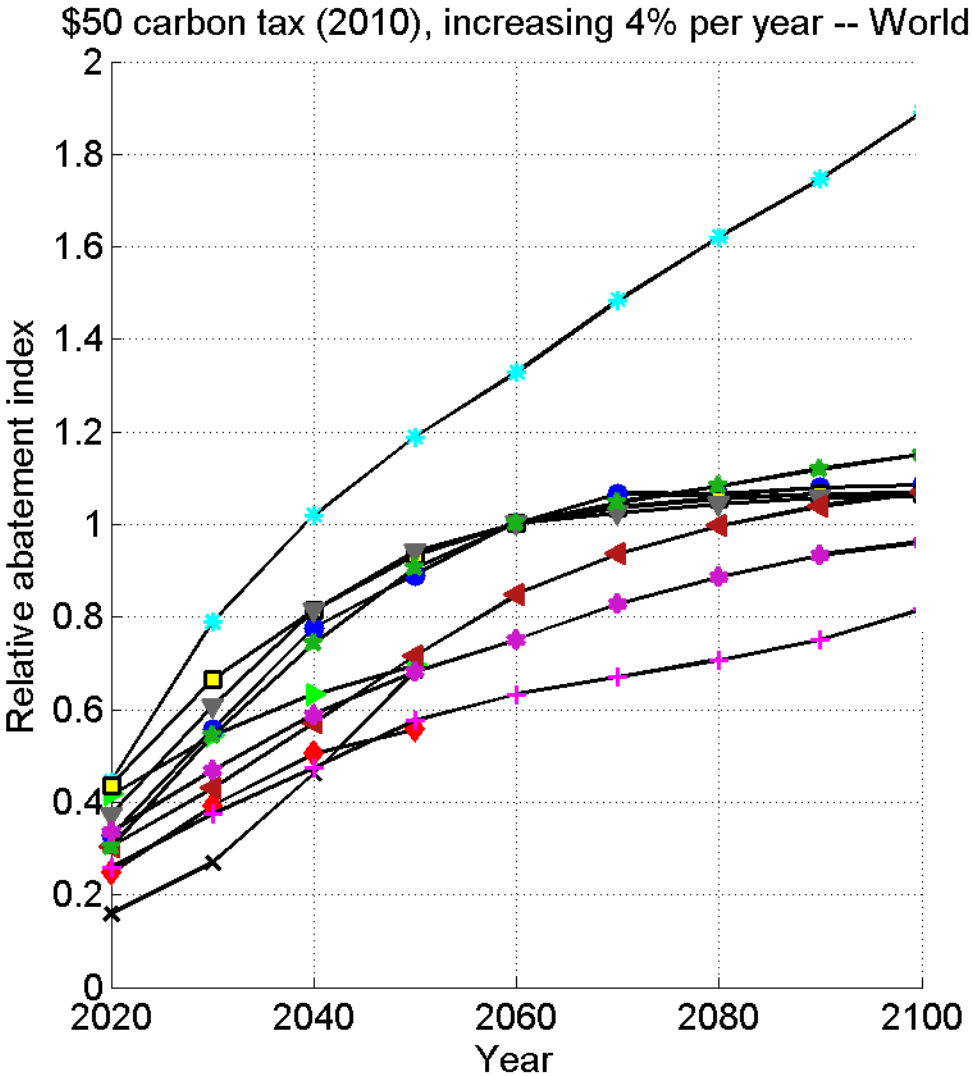


Diagnostic indicators for integrated assessment models of climate policy

Kriegler, Petermann, Krey, Schwanitz, Luderer, Ashina, Bosetti, Eom, Kitous, Méjean, Paroussos, Sano, Turton, Wilson, Van Vuuren

Technological Forecasting and Social Change 90 (AMPERE Special Issue), 2015

Relative abatement index

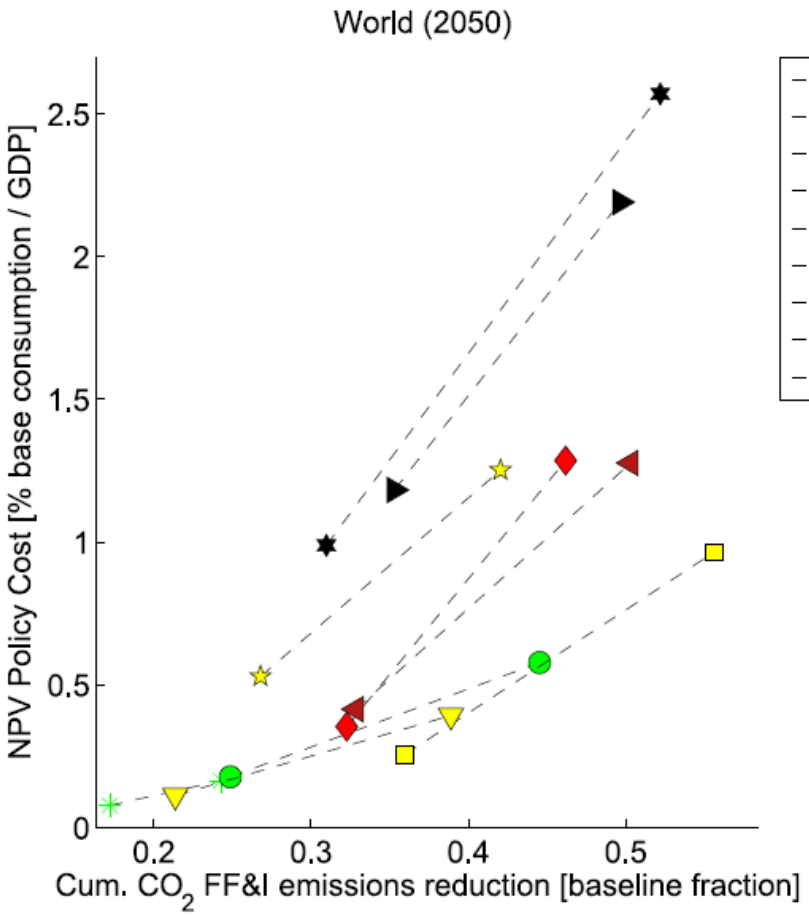


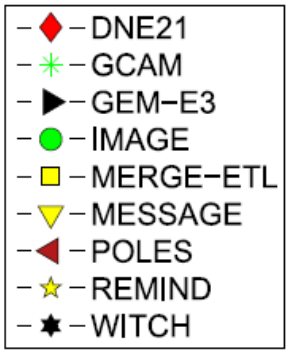
CO_2 emissions reductions (from fossil fuels & industry)
as a fraction of
baseline emissions

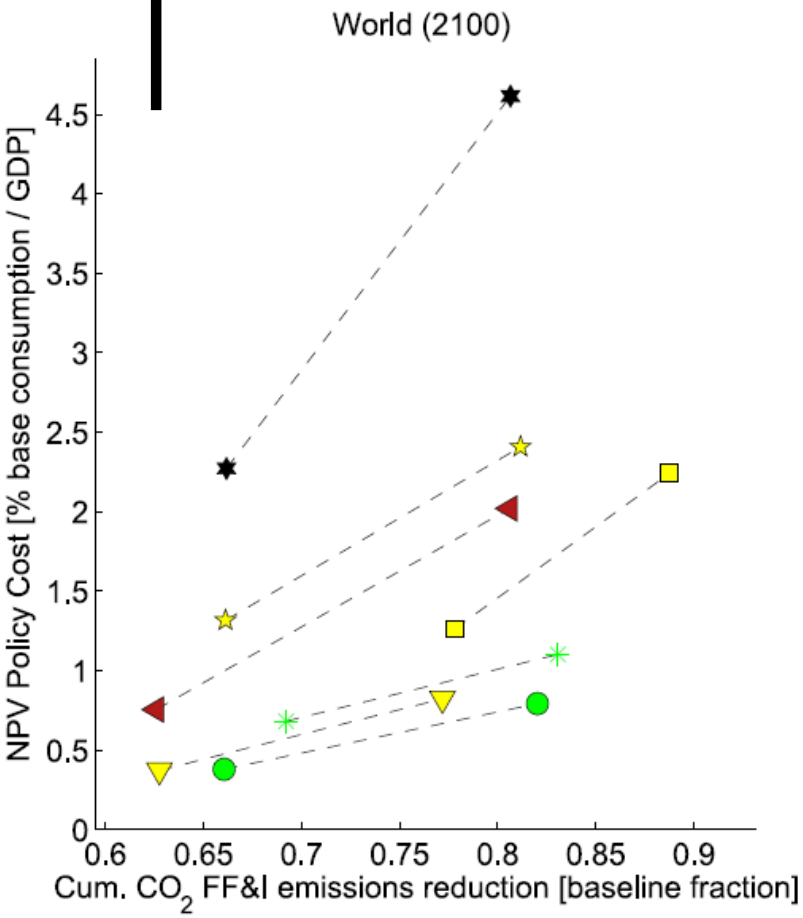
Mitigation costs in AMPERE WP3 study

(450/ 550 ppm CO2e)

IMACLIM: 7% (550 ppm),
18% (450 ppm) for 2010-2100







Model classification („fingerprints“)

Model	Relative Abatement Index	CoEI Indicator	Transformation Index (primary energy)	Cost per Abatement Value	Classification
AIM-Enduse	Low	Mixed	Mixed	TBD	PE – med response
DNE21+	Low	High	Low	Mixed	PE – low response
GCAM	[illegible]	Low	High	Medium	PE – high response
GEM-E3	[illegible]	High	TBD	Medium	GE – low response
IMACLIM	Low	High	Mixed	High	GE – low response
IMAGE	High	Low	Mixed	Low	PE – high response
MERGE-ETL	[illegible]	Low	High	Low	GE – high response
MESSAGE	[illegible]	Low	High	Low	GE – high response
POLES	Mix[illegible]	Mixed	Low	Low	PE – med response
REMIND	High	Low	High	Medium	GE – high response
WITCH	Low	High	Low	Medium	GE – low response

Highest cost

Lowest cost

Kriegler et al. (2015) Tech. For. & Soc. Change

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2. **The Social Costs of Carbon – Guiding Principle for Climate Policies**
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Social cost of carbon

Social cost of carbon (SCC) = damages due to an additional emission in monetary terms:

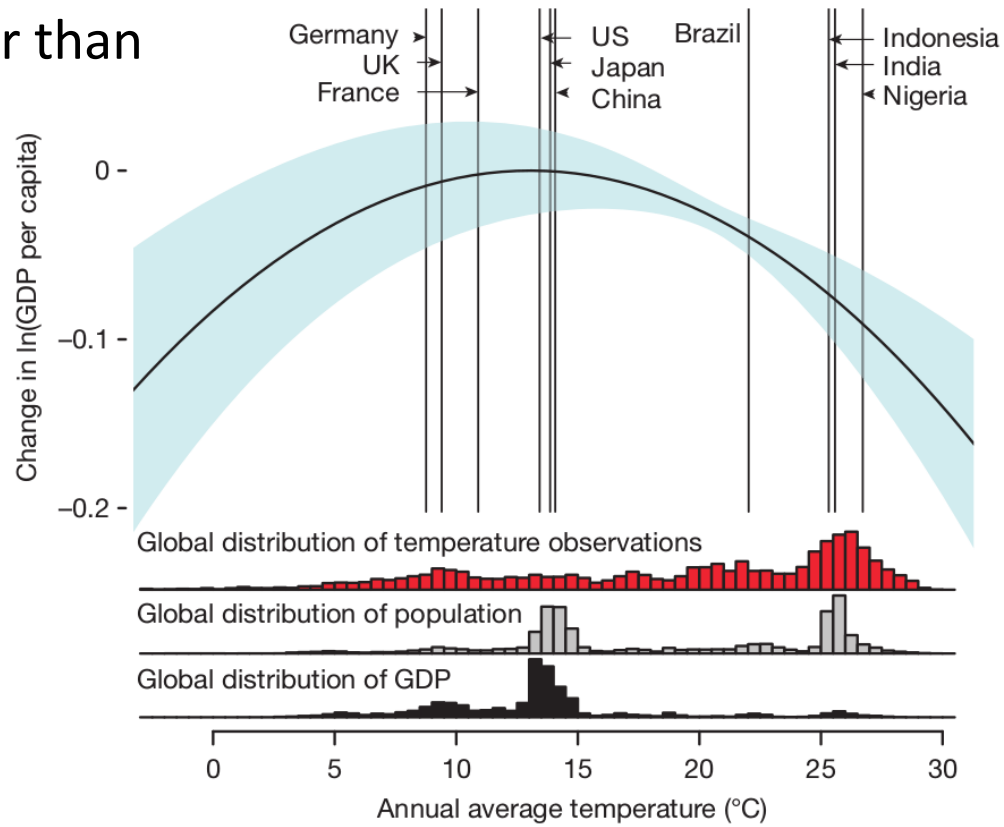
- Relevant in regulatory contexts (United States especially)
- Determined by
  - Climate impact estimates (descriptive)
  - Societal preferences, e.g. for equity across nations, generations, and income classes (normative)

$$\mathrm{SCC}_B = \frac{\sum_{t=1}^{T}\sum_{r=1}^{R}\Delta C_{tr}\frac{\partial W}{\partial C_{tr}}}{\frac{\partial W}{\partial C_{1B}}}$$

Main findings: Aggregate estimates

Aggregate estimates much larger than bottom-up studies suggest:

What explains the difference?



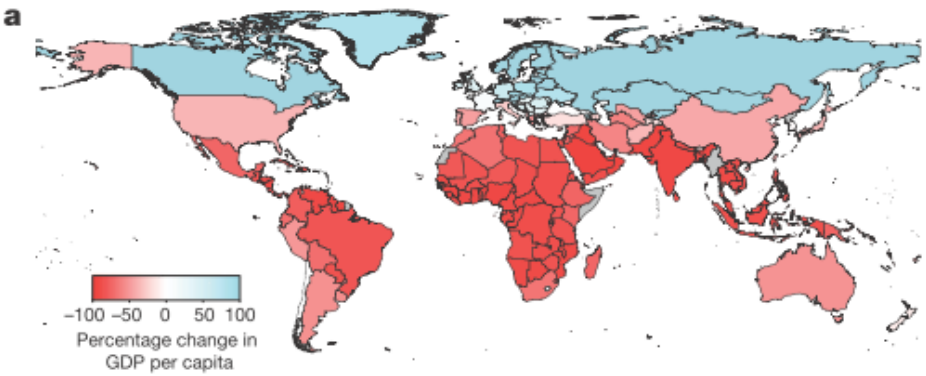
Hypothesis:
Direct impacts on human physiology & economic growth

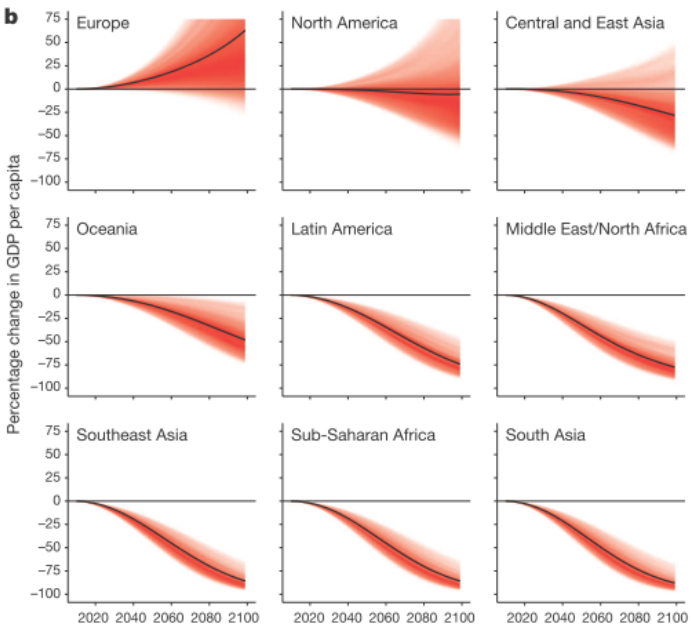
Figure from Burke et al. (2015)

LETTER

Global non-linear effect of temperature on economic production

Marshall Burke[1,2]*, Solomon M. Hsiang[3,4]* & Edward Miguel[4,5]





Nature, doi:10.1038/nature15725

Social cost of carbon: Inequalities

Three sources of inequality matter:

- Existing national and international income inequalities
- Climate impacts often regressive, as
  - poor countries warmer
  - adaptation harder when poor
  - the poor work in more exposed sectors
  - poor areas exposed to higher pollution
- Climate policy itself can be regressive or progressive

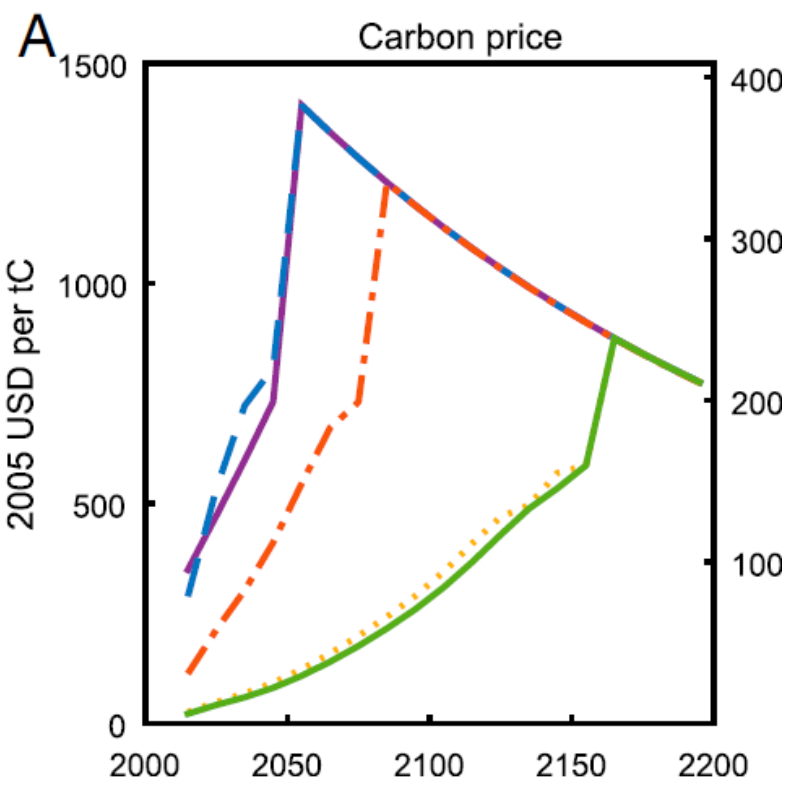
→ If inequalities are not addressed by redistribution, they strongly influence optimal climate policy

Social cost of carbon: Influence of inequality

Dennig et al. (2015):

Models often operate on coarse scale with global/regional representative agent

- subnational inequality in income and damages: no transfers
- equal regional consumption: unlimited, first-best transfers



Social cost of carbon: National institutions

1. Global governance level: determines optimal climate policy with national optimal carbon taxes without international transfers
2. National governance level: determination of distribution between households j in country

$$\max \sum_{t=0}^{T} \frac{1}{(1+\rho)^t} \sum_{i=1}^{N} \boxed{\sum_{j=1}^{h_i^t}} w_{ij}^t u_{ij}^t$$

Optimal climate policy

$$s.t. \sum_{j=1}^{h_k} L_{kj}^t = 0$$

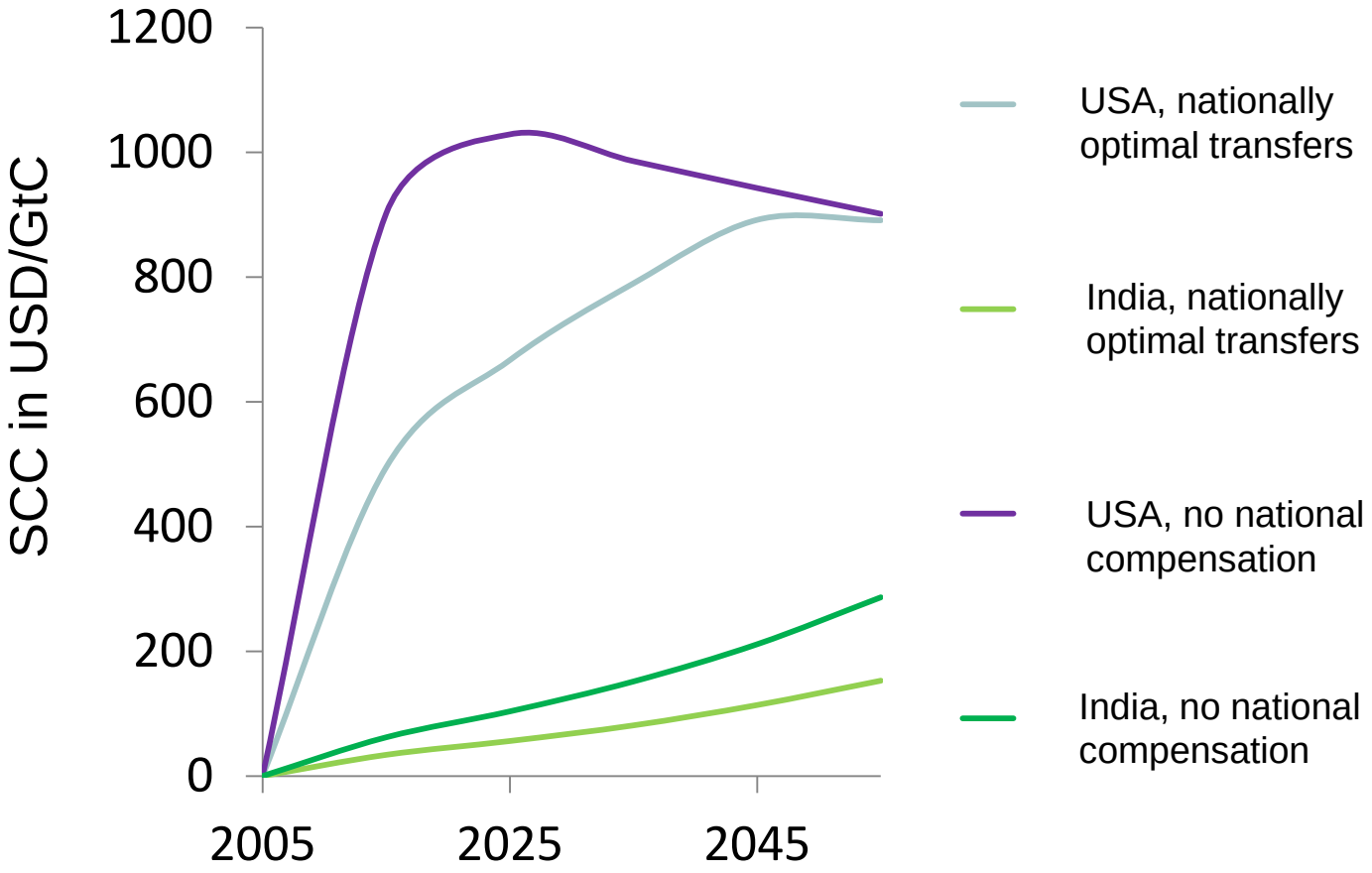
$$F_{kl}^t(\cdot) = 0$$

National distribution policy

Based on Kornek et al.(2017)

Social cost of carbon: Numerical example

Not addressing in-country inequalities strongly increases the SCC.



Based on Kornek et al.(2017)

Social cost of carbon: Inequalities

National:

- Implementation of climate policy into fiscal and tax policy decisive for efficiency and distributional impacts (Siegmeier et al. 2015)
- Revenue from climate policy can eliminate regressive effects of climate policy (Klenert et al., 2016)

International:

- International transfers influence optimal climate policy (Kornek et al., 2017)

Conclusion: Like the 2°C target, SCC are determined by many value judgements. However, in contrast to the 2°C target, there is no consensus on SCC.

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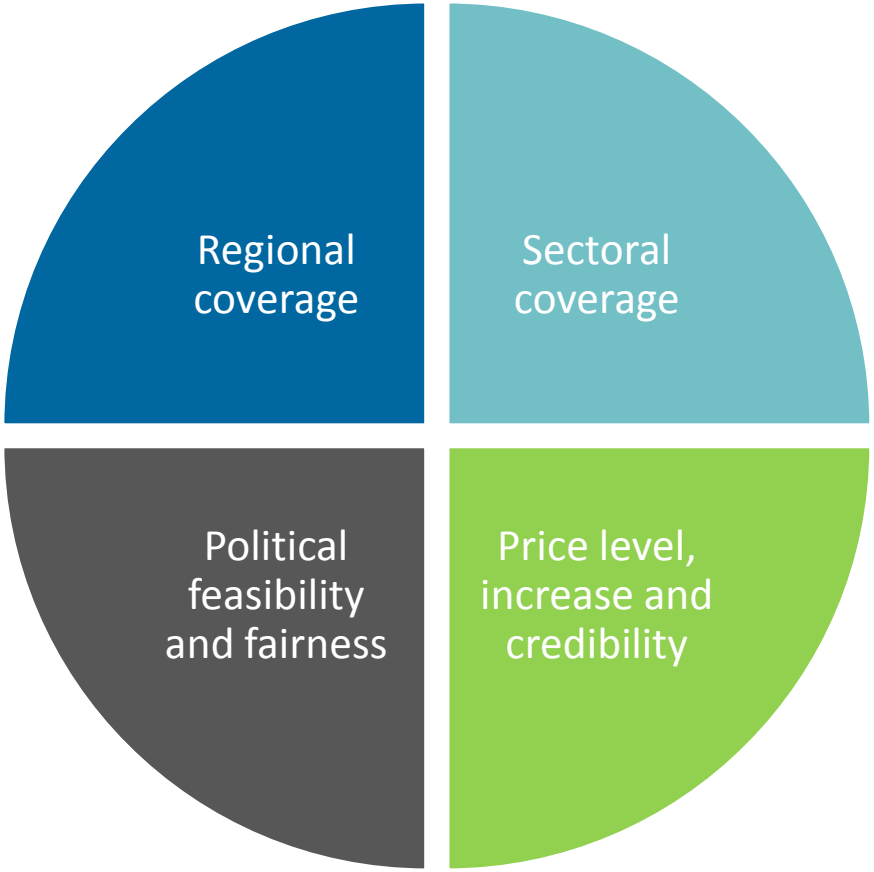
3. **Implementation Challenges for National Governments**

Why a carbon price is important

- A carbon price counteracts the oversupply of fossil fuels.
- Due to the fact that fossil fuels are largely subsidized the negative price is at ~150 €/tCO_2 presently.
- A carbon price changes the relative prices:
  - Relative prices of the renewables are often higher in emerging countries. High costs of capital are a significant problem.
  - The historic and present fluctuations of the oil price show transformative power of energy prices.
  - Climate policy would not have to fight constantly against market forces.
  - If interest rates rise, technological progress of the renewables is undone at least partly.
- Carbon price as hedging strategy, if price of renewables is not reduced fast enough.

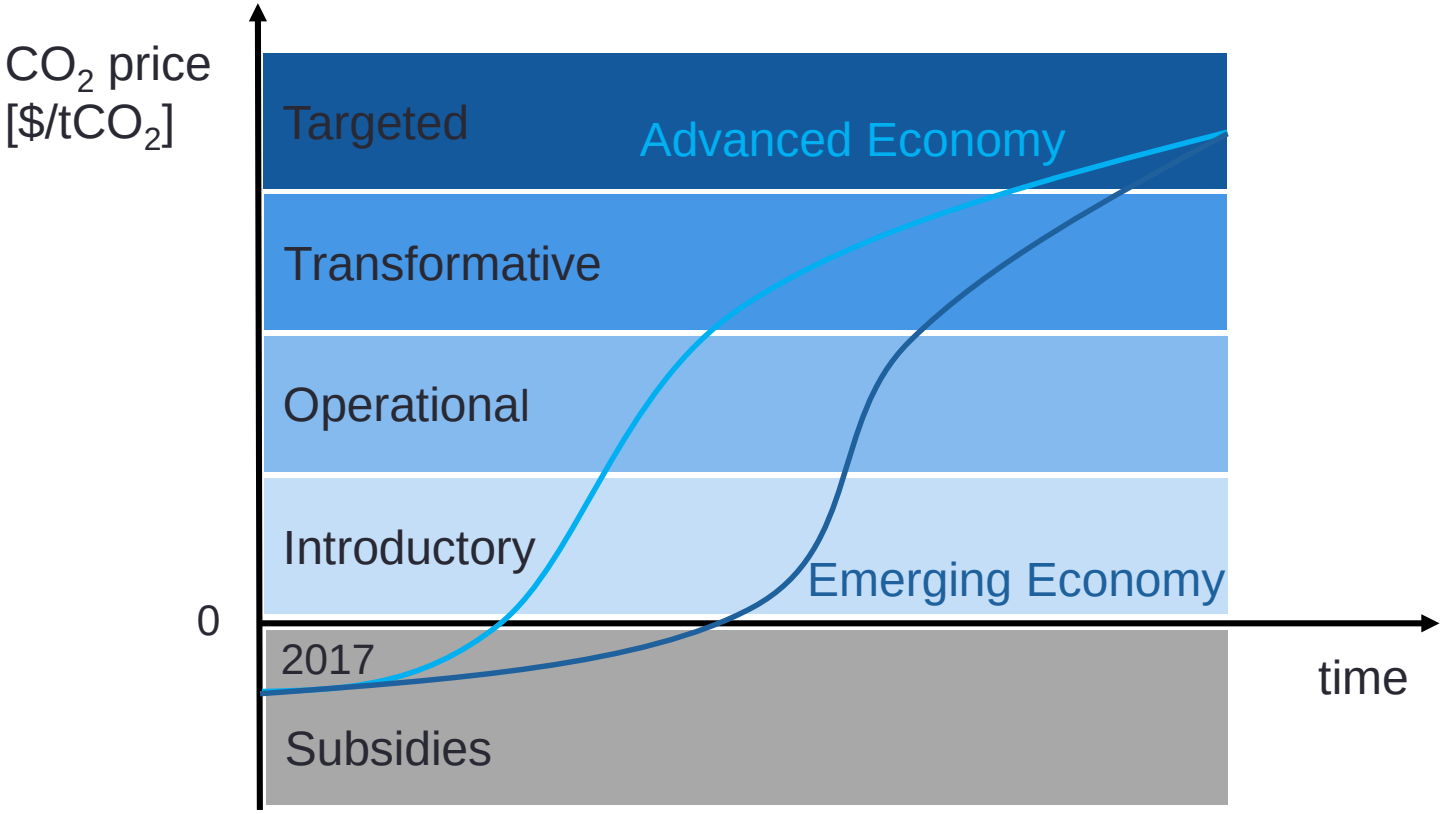
Four dimensions for effective carbon prices



Four dimensions for effective carbon prices

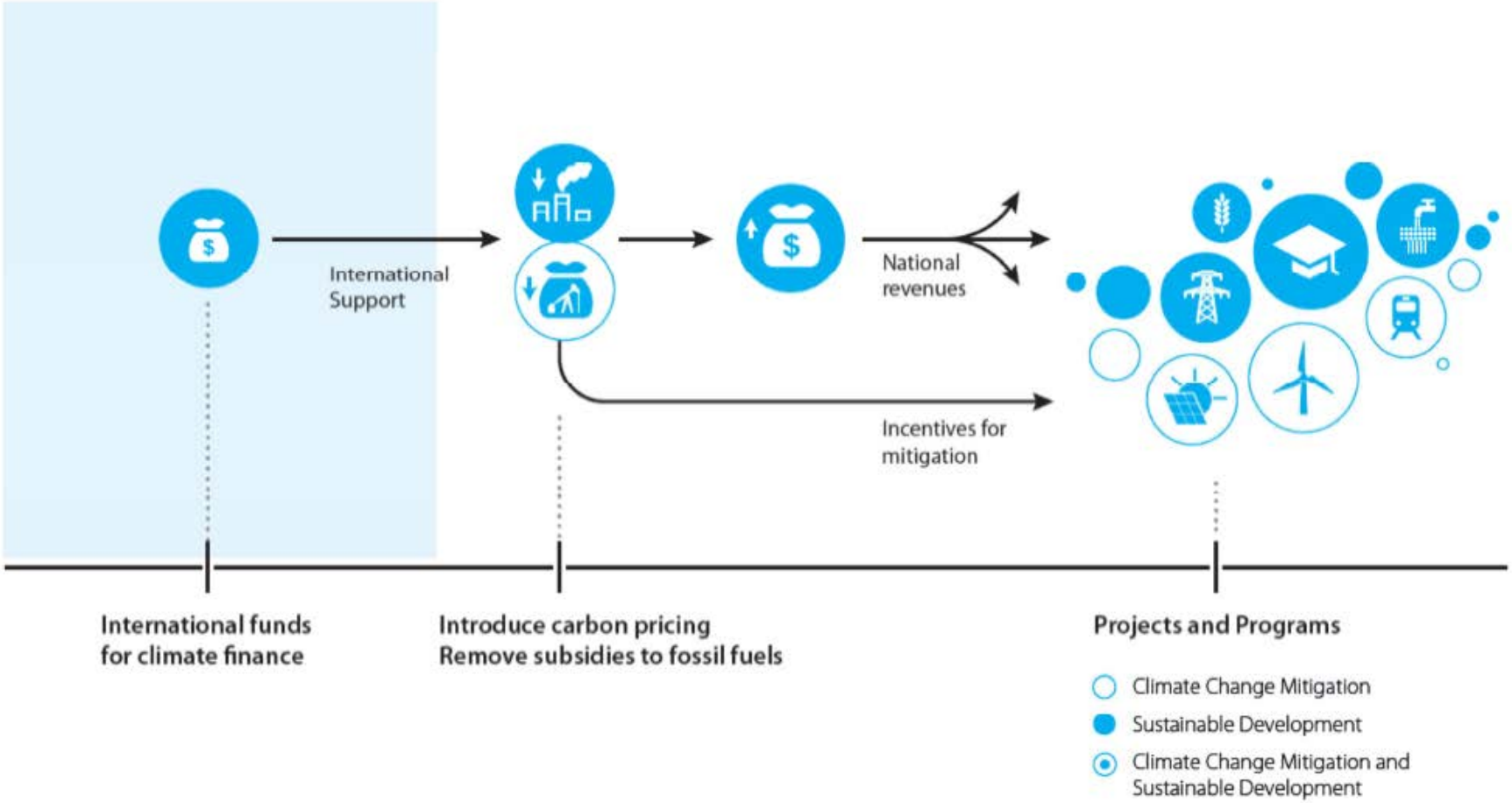
Carbon pricing in the G20 according to the level of development

Phasing out fossil fuel subsidies and carbon pricing (with taxes or emission trading systems) is essential



Own presentation; based on @CDP

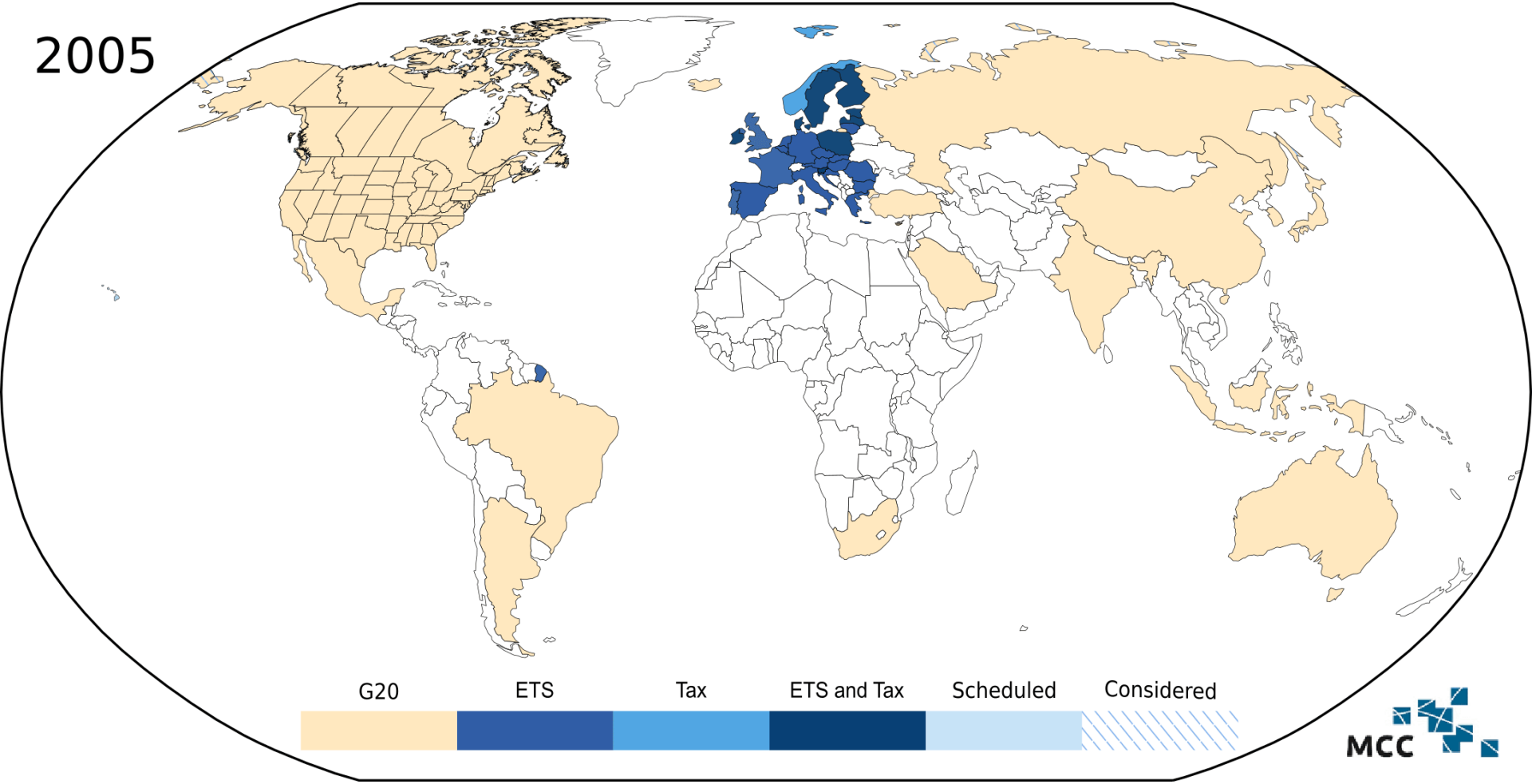
A proposal to rethink international climate finance



Steckel et al. (2017) WIREs CC

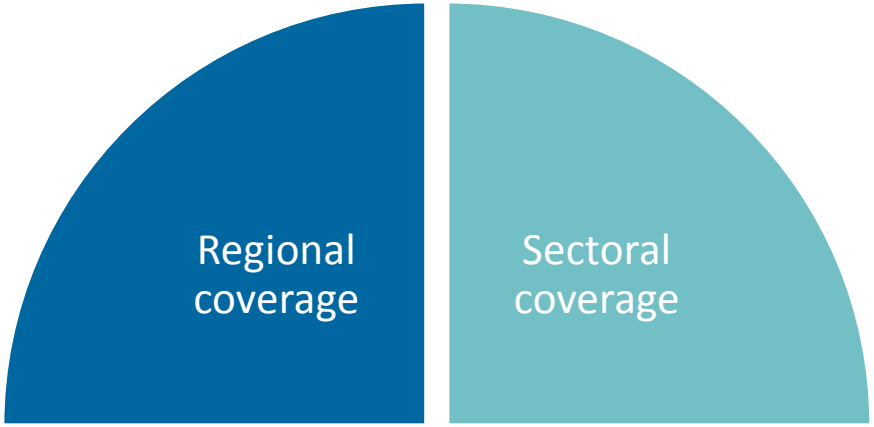
Carbon Pricing in G20 Countries

2005



Own presentation, based on Worldbank (2016)

Four dimensions for effective carbon prices



Sectoral Coverage

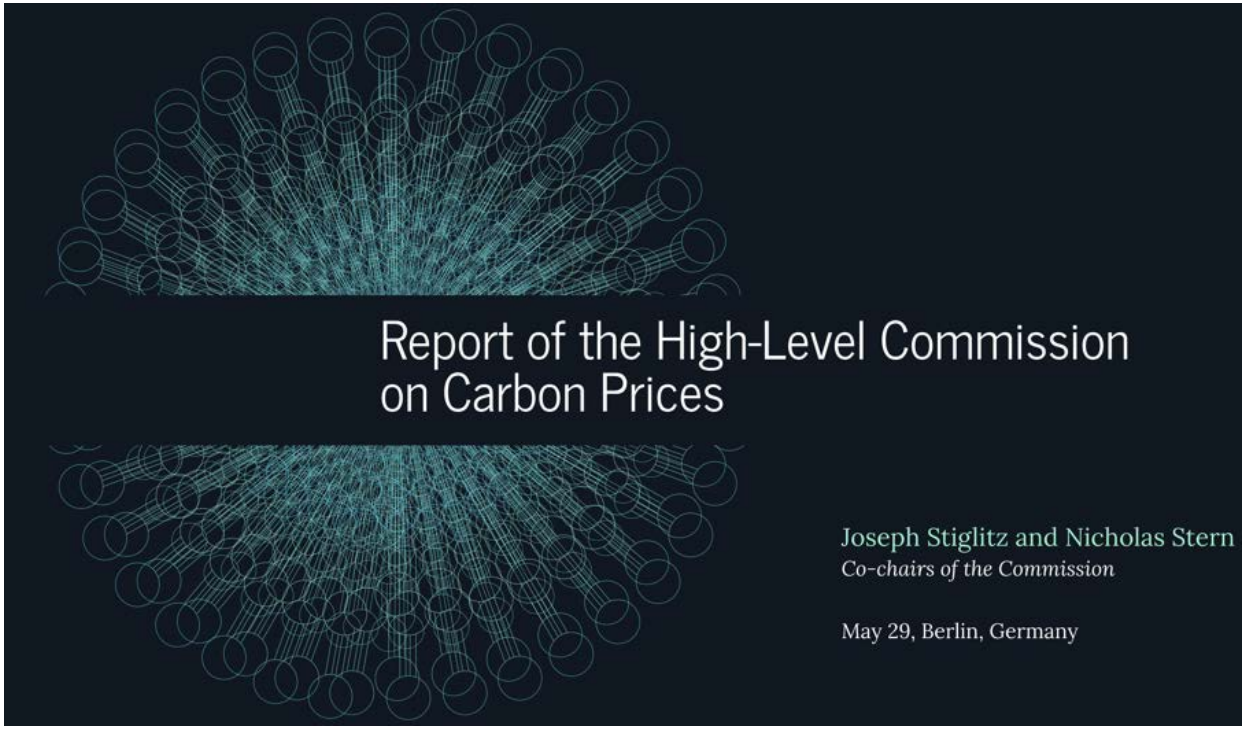
SECTORS	INDUSTRY	POWER	BUILDINGS	TRANSPORT	WASTE	AVIATION	FORESTRY
ASIA PACIFIC							
Beijing	●	●	●	●			
China	●	●				●	
Chongqing	●	●					
Fujian	●	●				●	
Guangdong	●	●				●	
Hubei	●	●					
New Zealand	●	●	● *	● *	●	● *	●
Republic of Korea	●	●	●	●	●	●	
Saitama	●		●				
Shanghai	●	●	●			●	
Shenzhen	●	●	●	●			
Tianjin	●	●					
Tokyo	●		●				
EUROPE & CENTRAL ASIA							
EU ETS	●	●				●	
Switzerland	●						
NORTH AMERICA							
California	●	●	● *	● *			
Ontario	●	●	● *	● *			
Québec	●	●	● *	● *			
RGGI		●					

* Sectors represent upstream coverage

ICAP (2017)

Four dimensions for effective carbon prices

Report of the High-Level Commission on Carbon Prices



Conclusion of the Stiglitz-Stern Commission

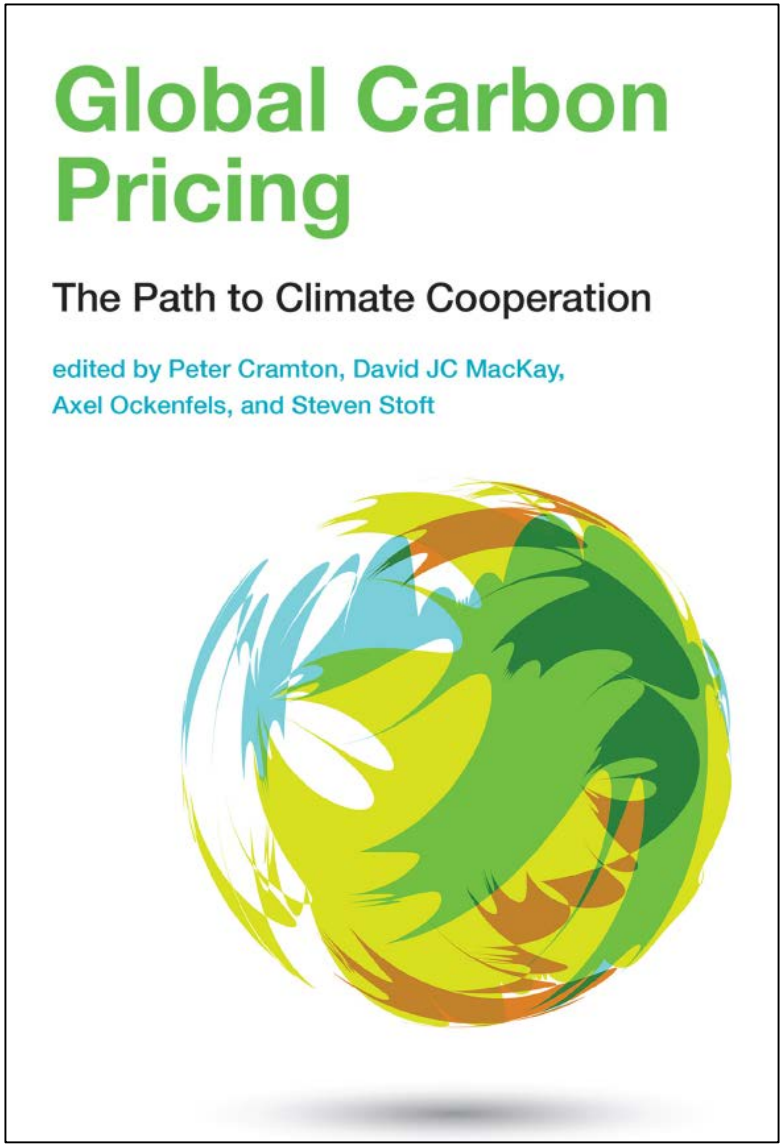
- Based on the analysis of three approaches:
  technical roadmaps, national roadmaps, global models

- Carbon price is nesessary to implement the Paris Agreement:
  40-80 \$/t CO_2 until 2020 and 50-100 \$/t CO_2 until 2030

- Assuming that the carbon price is complemented by measures and policies such as efficiency standards, R&D, urban development, favorable investment climate, etc.

- Emphasis on the relevance of the revenue side. Use for the reduction of other taxes, investments in clean infrastructure, etc.

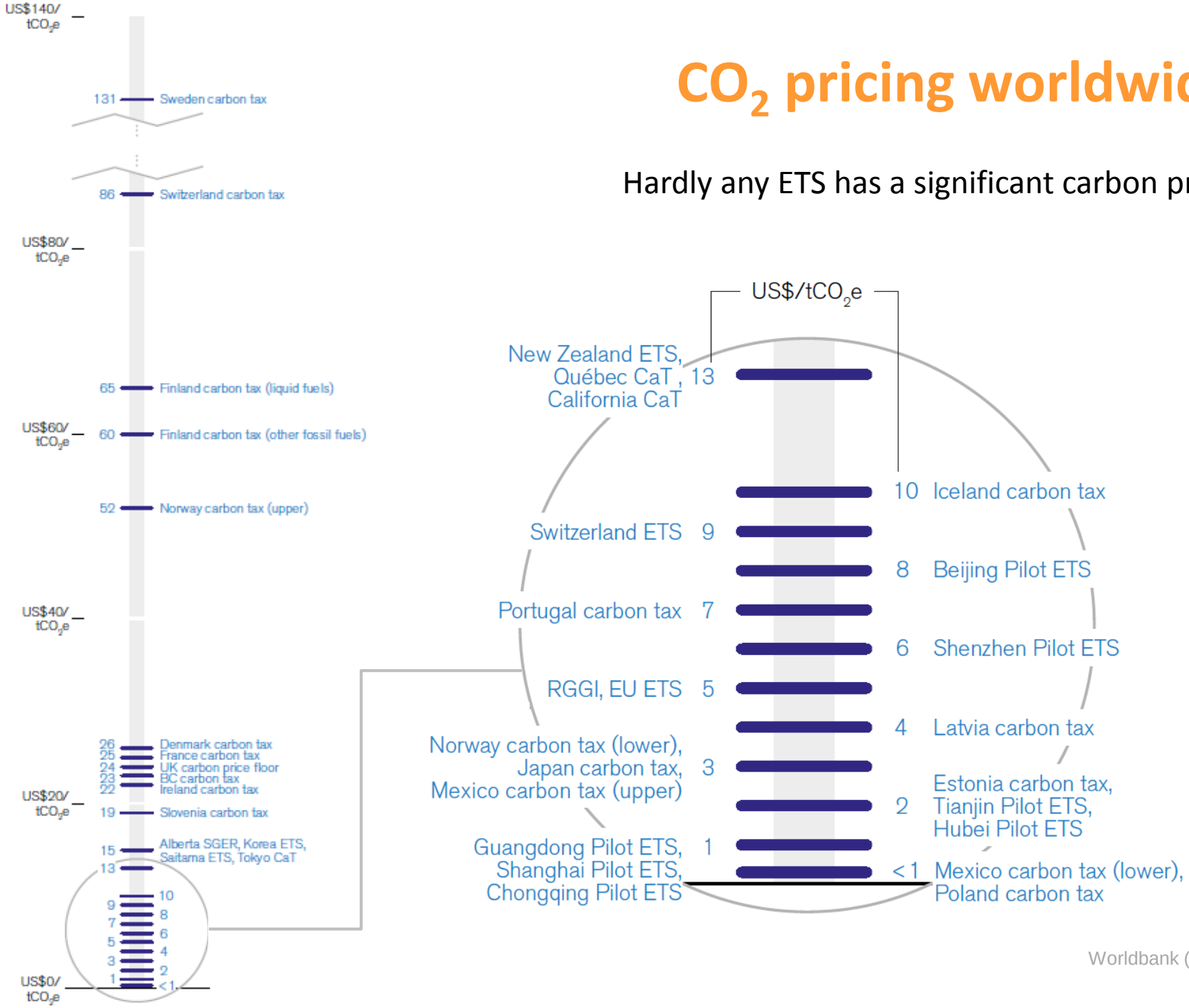
Stiglitz, Stern et al. CPLC (2017)



www.cramton.umd.edu/papers2015-2019/cramton-mackay-ockenfels-stoft-global-carbon-pricing.pdf

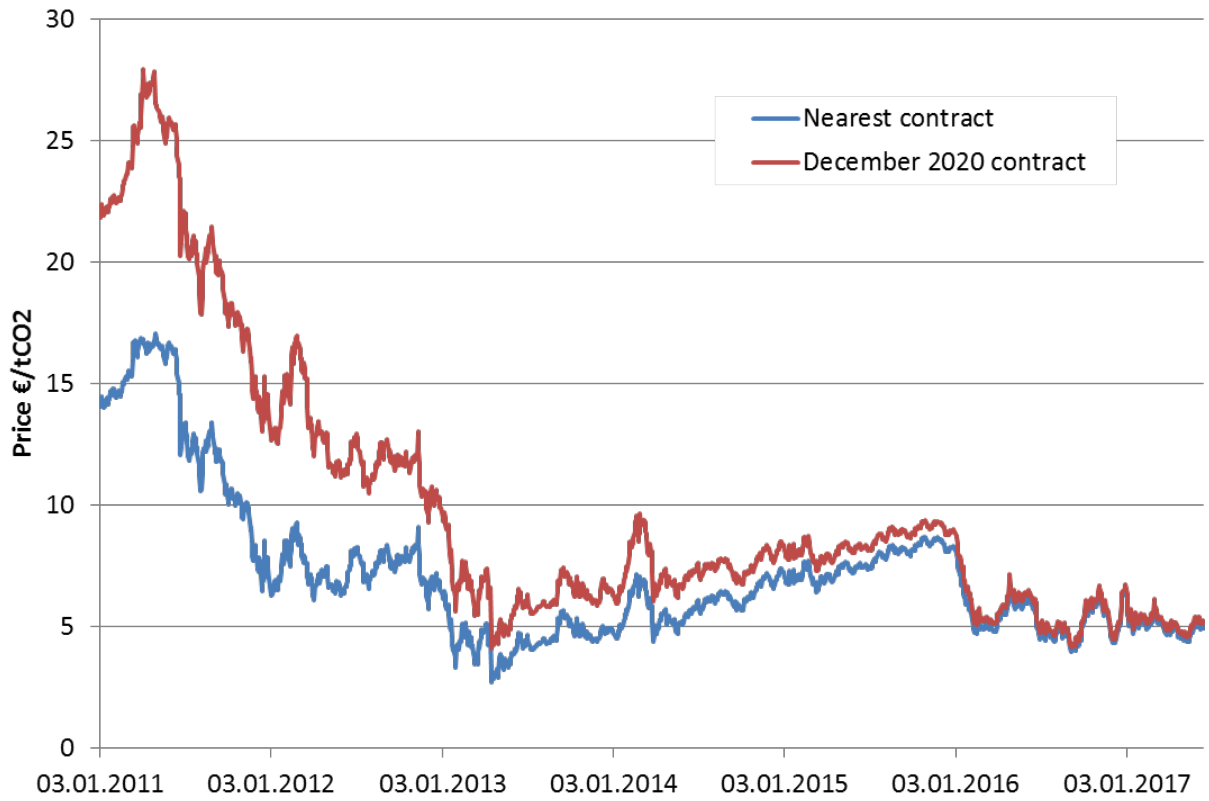
CO_2 pricing worldwide

Hardly any ETS has a significant carbon price.



Worldbank (2016)

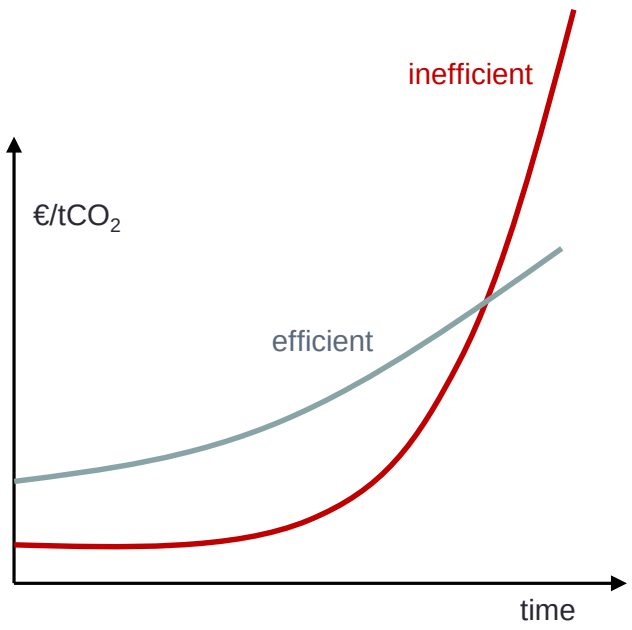
ETS lacks dynamic cost efficiency.



ICE Futures Europe

- Falling CO_2 price
- No increase expected before 2020
- Market Stability Reserve will be implemented, but effect might be limited

EU ETS: Reason for concern

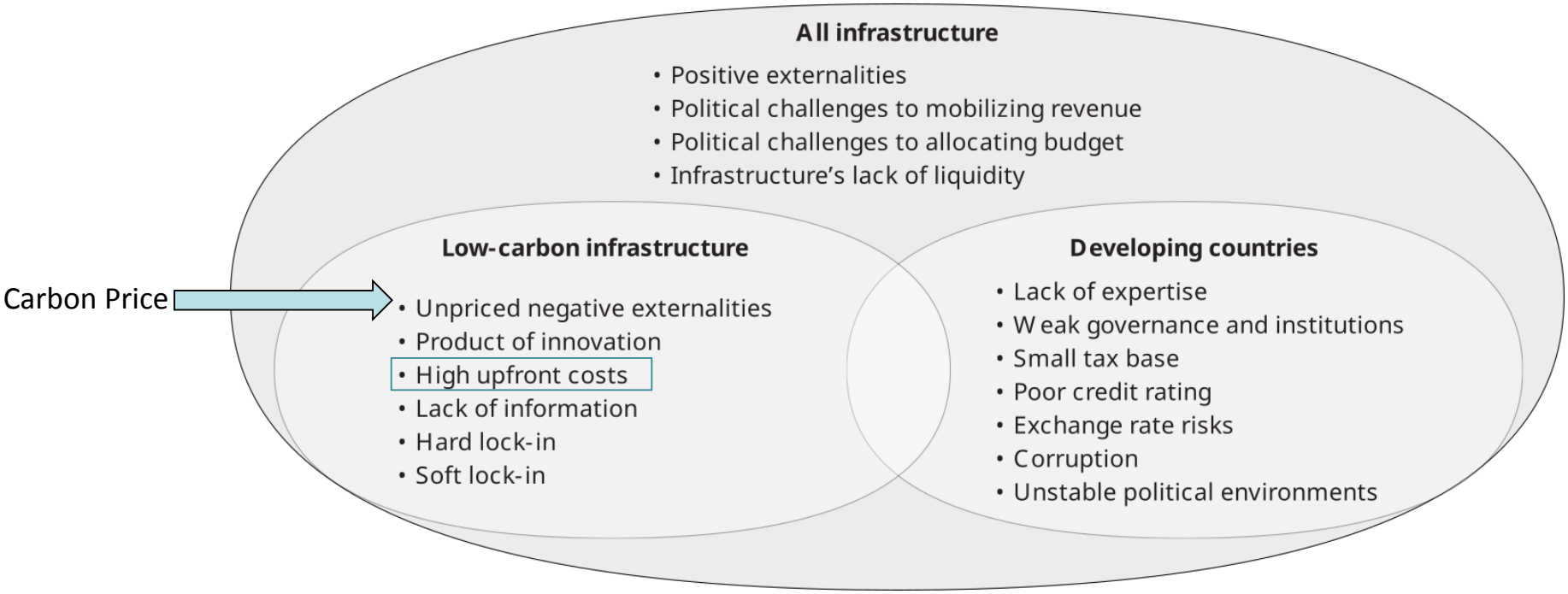


- Persistently low EUA price might lead to „hockey stick“ price curve
- Escalating price will induce future downward adjustment of the cap
- Concern over self-fulfilling prophecy & strategic gaming of the system

Salant (2016), Koch et al. (2016), Acworth et al. (2017), Fuss et al. (2017)

Barriers beyond lack of carbon pricing

…to financing low-carbon infrastructure

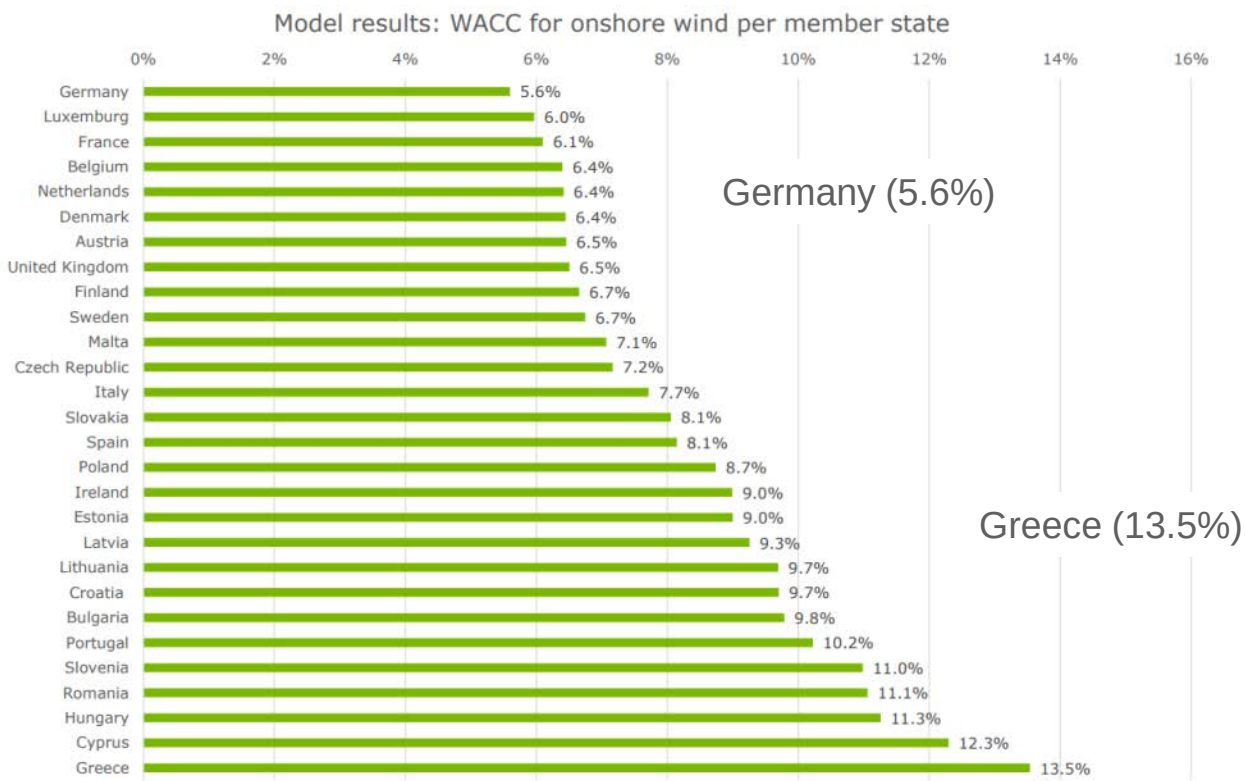


Based on Granoff et al. (2015), NCC

Cost of capital for renewable energy

Weighted average cost of capital (WACC) for…

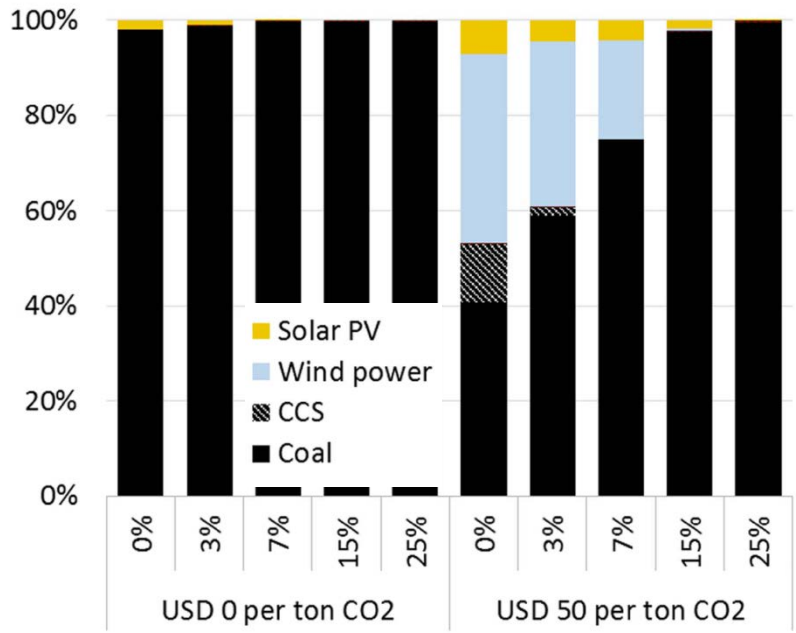
(b) Onshore wind in Europe



Noothout et al. (2016)

Cost of capital as a barrier to transition

Fig: Decarbonization of the energy sector for a range of weighted average cost of capital



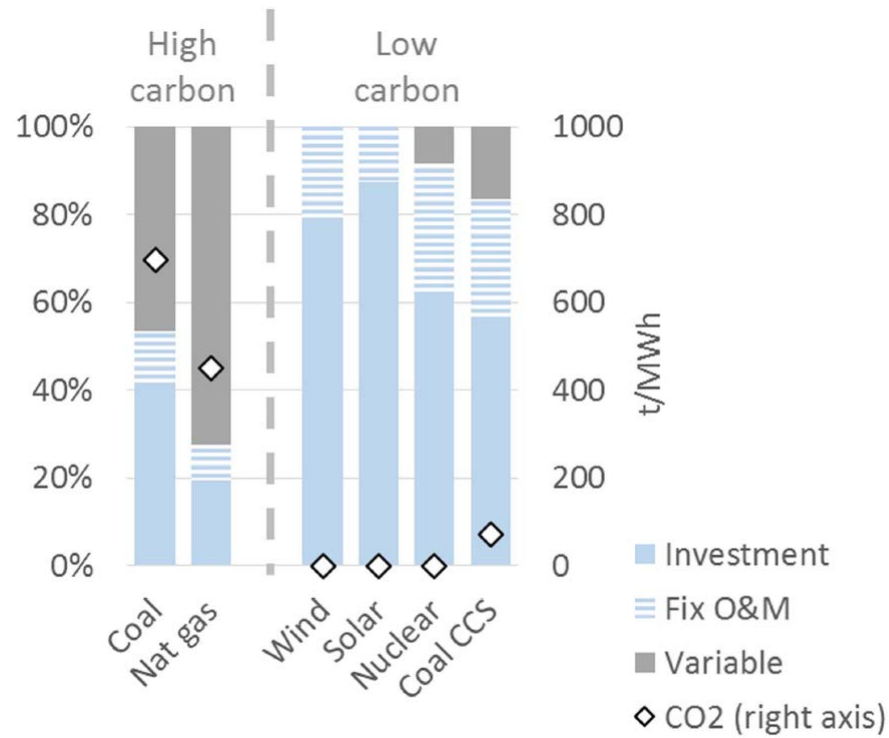
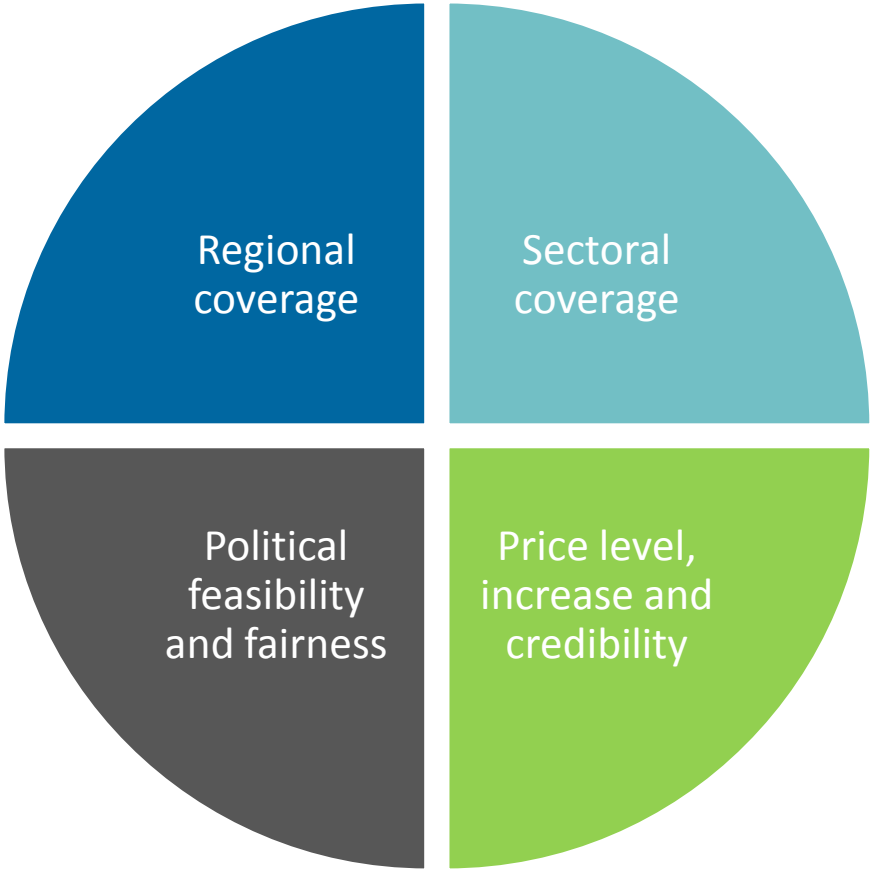


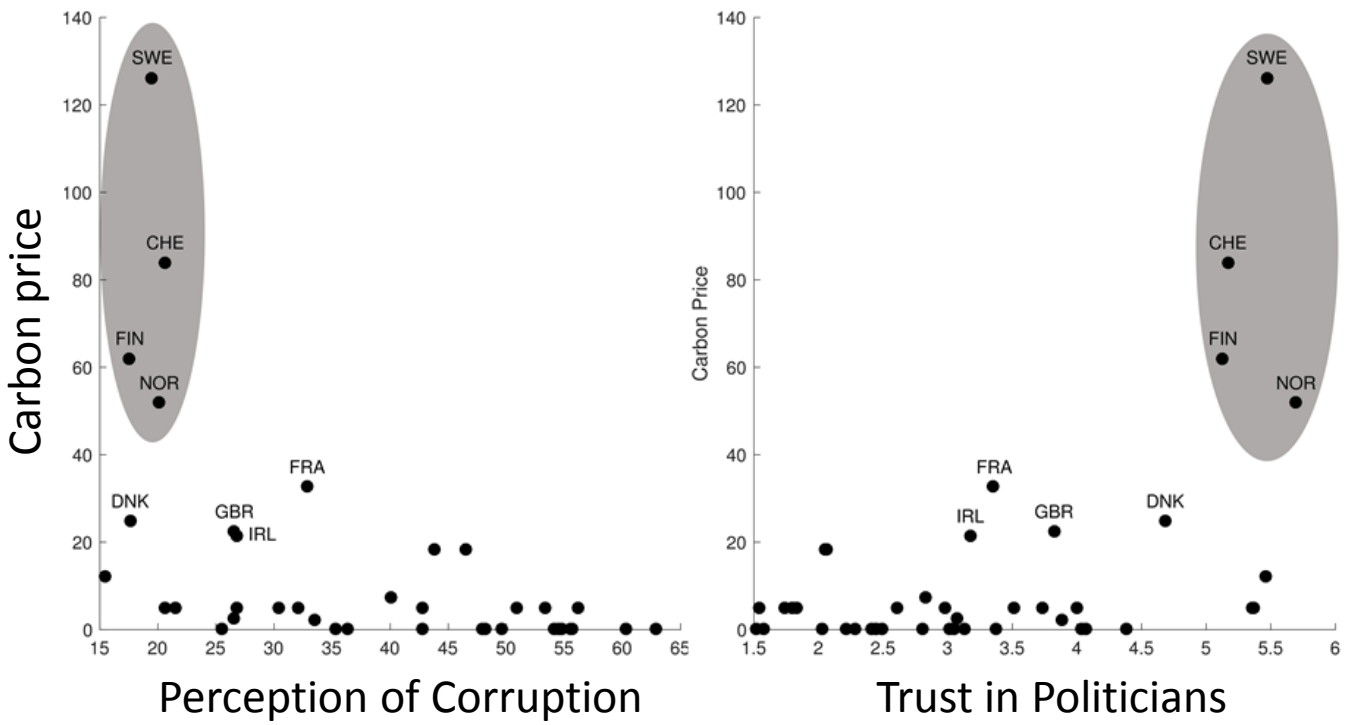
Fig: High capital intensity of low-carbon energy sources

Hirth und Steckel (2016), ERL

Four dimensions for effective carbon prices



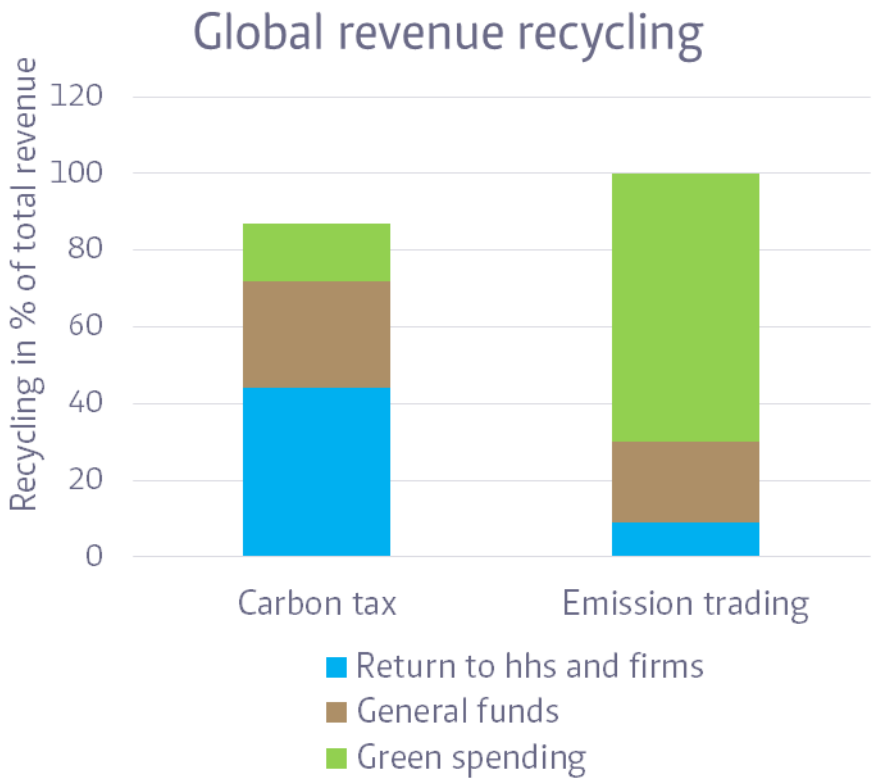
A high carbon price is only implemented in countries that are relatively high-trust and low-corruption



Klenert et al. (in prep.)

Global Revenue Potential and Recycling (2013)

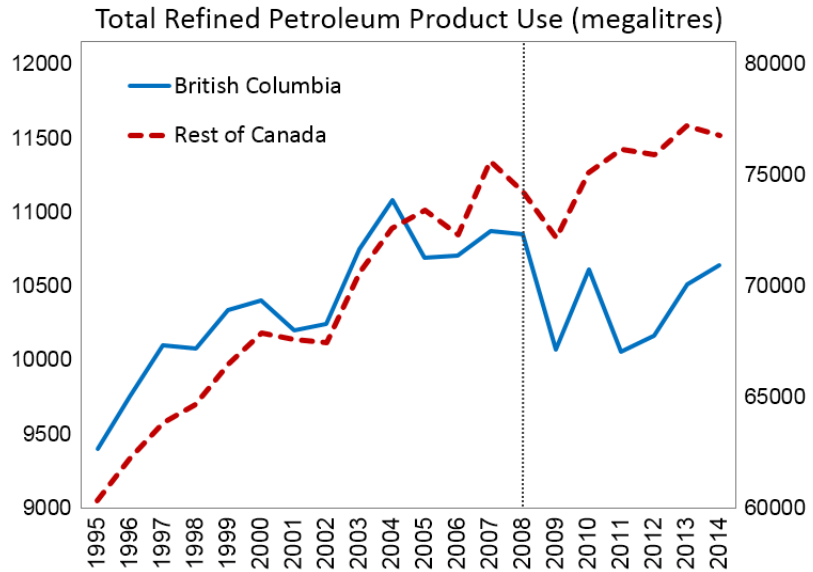
- **Carbon tax** schemes raised around **3 times** more government revenue (21.7 bn USD) than **emission trading schemes (6.57 bn USD).**
- Shares may not add up to 100% since annual budgeting might not match income flows and categories are not comprehensive.

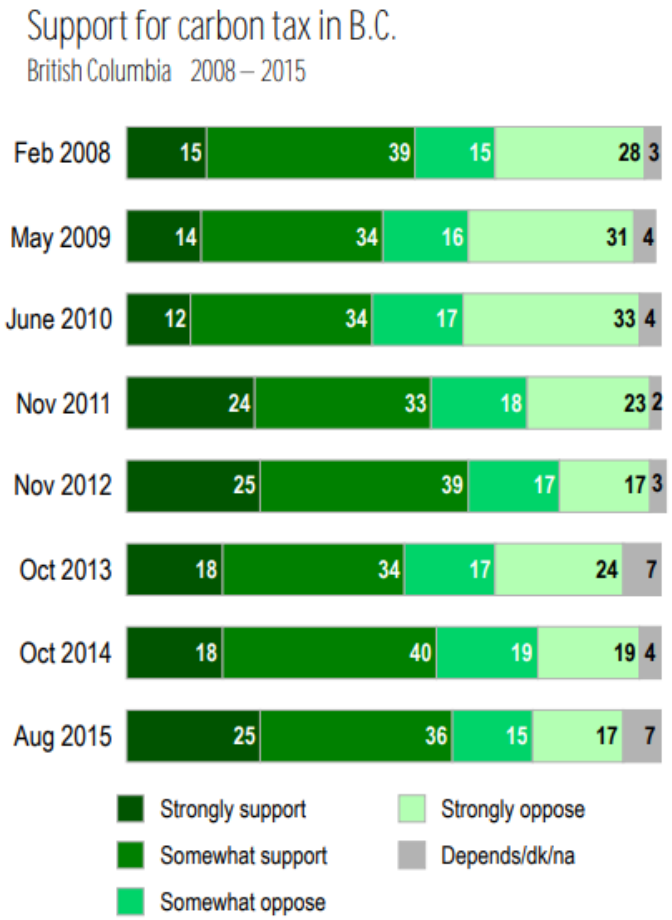


Klenert et al. (under review)

Carbon pricing and tax reduction – Example of British Columbia

- **Introduction of a carbon tax in 2008:**
  - **Significant decrease of CO_2-emissions**
  - **Continuous public support**
- **Use of revenues: reduction of corporation and income tax**





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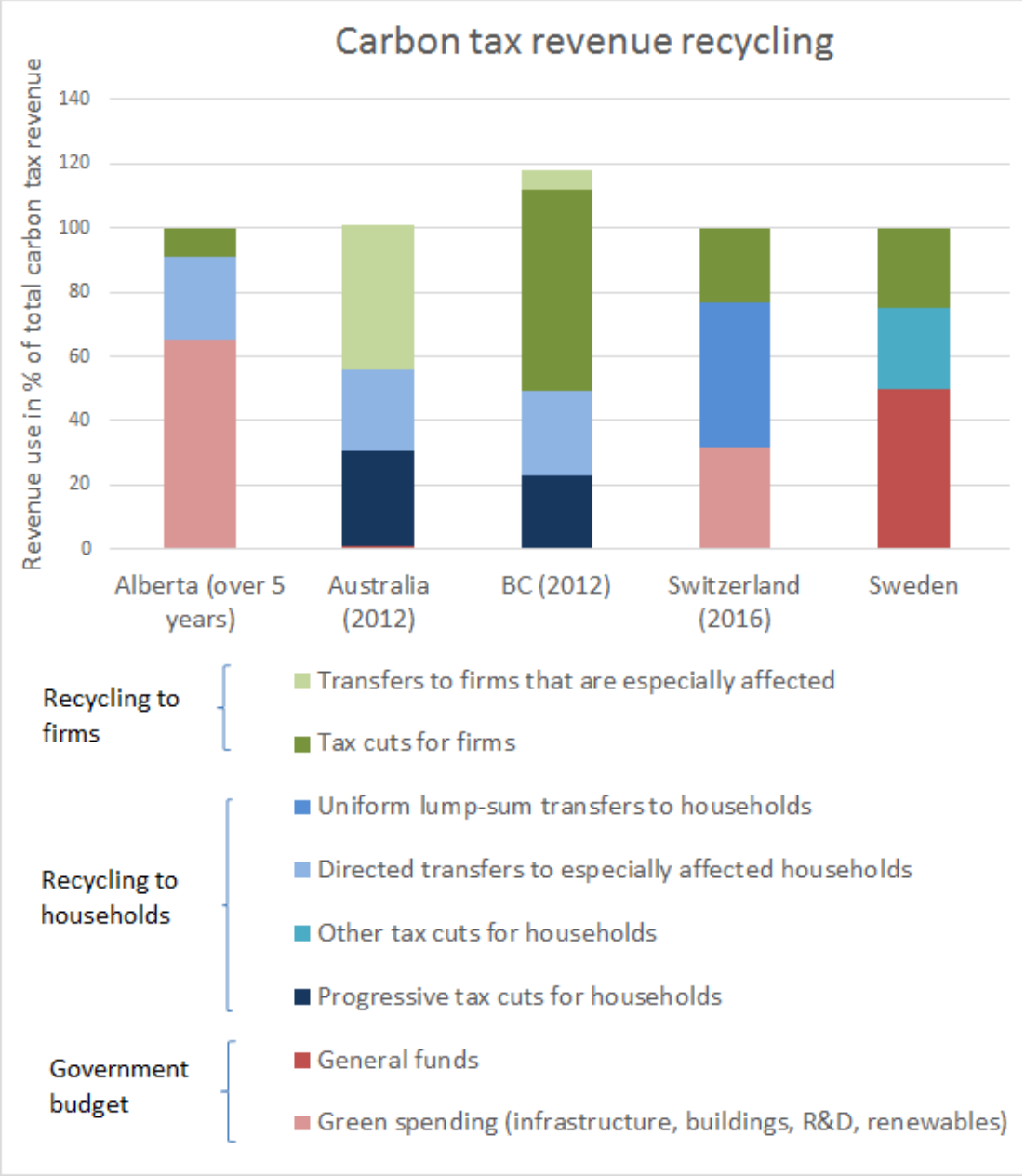
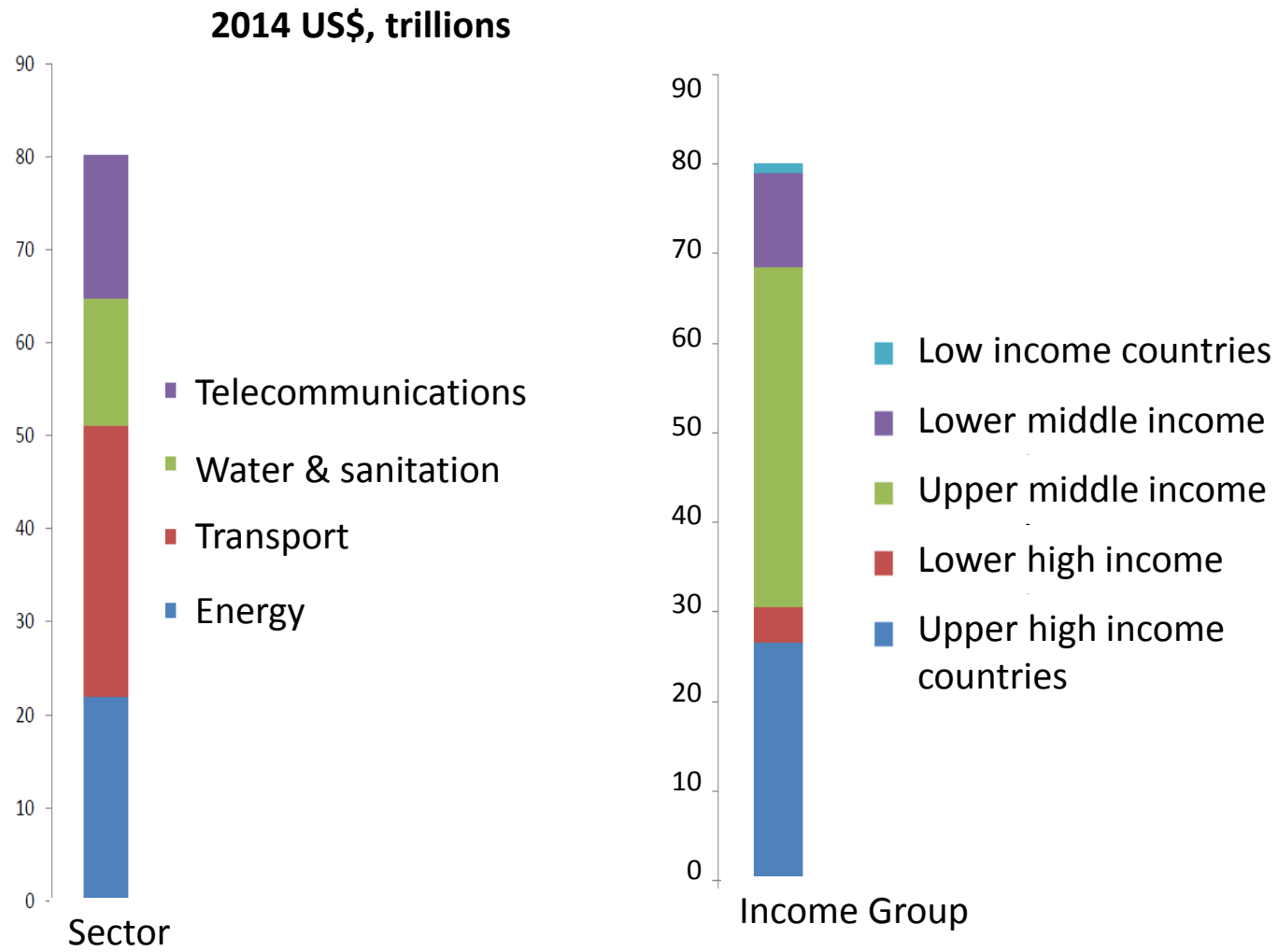


- Recycling of revenues:
  - **Cash transfers**
  - **Tax reductions**
  - **Public investment**
- All schemes return a share of the revenue to households (blue) and a share to firms (green)
- Three of the five use the revenue for some form of government financing/investment
- Except for Sweden, all revenue is (at some point) returned to the households

Klenert et al. (in prep.)

Projected cumulative infrastructure demand, 2015-2030

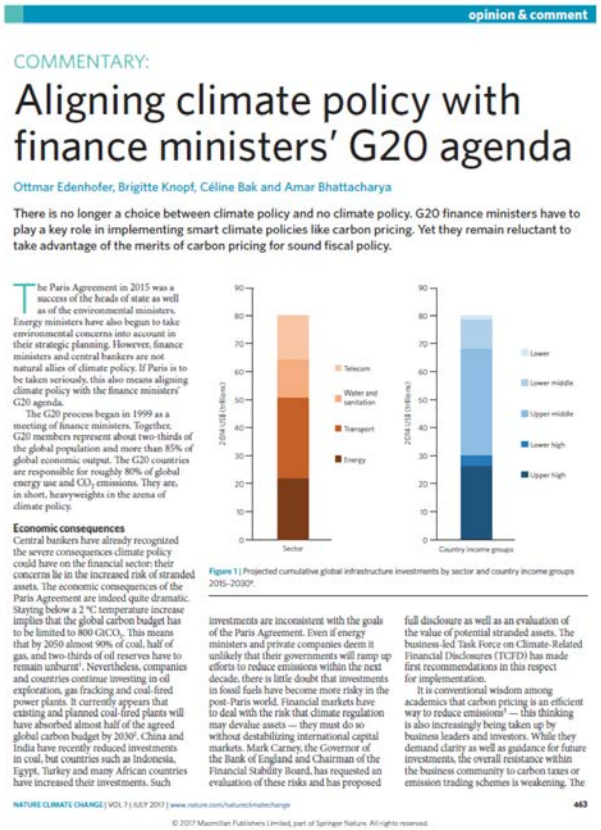


Bhattacharya, Chattopadhyay, and Nagrah (forthcoming)

Aligning climate policy with finance ministers‘ G20 agenda

nature climate change

G20 GERMANY 2017
HAMBURG



opinion & comment

COMMENTARY:

Aligning climate policy with finance ministers' G20 agenda

Ottmar Edenhofer, Brigitte Knopf, Céline Bak and Amar Bhattacharya

There is no longer a choice between climate policy and no climate policy. G20 finance ministers have to play a key role in implementing smart climate policies like carbon pricing. Yet they remain reluctant to take advantage of the merits of carbon pricing for sound fiscal policy.

The Paris Agreement in 2015 was a success of the heads of state as well as of the environmental ministers. Energy ministers have also begun to take environmental concerns into account in their strategic planning. However, finance ministers and central bankers are not natural allies of climate policy. If Paris is to be taken seriously, this also means aligning climate policy with the finance ministers' G20 agenda.

The G20 process began in 1999 as a meeting of finance ministers. Together, G20 members represent about two-thirds of the global population and more than 85% of global economic output. The G20 countries are responsible for roughly 80% of global energy use and CO_2 emissions. They are, in short, heavyweights in the arena of climate policy.

Economic consequences

Central bankers have already recognized the severe consequences climate policy could have on the financial sector: their concerns lie in the increased risk of stranded assets. The economic consequences of the Paris Agreement are indeed quite dramatic. Staying below a 2 °C temperature increase implies that the global carbon budget has to be limited to 800 $GtCO_2$. This means that by 2050 almost 90% of coal, half of gas, and two-thirds of oil reserves have to remain unburnt[1]. Nevertheless, companies and countries continue investing in oil exploration, gas fracking and coal-fired power plants. It currently appears that existing and planned coal-fired plants will have absorbed almost half of the agreed global carbon budget by 2030[2]. China and India have recently reduced investments in coal, but countries such as Indonesia, Egypt, Turkey and many African countries have increased their investments. Such investments are inconsistent with the goals of the Paris Agreement. Even if energy ministers and private companies deem it unlikely that their governments will ramp up efforts to reduce emissions within the next decade, there is little doubt that investments in fossil fuels have become more risky in the post-Paris world. Financial markets have to deal with the risk that climate regulation may devalue assets — they must do so without destabilizing international capital markets. Mark Carney, the Governor of the Bank of England and Chairman of the Financial Stability Board, has requested an evaluation of these risks and has proposed full disclosure as well as an evaluation of the value of potential stranded assets. The business-led Task Force on Climate-Related Financial Disclosures (TCFD) has made first recommendations in this respect for implementation.

It is conventional wisdom among academics that carbon pricing is an efficient way to reduce emissions[3] — this thinking is also increasingly being taken up by business leaders and investors. While they demand clarity as well as guidance for future investments, the overall resistance within the business community to carbon taxes or emission trading schemes is weakening. The

Figure 1 | Projected cumulative global infrastructure investments by sector and country income groups 2015–2030[4].

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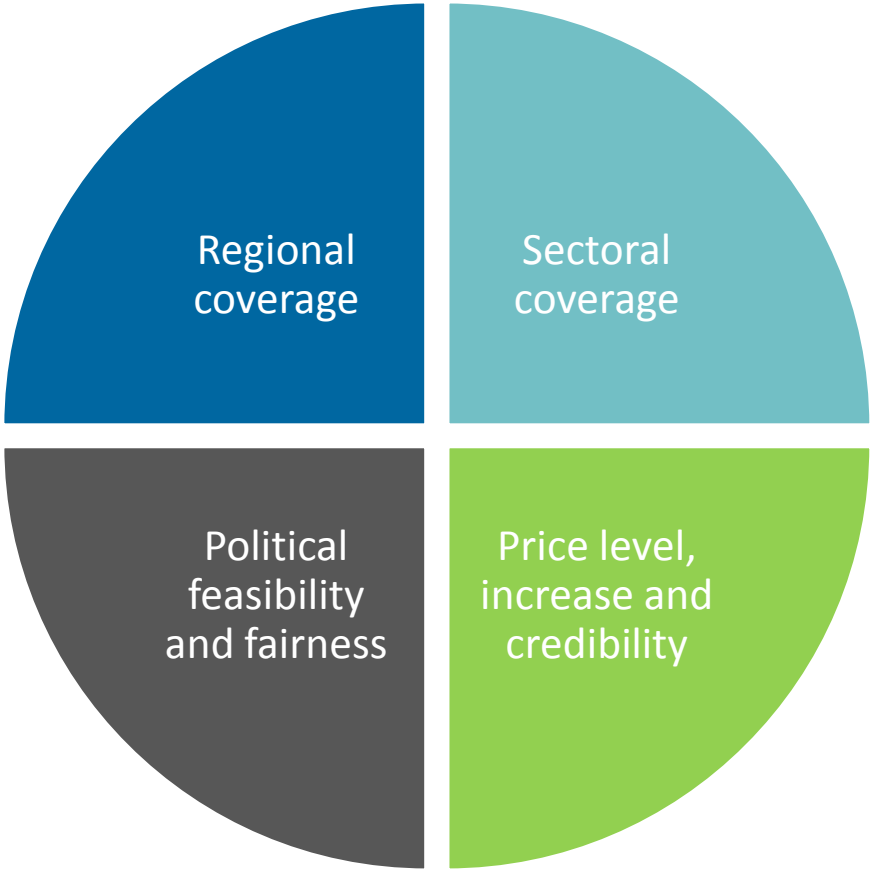
http://www.nature.com/nclimate/journal/v7/n7/full/nclimate3331.html?WT.feed_name=subjects_climate-change

It needs tremendous progress in all four dimensions to make CO_2 pricing effective.



Take home messages (I)

1. Macroeconomic Implications of the Paris Agreement:

   a) Emissions are still on the rise, the main factor is coal
   b) Moderate macro-economic mitigation costs
   c) Coordinated and increasing Carbon Prices are required after 2030 for the 2°C target
   d) Modelling comparison indicates:
      - The reponsiveness of emission reductions to carbon prices depends on the availability of technologies
      - The macro-economic costs are determined by general equilibrium effects; general equilibrium models exhibit higher macro-economic costs than partial equilibrium models

Take home messages (II)

2. The Social Costs of Carbon (SCC) – Guiding Principle for Climate Policies?

a) Bottom-up estimates of SCC have been increased significantly
b) SCC are a normative concept: Intergenerational and intragenerational inequality increases SCC
c) SCC ranges are still too broad for policy applications
d) The 2°C target is a normative substitute to SCC; it determines the timing of mitigation efforts as well as carbon prices

Take home messages (III)

3. International Cooperation and Coordination:
   a) Carbon Prices and Strategic Transfers are helpful for the ratched-up process
   b) Climate Finance can reduce capital costs

4. Implementation Challenges for National Governments
   a) There are four dimensions of effective carbon prices; in all dimensions considerable progress is needed
   b) There is a remarkable revenue raising potential of CO_2 Prices (2% of global GDP)
   c) The revenue aspect of carbon pricing is important to overcome political barriers