Potsdam-Institut für Klimafolgenforschung
PIK

Climate Change: Solutions
- Adaptation and Mitigation –
(including the economical perspective*)

Fred F. Hattermann

Definition of adaptation and mitigation

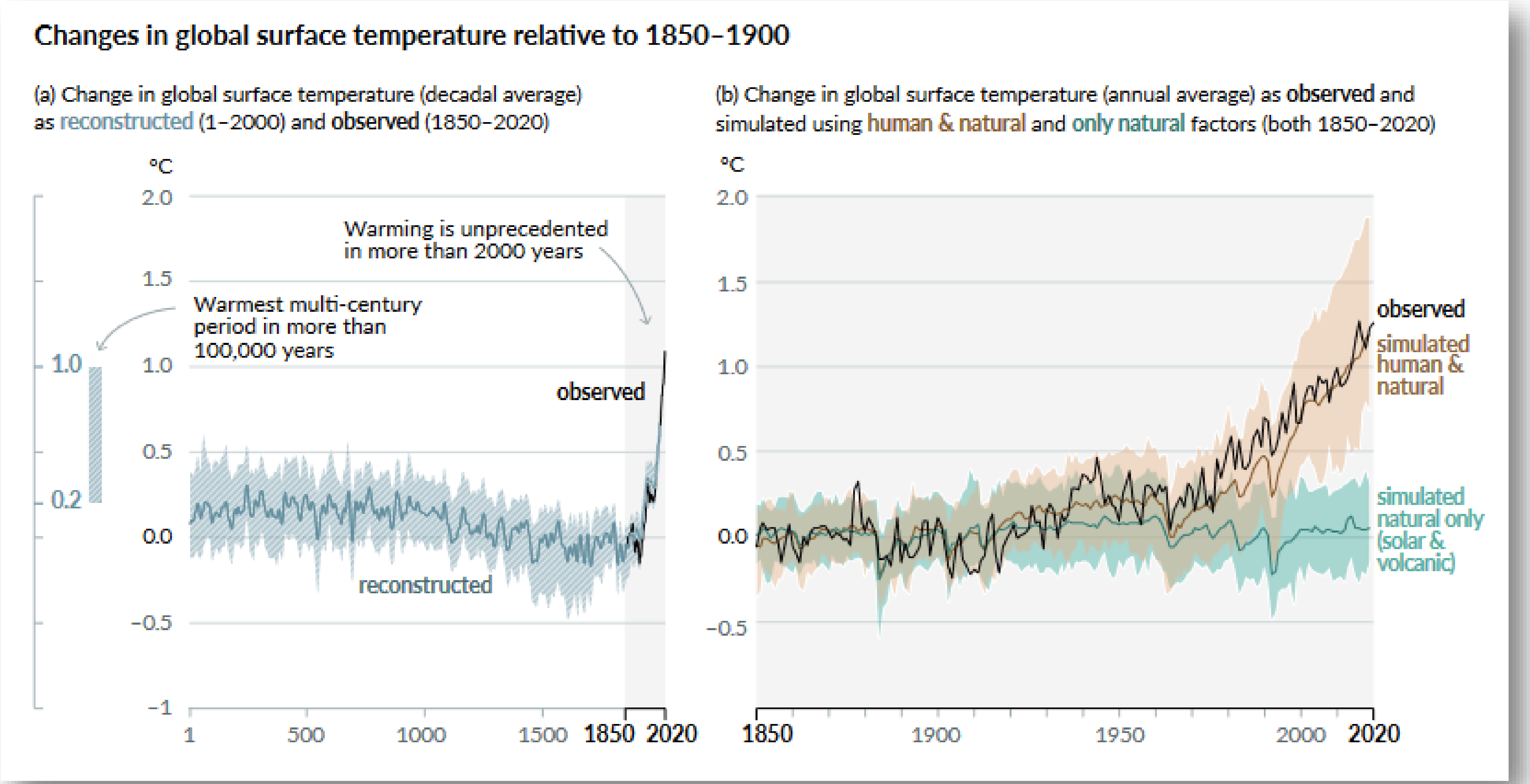
Hochschule
für nachhaltige Entwicklung
Eberswalde

In essence:

- Adaptation can be understood as the process of adjusting to the current and future effects of climate change.
- Mitigation means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere.

Agenda

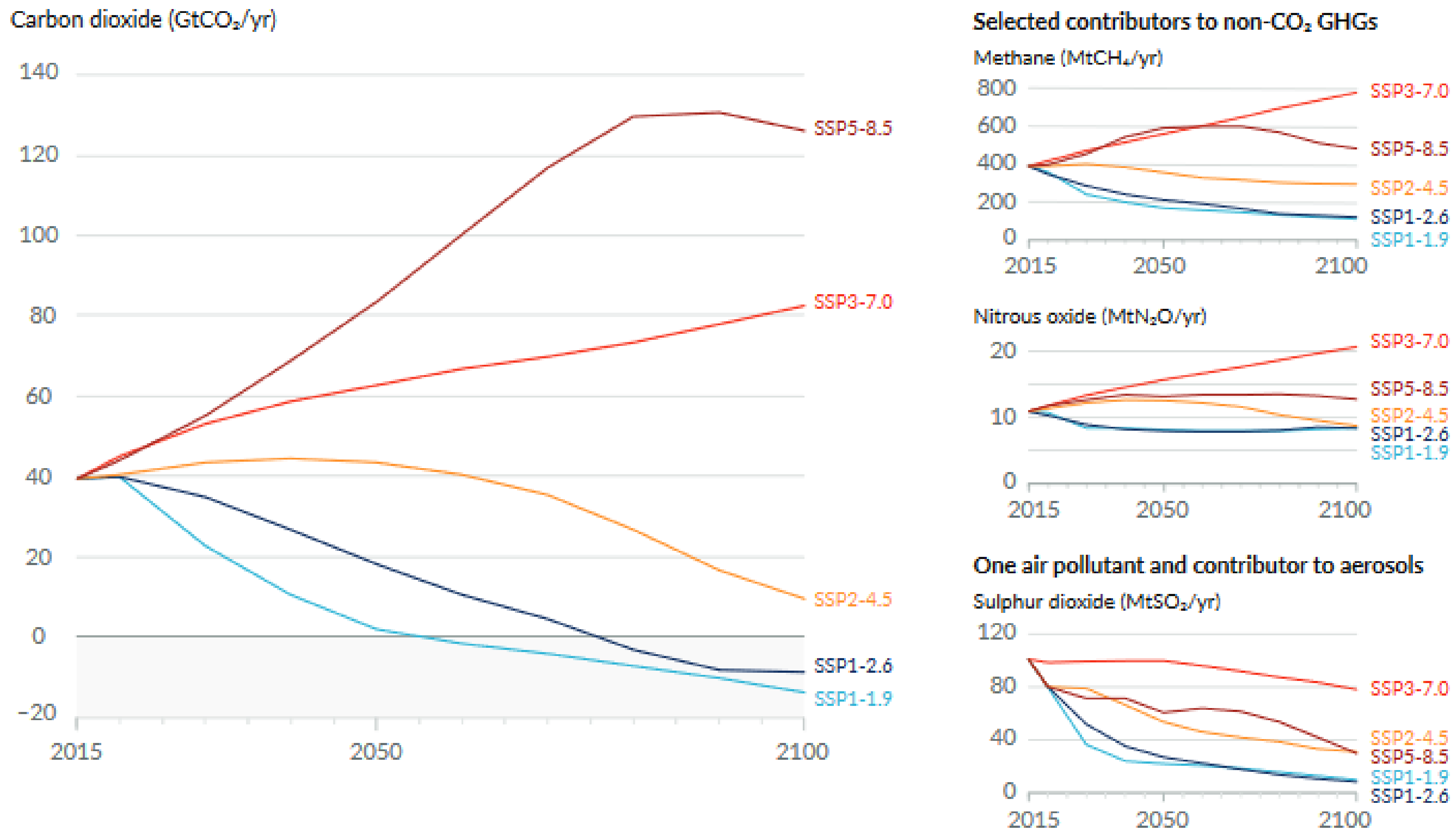
1. Introduction: CC and selected impacts
2. How is a climate scenario defined?
3. Does the polluter pay?
   Internalizing the climate externality
4. Suggested tasks for presentations



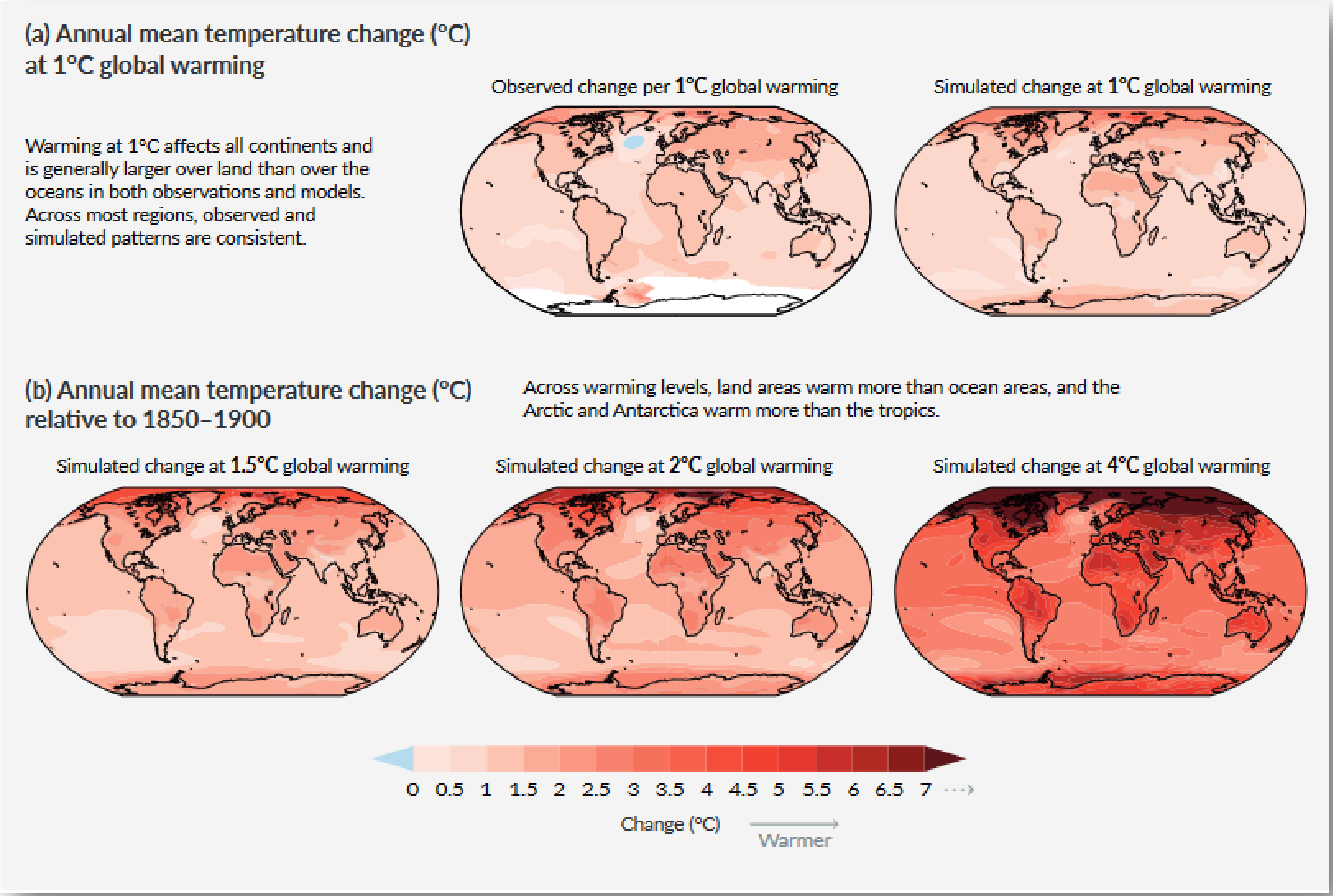
IPCC AR6 2021 summary for policy makers

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

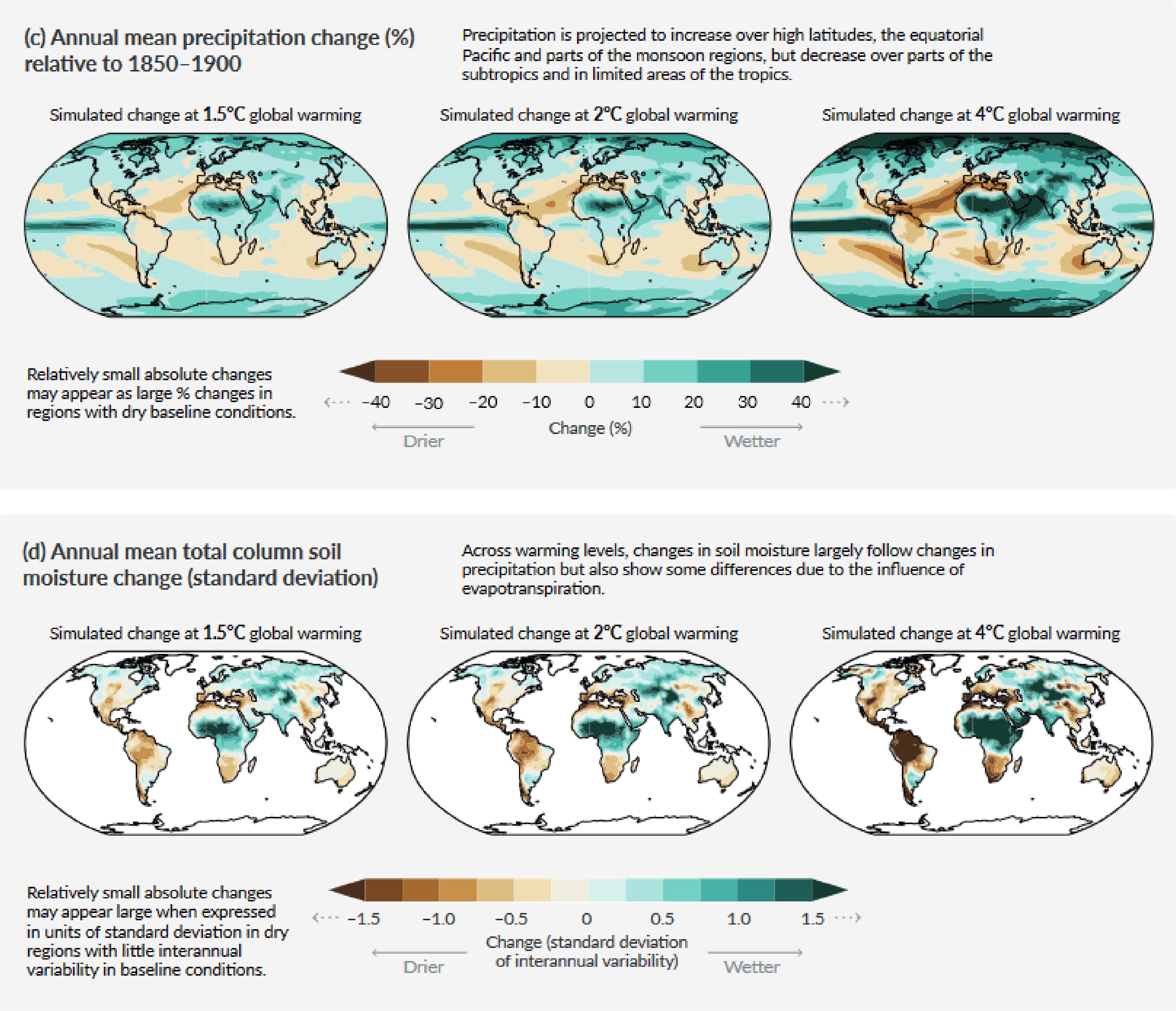
(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios



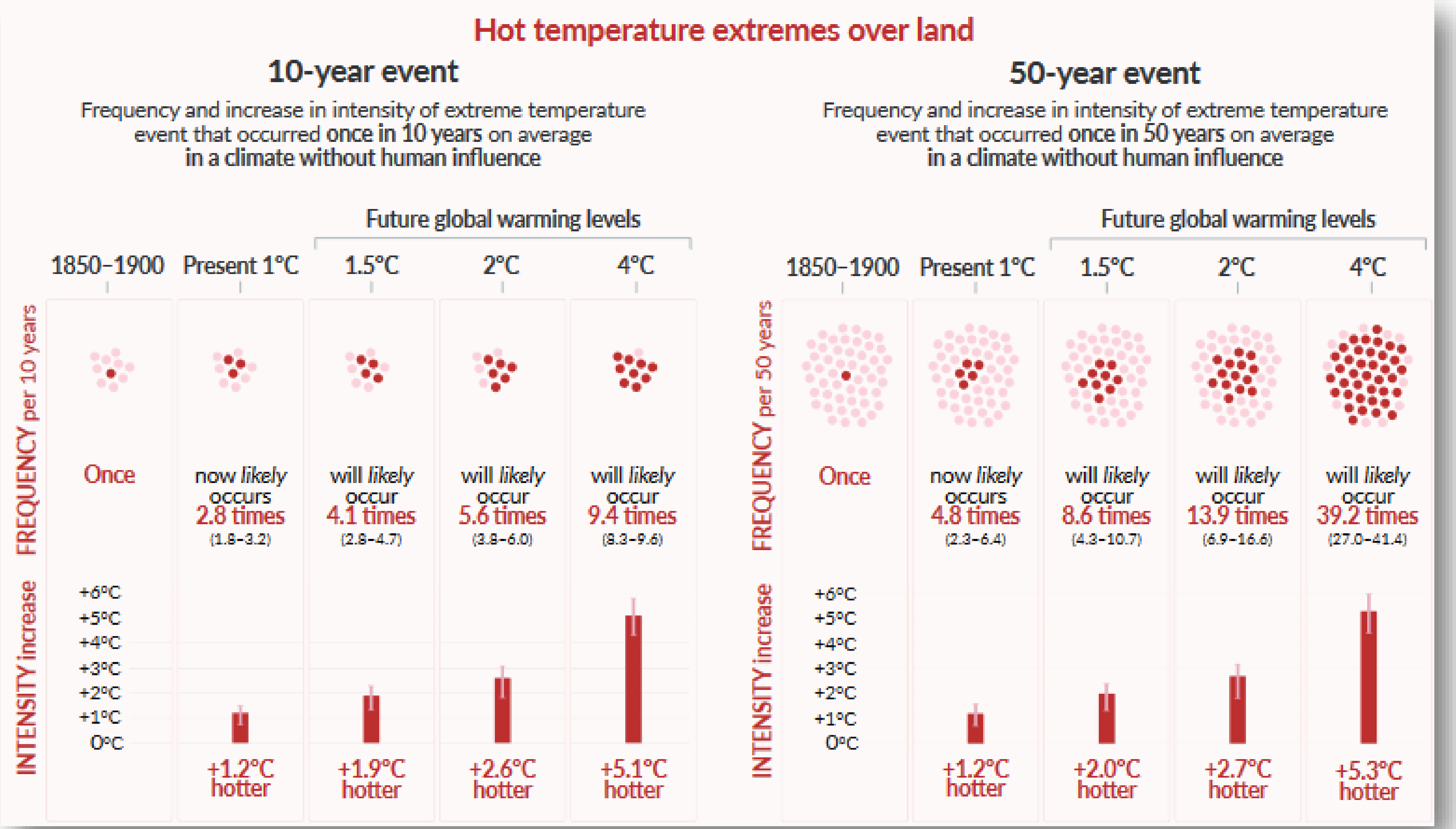
IPCC AR6 2021 summary for policy makers



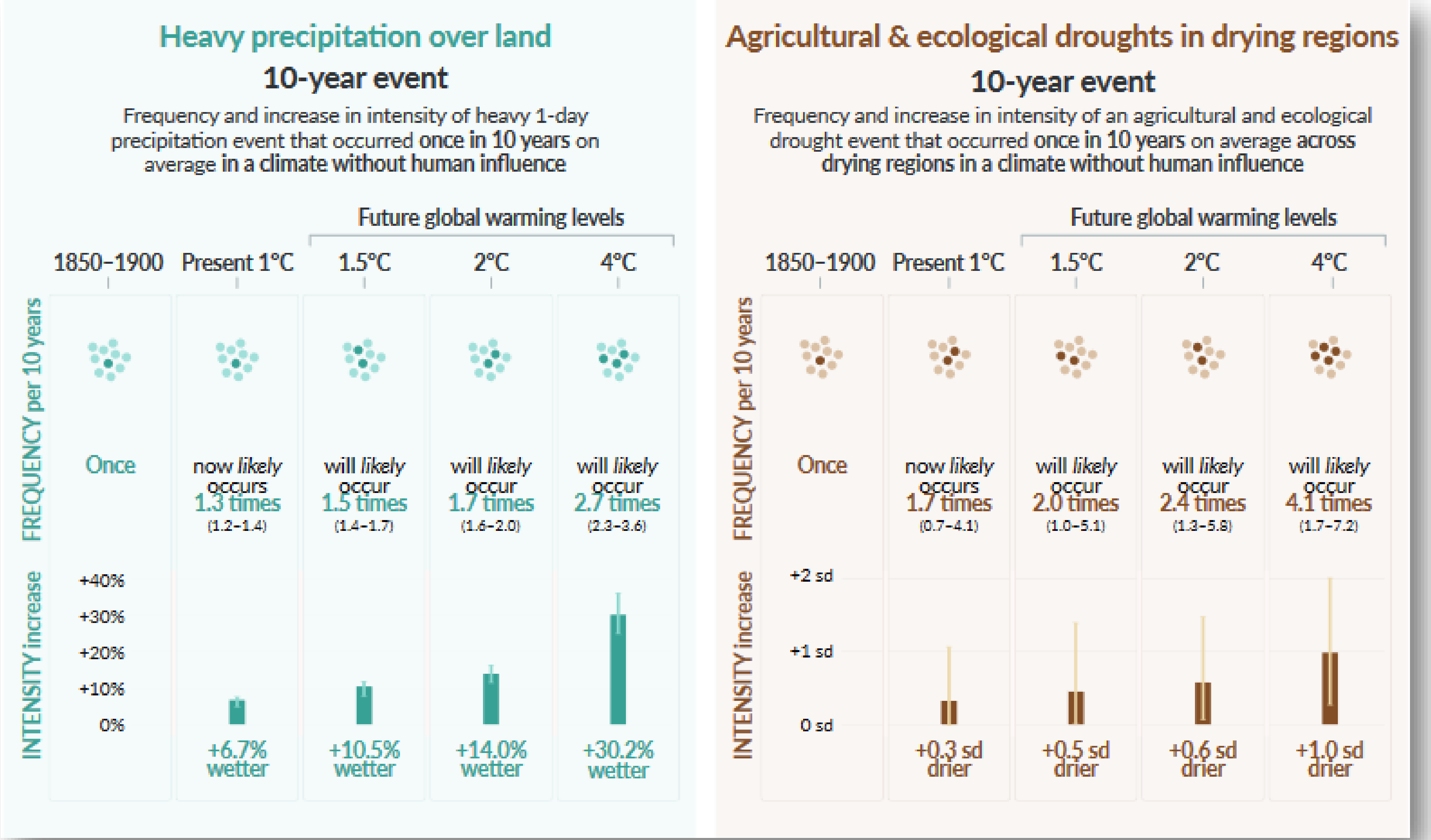
IPCC AR6 2021 summary for policy makers



IPCC AR6 2021 summary for policy makers

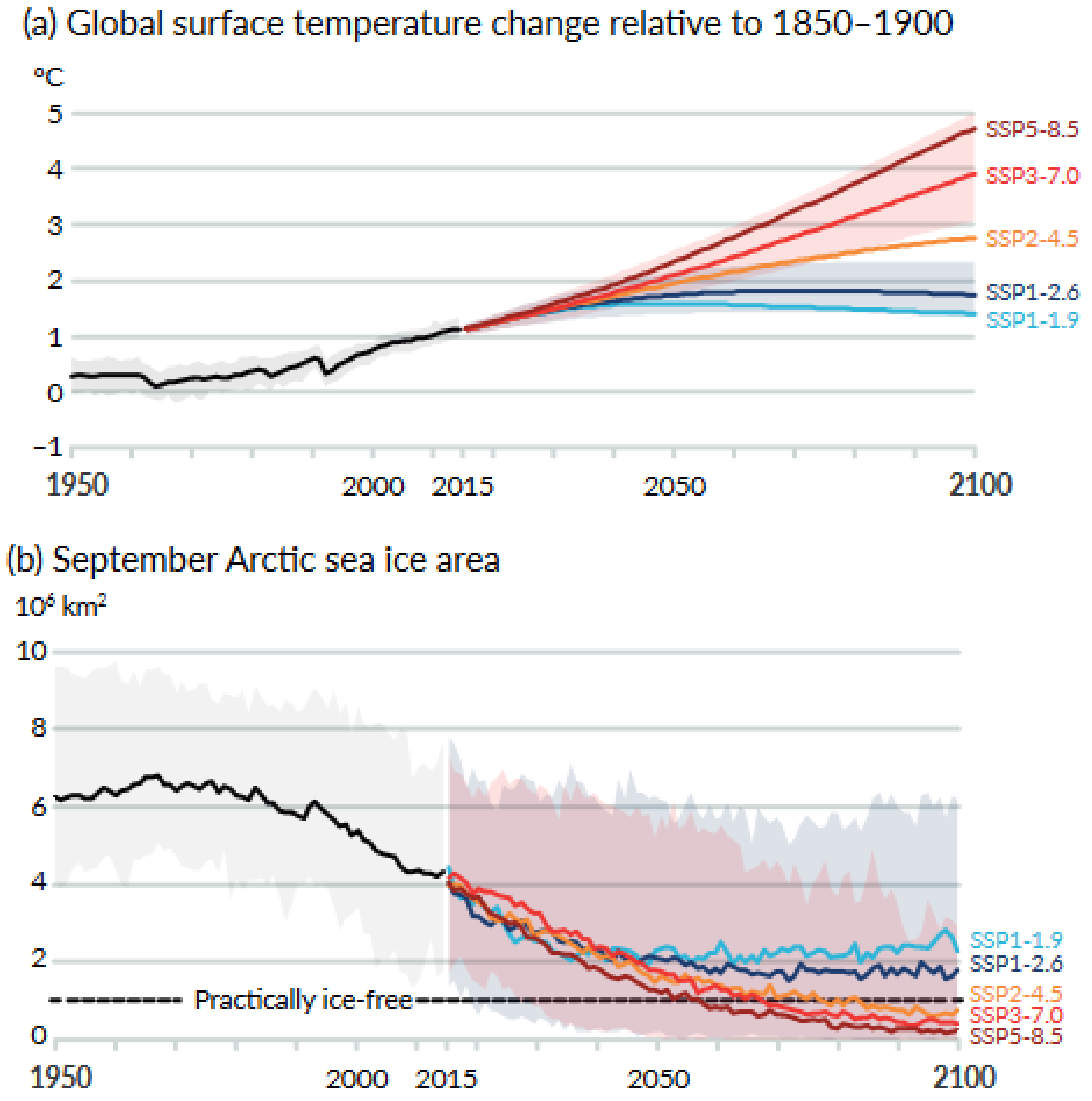


IPCC AR6 2021 summary for policy makers



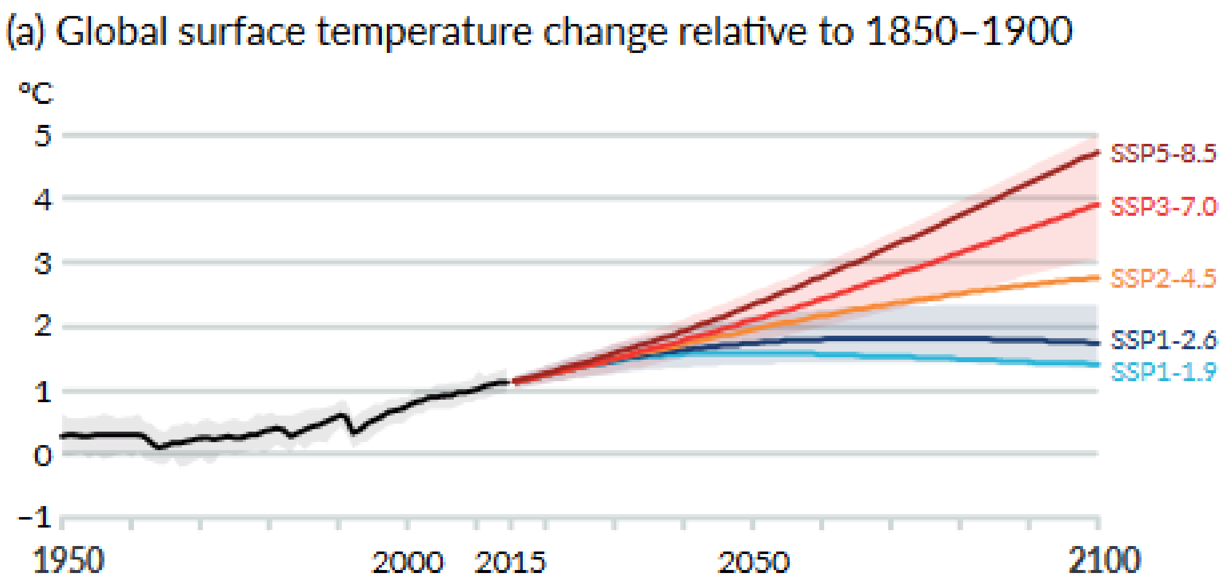
IPCC AR6 2021 summary for policy makers

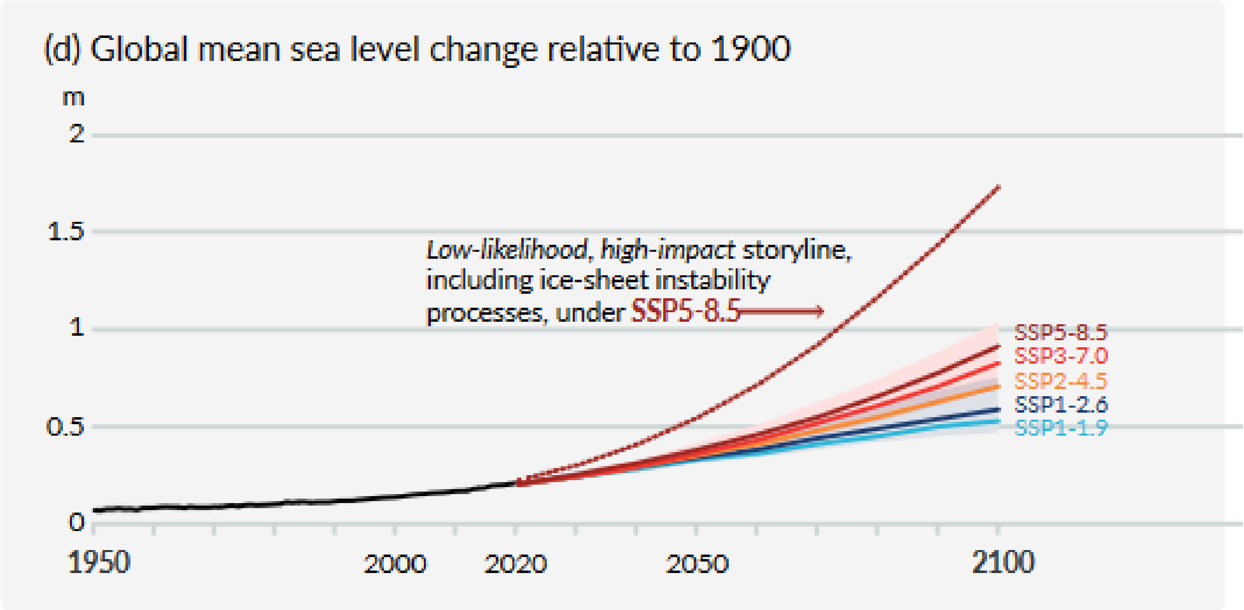
Global surface temperature and Arctic sea ice area



IPCC AR6 2021 summary for policy makers

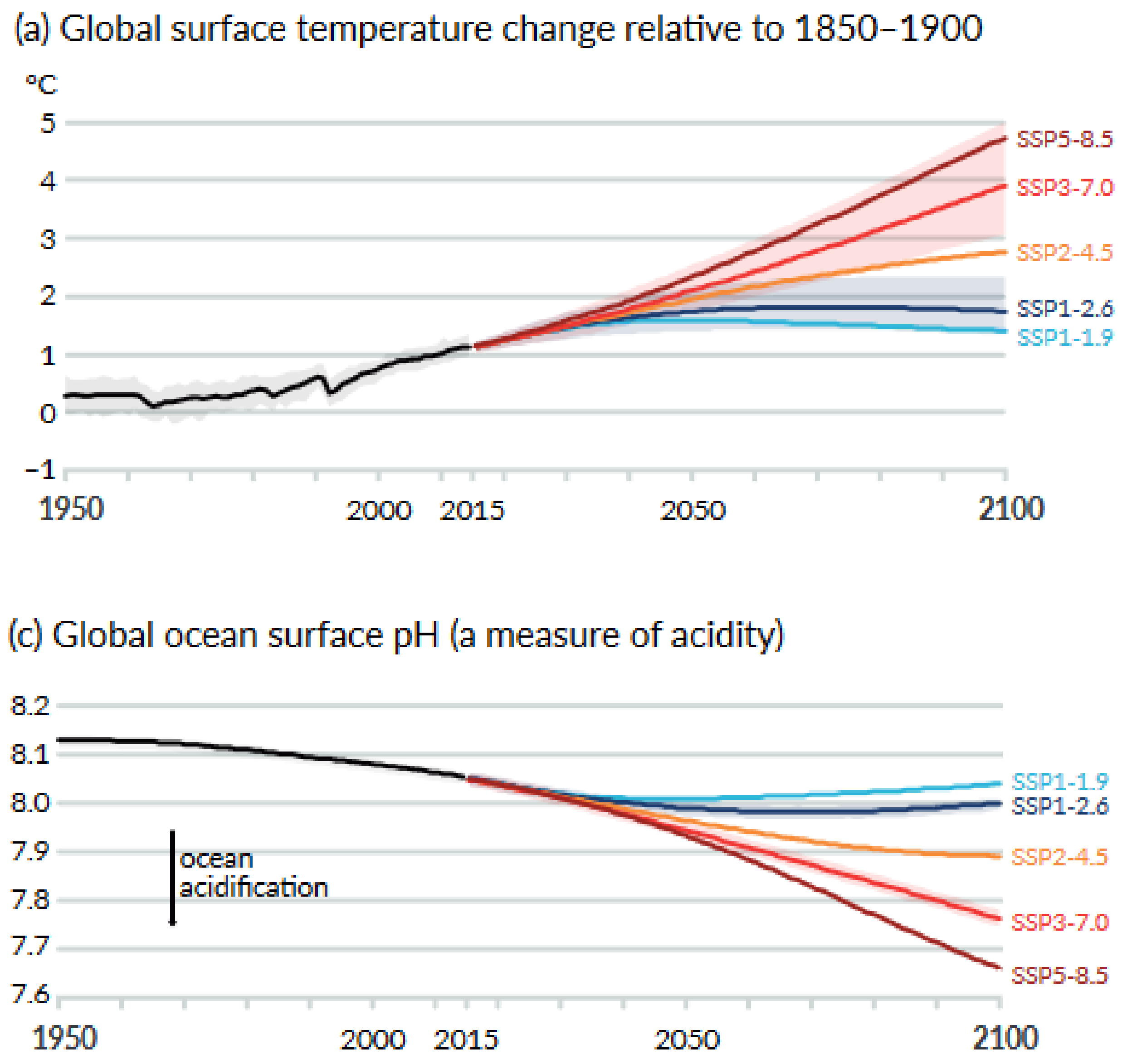
Global surface temperature and global mean sea level





IPCC AR6 2021 summary for policy makers

Global surface temperature and ocean surface pH

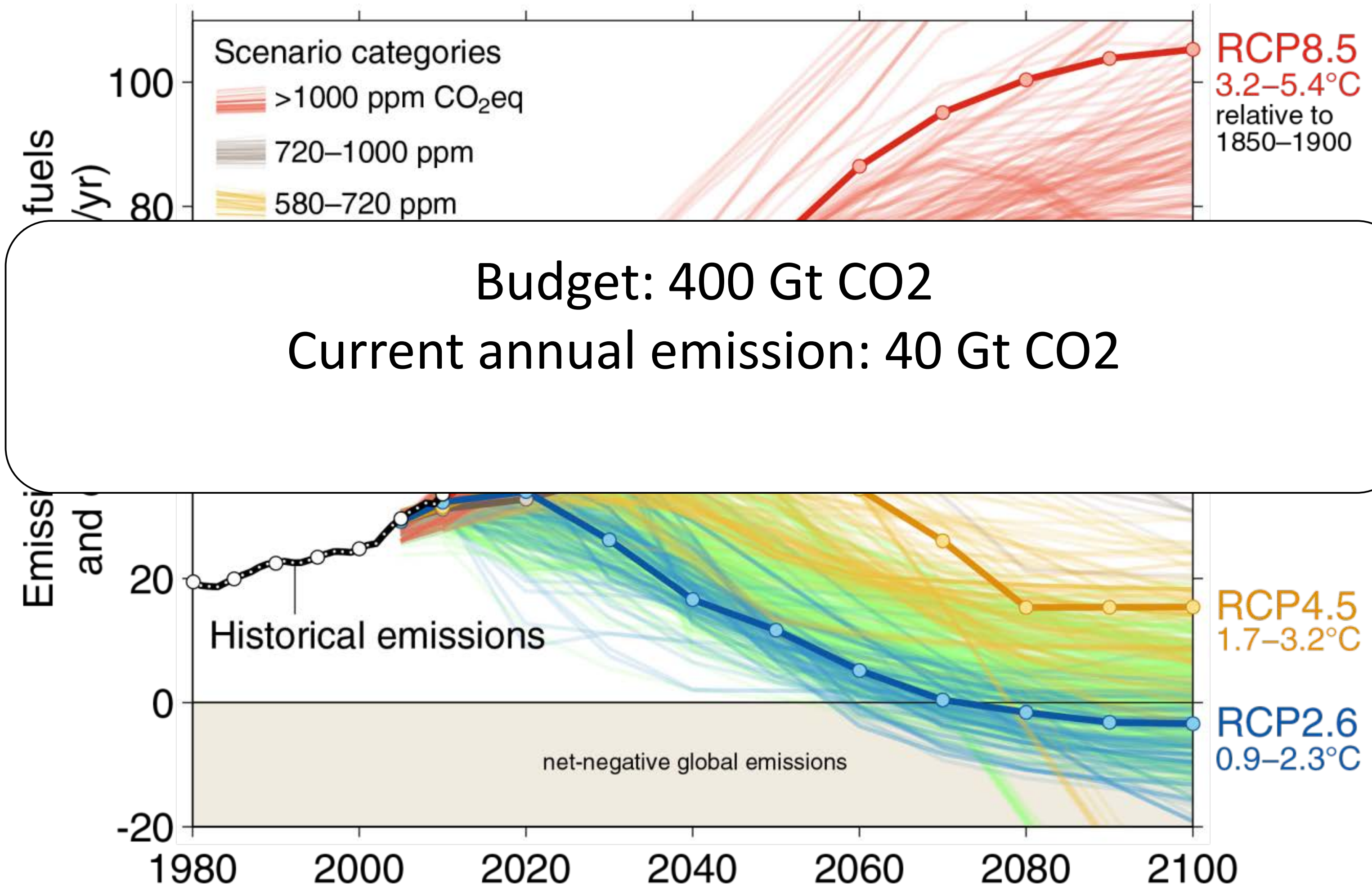


IPCC AR6 2021 summary for policy makers

From emissions to temperatures

Business-as-usual in red

Hochschule für nachhaltige Entwicklung Eberswalde



Budget: 400 Gt CO2

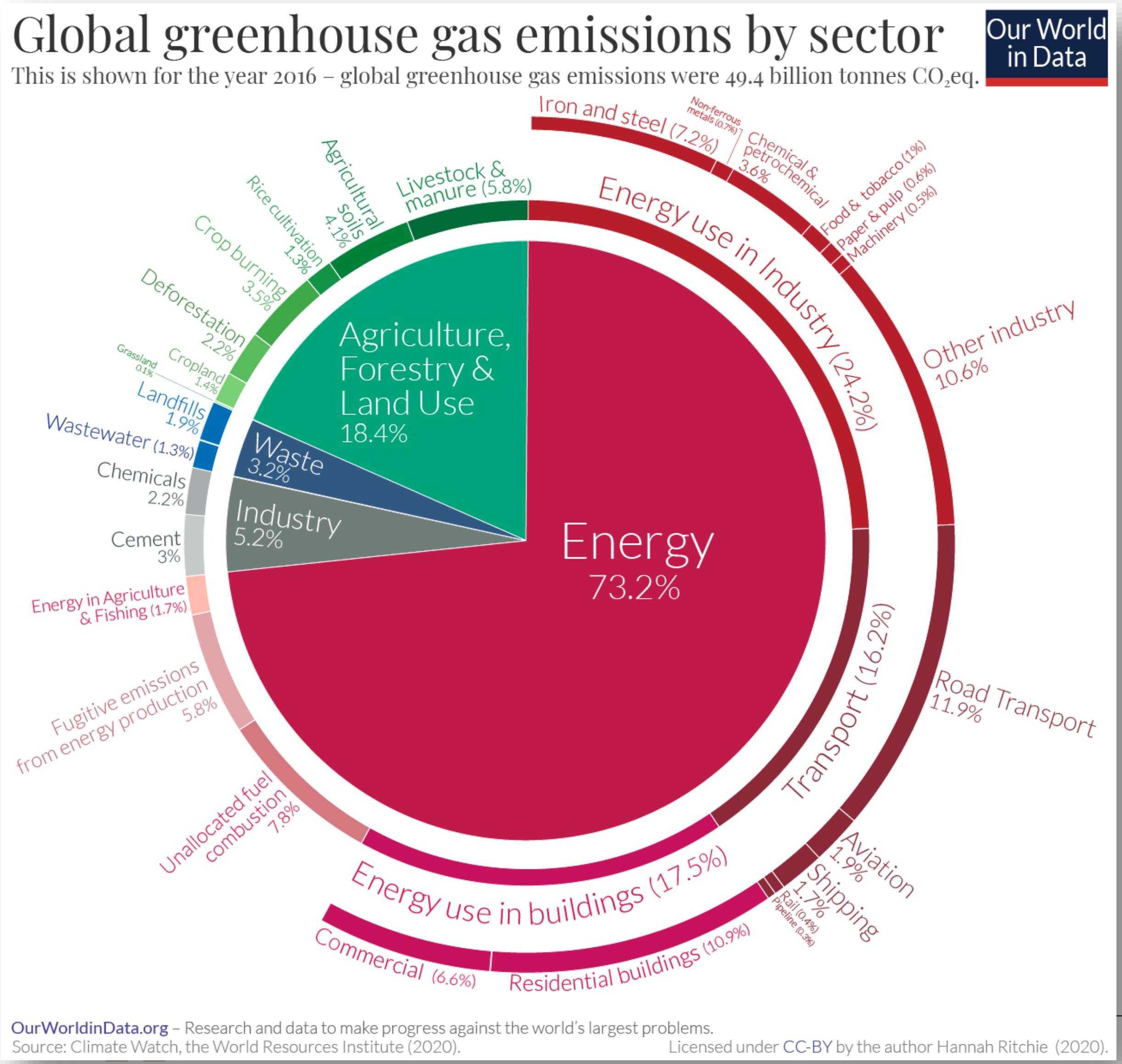
Current annual emission: 40 Gt CO2

PIK

World Meteorological Organization, 2014

What share do different sectors have in global GHG emissions?

Hochschule
für nachhaltige Entwicklung
Eberswalde



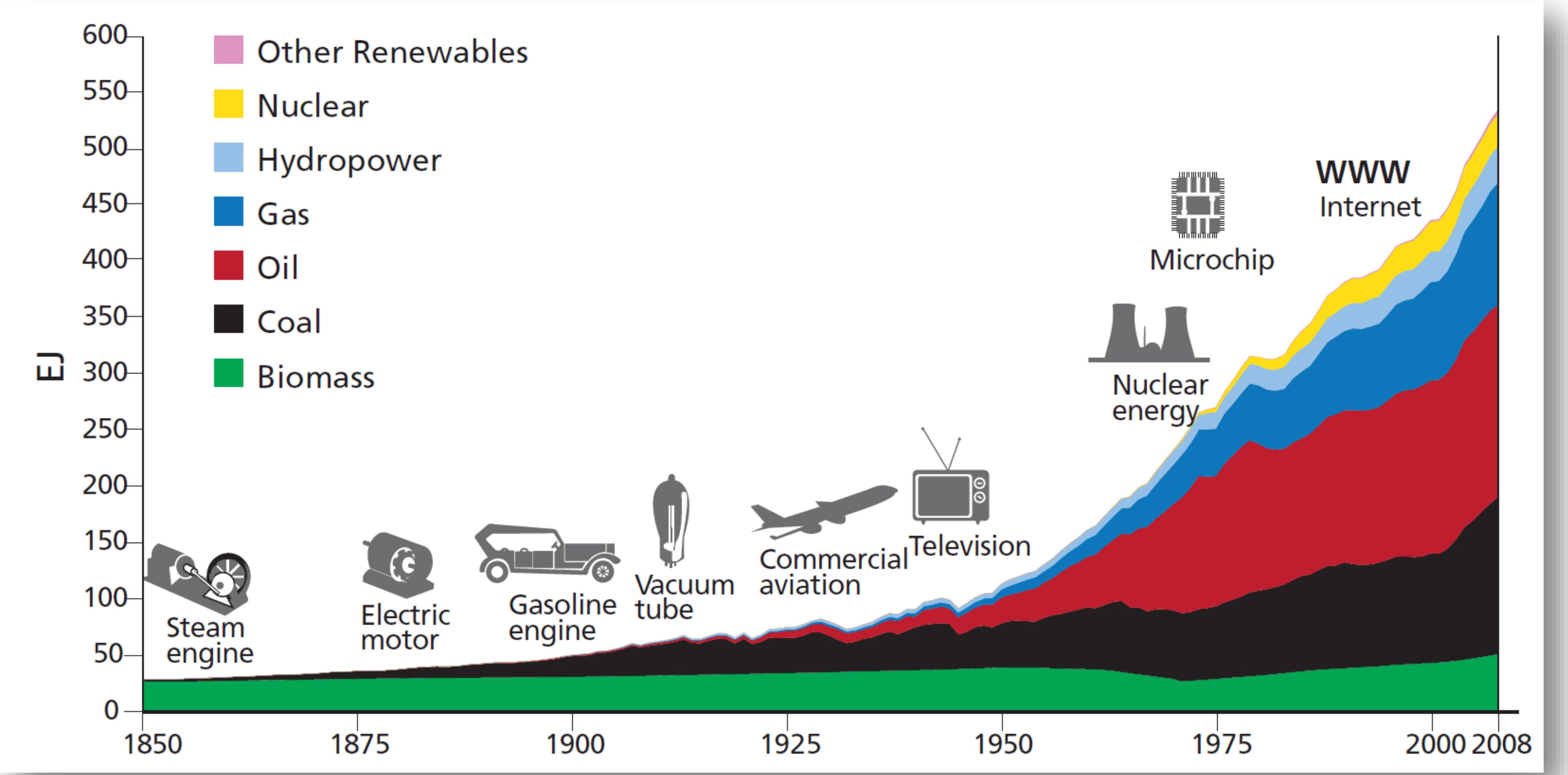
- <u>What are the biggest emitters within energy?</u>

Energy-demand (or end-use) sectors (direct and indirect emissions)

- Industry
- Buildings
- Transport

One can also separate out the direct emissions of the energy supply sector.

Size and complexity of energy systems significantly increased with economic growth, technological progress and population



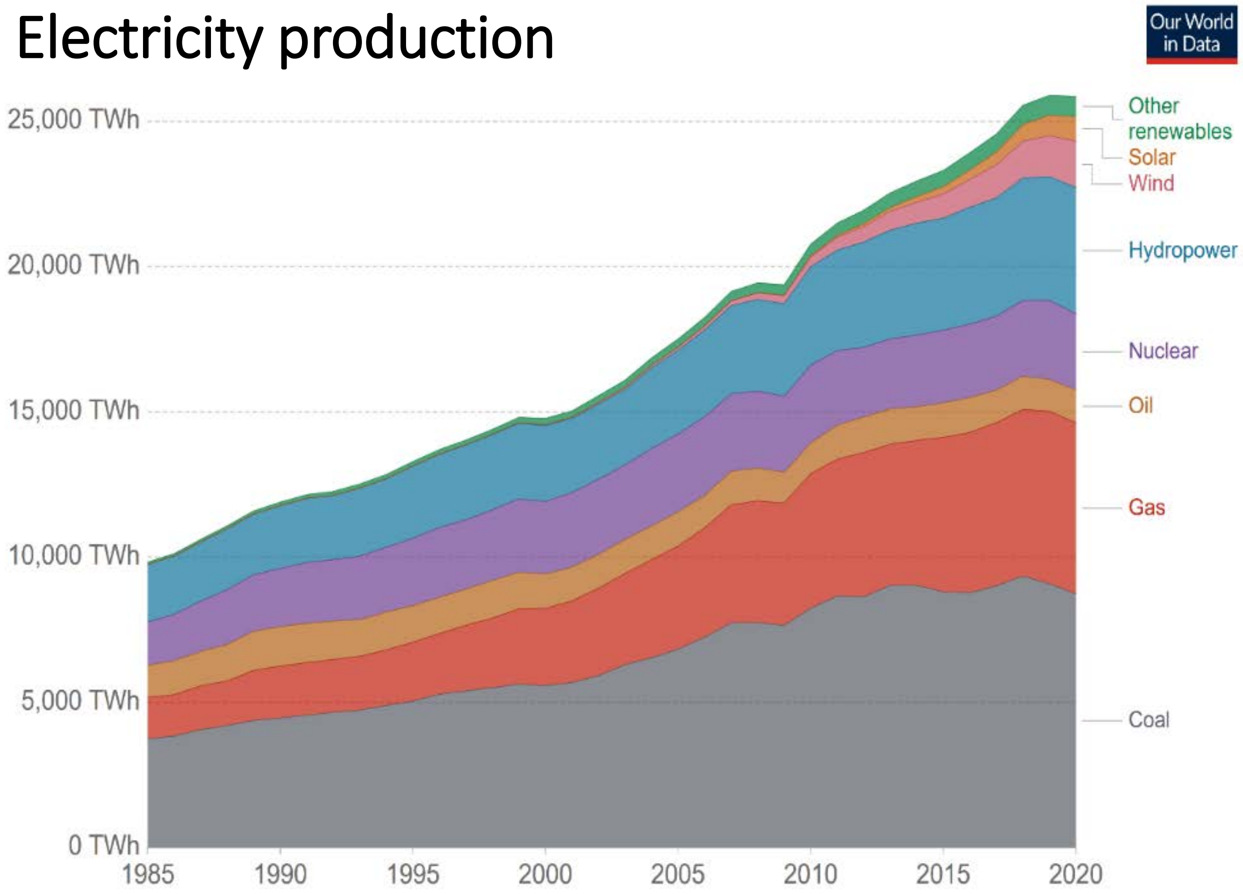
Global Energy Assessment 2012

The history of carbon emissions

The power sector

Hochschule
für nachhaltige Entwicklung
Eberswalde

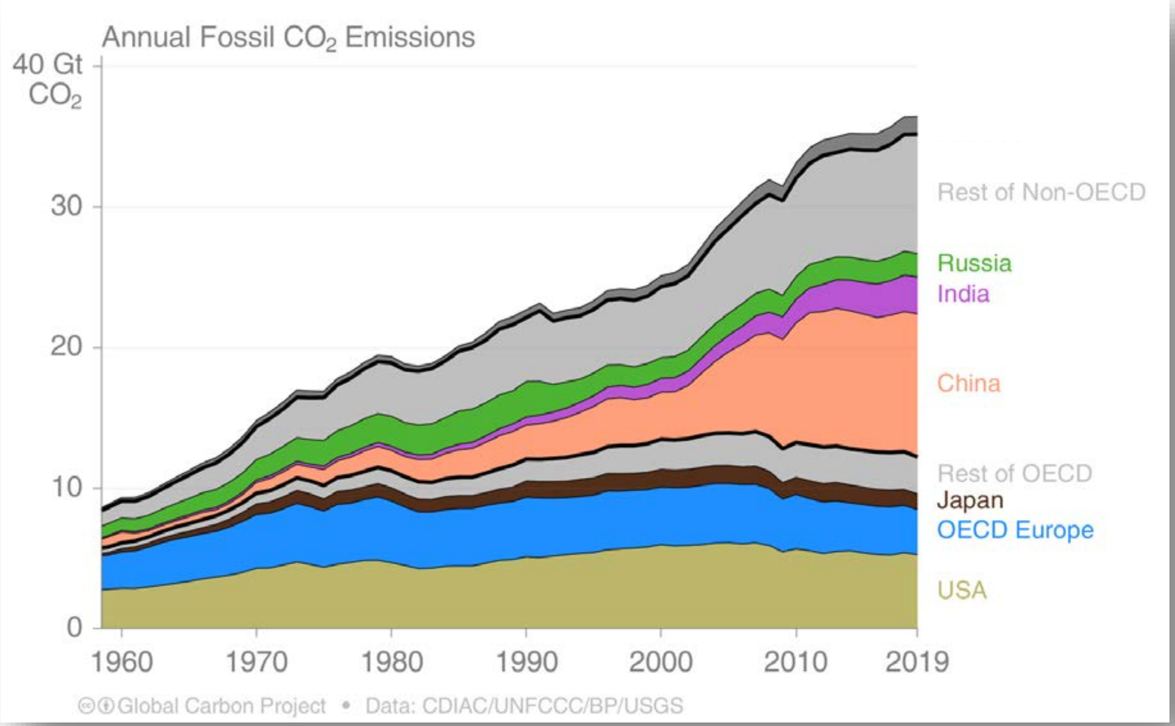
Electricity production

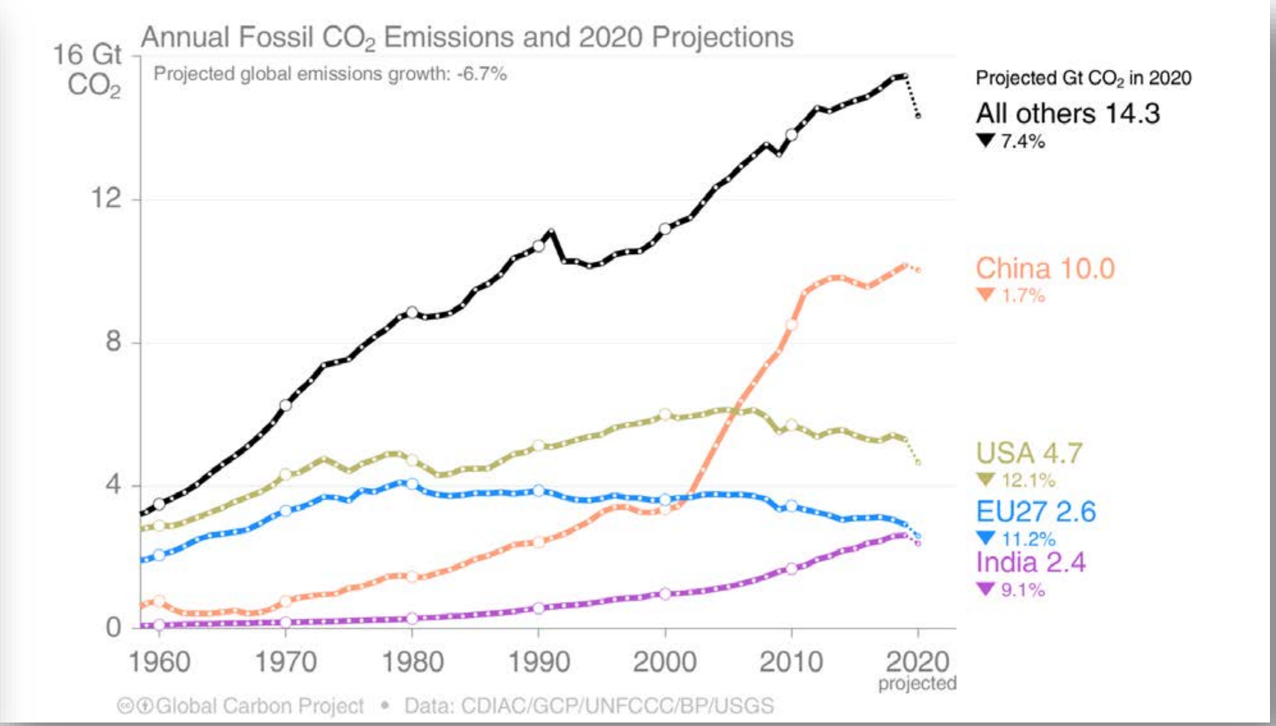


Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2021)
Note: 'Other renewables' includes biomass and waste, geothermal, wave and tidal.

PIK

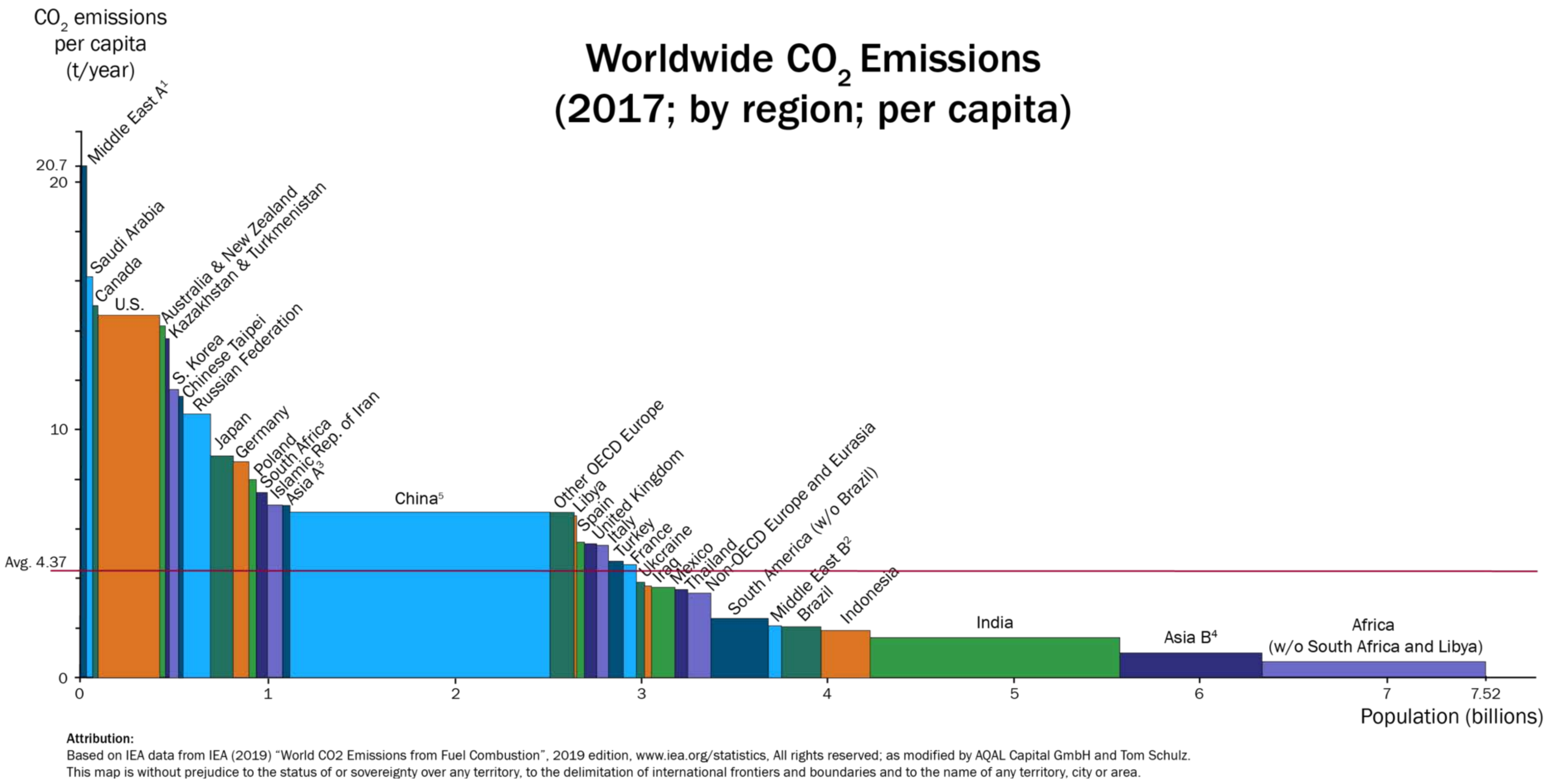
Different regional emission trends





Source: Global Carbon Project

Per capita emissions and development are linked



Data Source: IEA

How is the climate of your birthplace in the year 2100?

Hochschule
für nachhaltige Entwicklung
Eberswalde

Raw data accessible online:

- https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cordex-domains-singlelevels?tab=form
- However: …too complex to be used in this course…

P I K

How is the climate of your birthplace in the year 2100?

Hochschule
für nachhaltige Entwicklung
Eberswalde

Luckily, the IPCC WGI established an "Atlas" for the general public:

- Data from only *some* model runs for only *some* parameters and *some* time frames.
- Easy to use.
- https://interactive-atlas.ipcc.ch/

P I K

How is the climate of your birthplace in the year 2100?

Hochschule
für nachhaltige Entwicklung
Eberswalde

Task:

Please go to https://interactive-atlas.ipcc.ch/ **and find out how the climate will change**

→ at your birthplace → between the 1981-2010 period and the 2081-2100 period

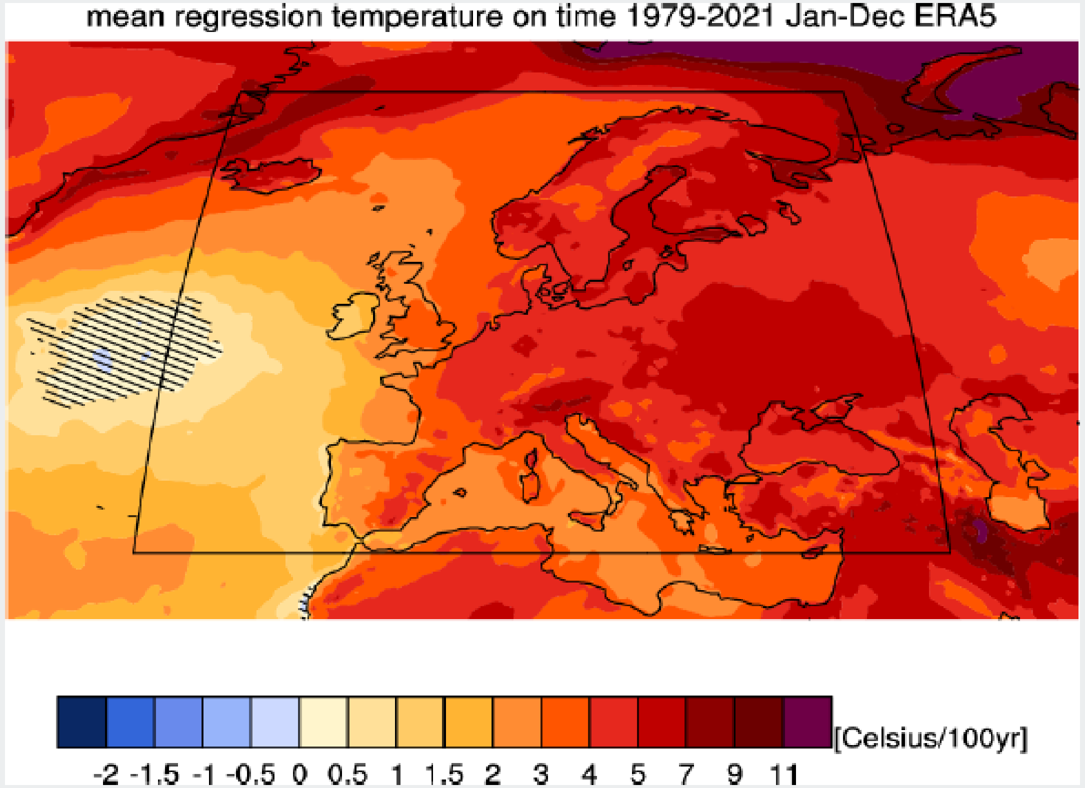
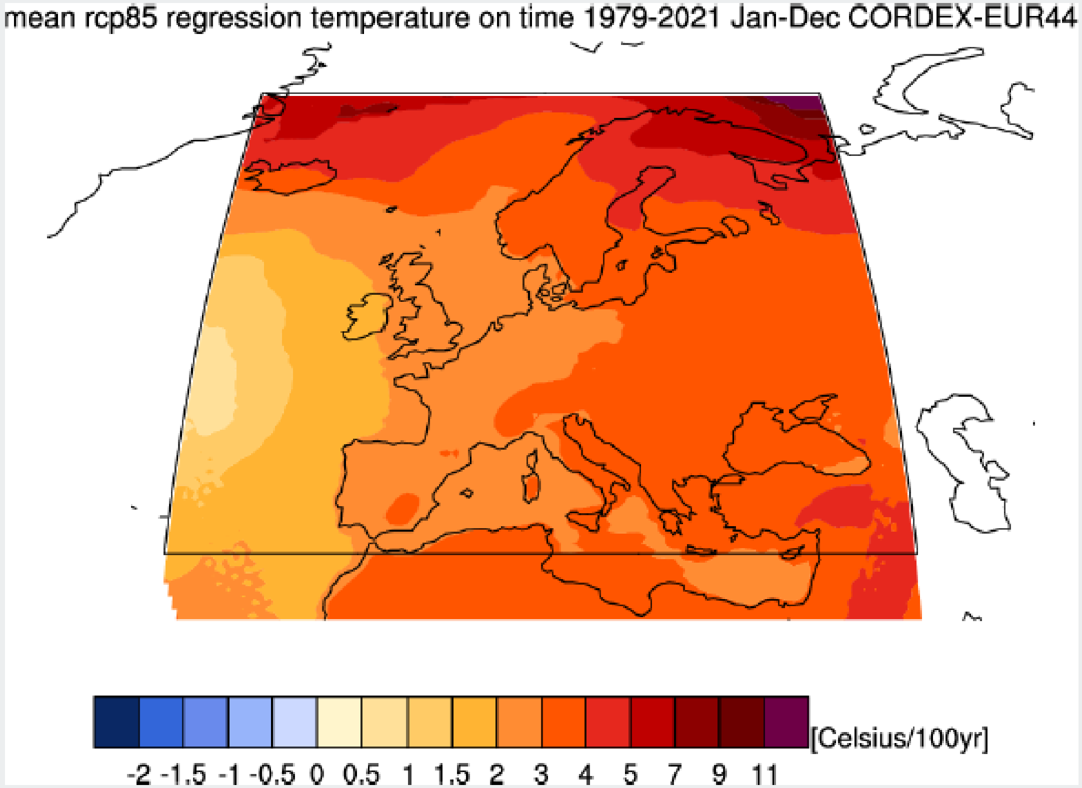
→ in the RCP8.5 scenario → for the following parameters:

Parameter	1981-2010	2081-2100	Difference	Change in %
Mean temperature				
Min. of min. temperatures				
Max. of max. temperatures				
Max. 5-day precipitation				
Frost days				

P I K

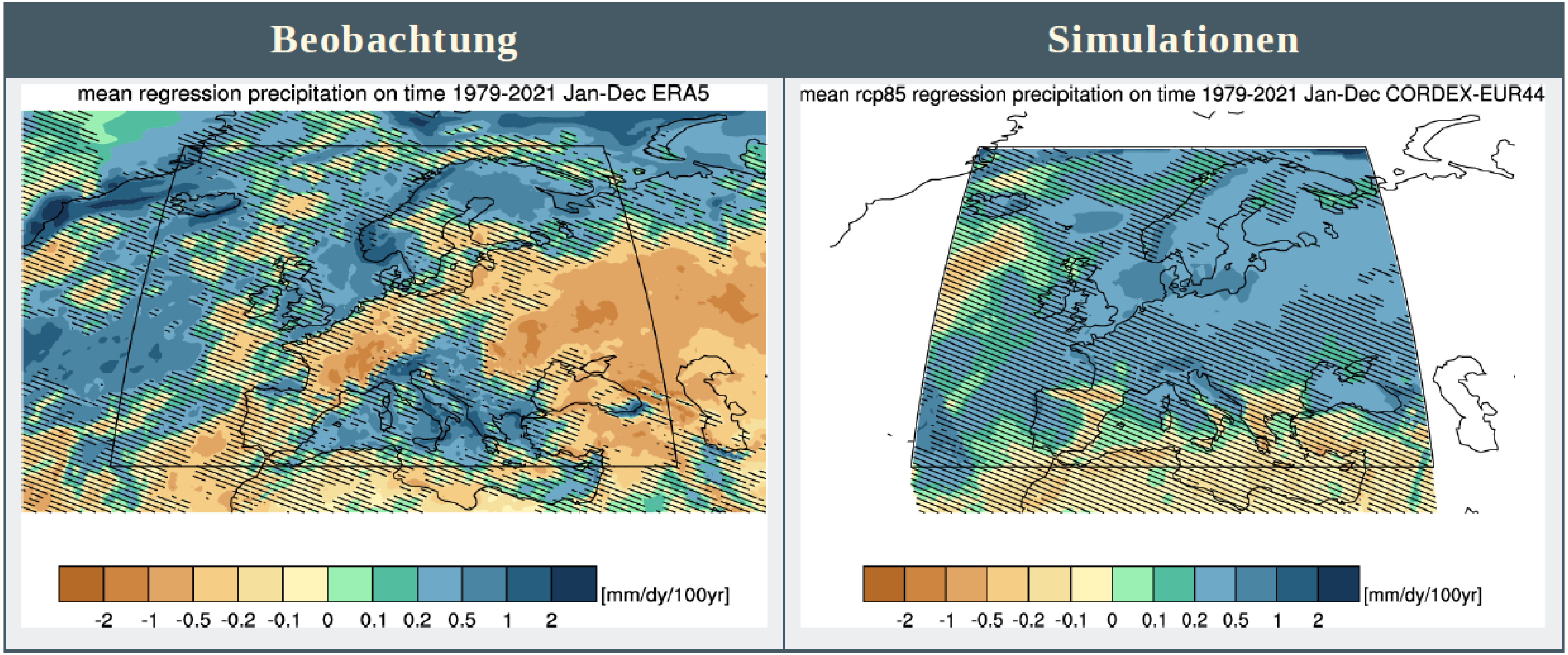
Observed versus simulated trends (1979-2020)

Hochschule
für nachhaltige Entwicklung
Eberswalde

Beobachtung	Simulationen
	

PIK

Observed versus simulated trends (1979-2020)



Agenda

1. Motivation & approach
2. How is a climate scenario defined?
3. Adaptation and mitigation
4. Internalizing multiple market failures

Climate change scenario: definition

- **Climate change scenarios are projections of greenhouse gas (GHG) emissions** used to assess future vulnerability to climate change
- They are indeed **socioeconomic scenarios**
- **Needed are estimates** of future population growth, economic development, the structure of governance, social values, and patterns of technological change
- **Economic and energy modelling** are applied to quantify the effects of such different drivers and mitigation options

The "Shared Socioeconomic Pathways" (SSPs) of the IPCC

- A new set of climate scenarios has been developed for the sixth IPCC report (IPCC AR6).
- The SSPs represent narratives for different socio-economic pathways resulting in different increases of atmospheric greenhouse gas concentrations …
- and leading to different levels of global warming.

Five basic SSP scenarios were defined

Hochschule für nachhaltige Entwicklung Eberswalde

- **SSP1: The sustainable and "green" pathway describes an increasingly sustainable world.** Global commons are preserved, and the limits of nature are respected. The focus is more on human well-being than on economic growth. Income inequalities between states and within states are being reduced. Consumption is oriented towards minimizing material resources and energy usage.
- **SSP2: The "Middle of the road" or medium pathway extrapolates the past and current global development into the future.** Income trends in different countries diverge significantly. There is a certain cooperation between states, but it is barely expanded. Global population growth is moderate, leveling off in the second half of the century. Environmental systems are facing a certain degradation.
- **SSP3: Regional rivalry. A revival of nationalism and regional conflicts pushes global issues into the background.** Policies increasingly focus on questions of national and regional security. Investments in education and technological development are decreasing. Inequality is rising. Some regions suffer drastic environmental damage.
- **SSP4: Inequality.** The chasm between globally cooperating developed societies and those stalling at a lower developmental stage with low income and a low level of education is widening. Environmental policies are successful in tackling local problems in some regions, but not in others.
- **SSP5: Fossil-fueled Development.** Global markets are increasingly integrated, leading to innovations and technological progress. The social and economic development, however, is based on an intensified exploitation of fossil fuel resources with a high percentage of coal and an energy-intensive lifestyle worldwide. The world economy is growing and local environmental problems such as air pollution are being tackled successfully.

PIK

The "Shared Socioeconomic Pathways" (SSPs) of the IPCC

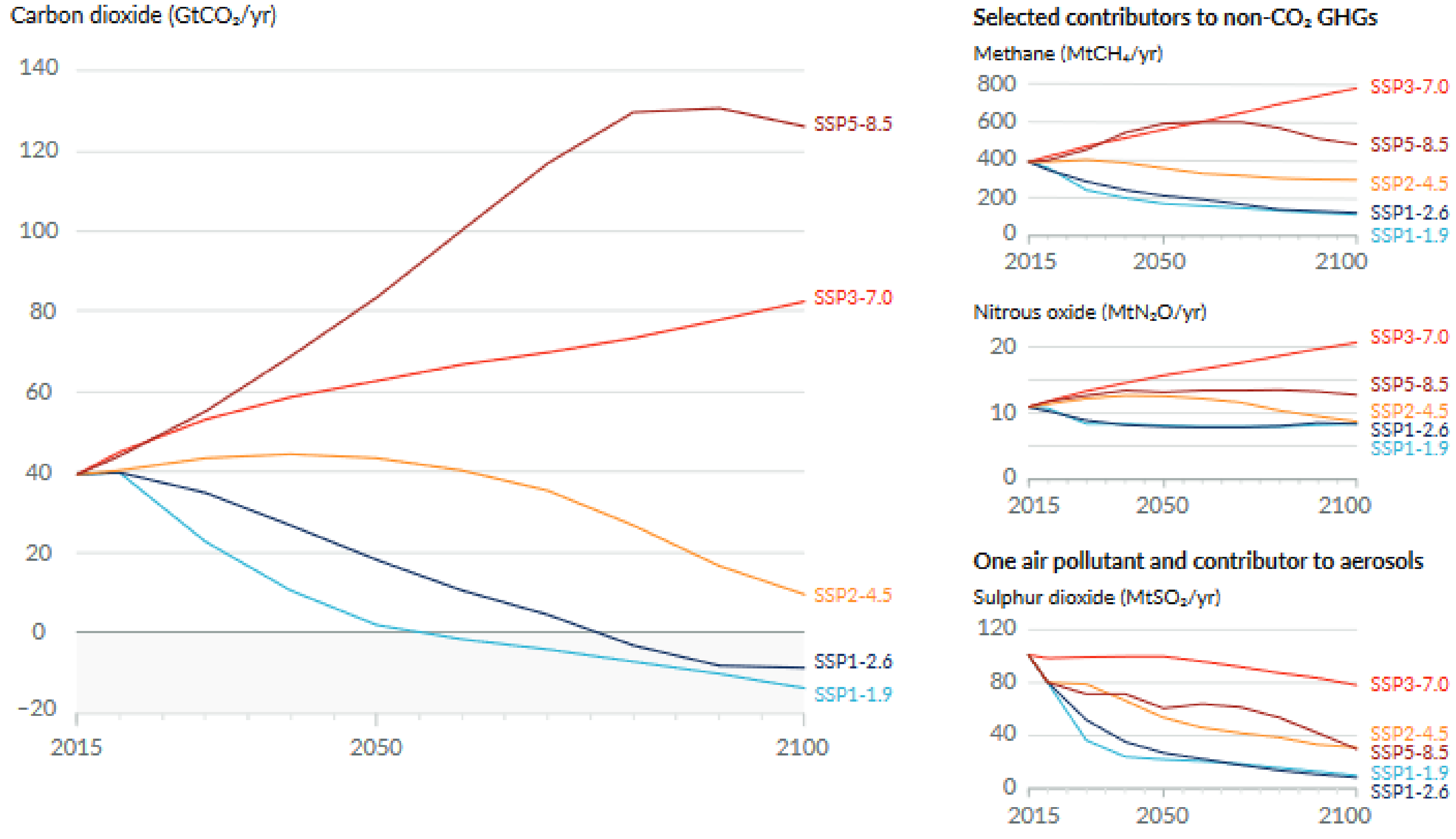
Hochschule
für nachhaltige Entwicklung
Eberswalde

- A new set of climate scenarios has been developed for the sixth IPCC report (IPCC AR6).
- The SSPs represent narratives for different socio-economic pathways resulting in different increases of atmospheric greenhouse gas concentrations …
- and leading to different levels of global warming.

P I K

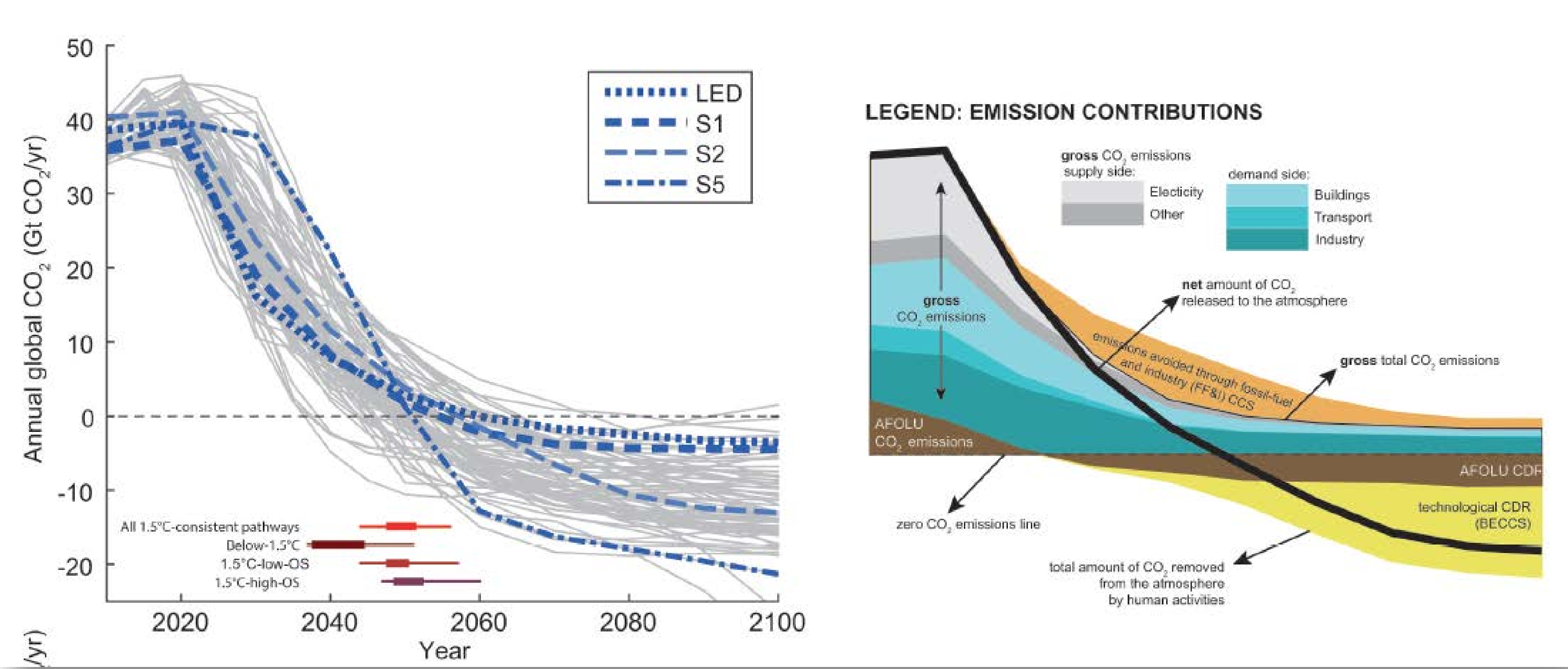
Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios



IPCC AR6 2021 summary for policy makers

Creating negative emissions through carbon dioxide removal (CDR)



BECCS CDR: Bioenergy with Carbon Capture Storage
AFOGU CDR: Agriculture, Forestry and other Landuse

IPCC SR 1.5

Expert community controversy about climate policy choice

Heated debates about the ‚right‘ policy approach to combat climate change

‚Market based‘ approaches (carbon pricing, taxes, emissions trading)

[often, but not only advocated by economists]

vs.

Regulation, standards, subsidies

[often, but not only advocated by political & social scientists, environmentalists]

vs.

…smart combinations?

A very brief history of the UNFCCC

(United Nations Framework Convention on Climate Change)

Hochschule
für nachhaltige Entwicklung
Eberswalde

- Following the creation of the IPCC, the need for a global treaty on emissions is established
- UNFCCC enters into force in 1994 with near-universal membership
- First Conference of the Parties (COP1) in Berlin in 1995

1988: IPCC established

1992: UNFCCC adopted at Earth Summit in Rio

1997: Kyoto Protocol signed

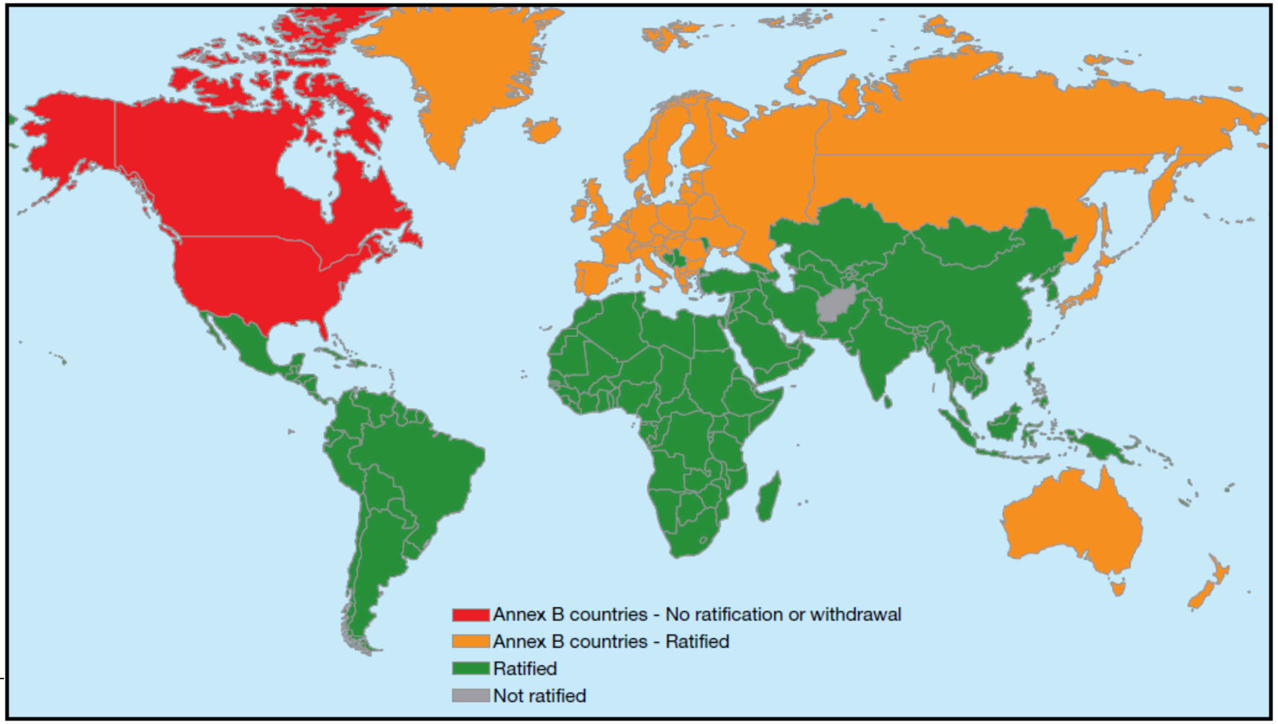
2009: COP15 in Copenhagen

2015: COP21 in Paris

Kyoto Protocol

Hochschule
für nachhaltige Entwicklung
Eberswalde

- An international treaty on climate change signed 1997 under the UNFCCC
- Meet objective of UNFCCC
- Idea: rich ("Annex B") countries commit to limiting their GHG emissions
  - To 5.2% below 1990 levels during the compliance period
  - This corresponds to about 20% below BAU, according to ex-ante model estimates
- No caps on non-Annex B countries
- USA did not ratify
- First compliance (commitment) period: 2008-12 (Canada, Japan, Russia, dropped out afterwards)
- Extended in Doha 2012 to a second compliance period, but with further reduced participation: covers only 15% of global emissions



Source: UNFCC

Annex B of the Kyoto Protocol

Country	Kyoto target 2008-2012 (percent change from 1990 emissions)	Projected emissions in 2000 (percentage change from 1990 emissions)
Australia	+8	+15
Bulgaria	-8	-28
Canada	-6	+10
Croatia	-5	na
Estonia	-8	-46
European Union	-8	+3
Hungary	-6	-18
Iceland	+10	+5
Japan	-6	+4
Latvia	-8	-26
Liechtenstein	-8	+18
Lithuania	-8	na
Monaco	-8	na
New Zealand	0	+16
Norway	+1	+11
Poland	-6	-17
Romania	-8	na
Russian Federation	0	-17
Slovakia	-8	-16
Slovenia	-8	na
Switzerland	-8	-3
Ukraine	0	na
United States	-7	+4

Perman et al. 2003

Flexibility Mechanisms under the Kyoto Protocol

Idea: introduce market-based mechanisms to increase efficiency

International emission trading

- Annex-B countries that overachieve their targets can sell certificates to other countries

Clean Development Mechanism (CDM)

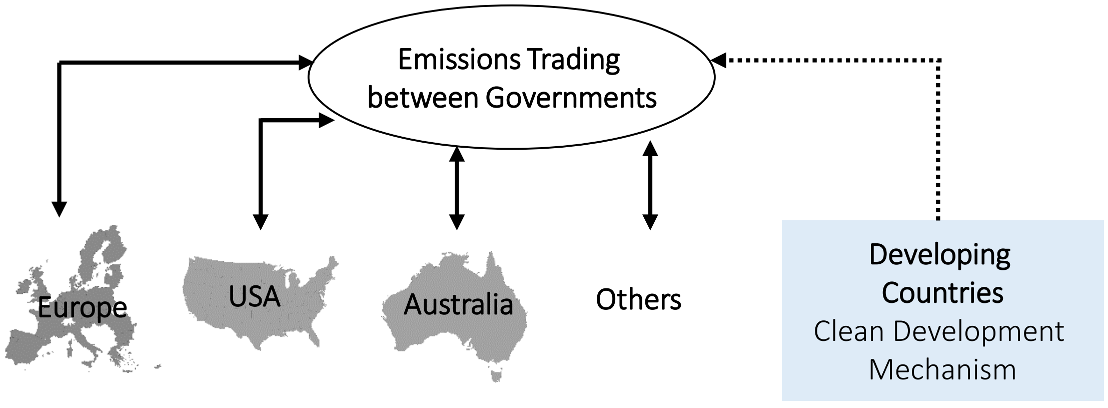
- Project-based emission reduction in non-Annex-B countries
- Certificates (CERs) can be "imported" to Annex-B countries

Joint Implementation (JI)

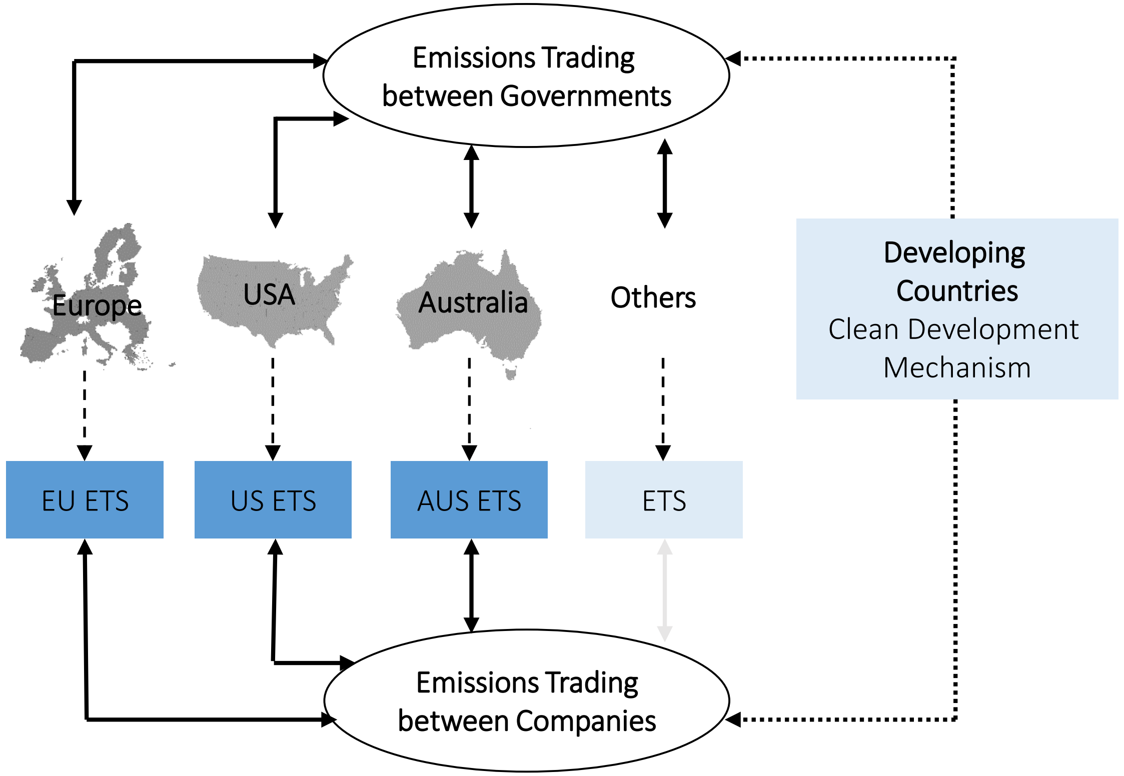
- Project-based emission reduction in Annex-B countries
- Certificates can be "imported" to Annex-B countries
- Only 10% of the size of CDM

Kyoto Emissions Trading Architecture

Hochschule
für nachhaltige Entwicklung
Eberswalde



Envisaged Kyoto structure: devolving trading to private sector



Initial idea:
Devolve govt. trading to private sector (didn‘t materialize internationally)

Flachsland (2009)

How does your country perform?

Hochschule
für nachhaltige Entwicklung
Eberswalde

Task: Investigate the state of mitigation using the climate actions tracker

-> https://climateactiontracker.org/

Questions:

- How does your country perform?
- Where do we get (global temperature increase) based on current policies and actions? Based on pledges and targets? Based on optimistic scenario? -> “The CAT Thermometer”
- How huge is the 2030 emissions gap? -> “CAT emission gap”

P I K

Agenda

1. Introduction: CC and selected impacts
2. How is a climate scenario defined?
3. Does the polluter pay?
   Internalizing the climate externality
4. Suggested tasks for presentations

Expert community controversy about climate policy choice

Hochschule
für nachhaltige Entwicklung
Eberswalde

Heated debates about the ‚right' policy approach to combat climate change

‚Market based' approaches (carbon pricing, taxes, emissions trading)

[often, but not only advocated by economists]

vs.

Regulation, standards, subsidies

[often, but not only advocated by political & social scientists, environmentalists]

vs.

…smart combinations?

P I K

Climate Change and Policy Intervention

Hochschule
für nachhaltige Entwicklung
Eberswalde

Global warming will severely affect economy and human well-being (negatively)

- Do these impacts not already ‚justify' a policy intervention from an economic perspective?

Economic perspective: No! Not climate impacts justify intervention, but market failures

- **There is a conceivable outcome where an individual may be made better-off without making someone else worse-off.**

PIK

"Climate change is the biggest market failure the world has ever seen."

(Stern Review 2007)

Definition: Market Failure

Market failure

- A situation in which the market-driven allocation of goods and services (i.e., the competitive equilibrium) is not Pareto-efficient (or "Pareto-optimal")
- That is, there exists another conceivable outcome where an individual may be made better-off without making someone else worse-off

Market failures can be the results of ...

  - ... the nature of a market (interaction)
  - ... the nature of a good (missing market, externality)

Definitions

Externality:

An externality is a cost or benefit caused by a producer that is not financially incurred or received by that producer.

Internalization:

Internalization occurs when a transaction is handled by an entity itself rather than routing it out to someone else.

Marginal costs:

In economics, the marginal cost of production is the change in total production cost that comes from making or producing one additional unit.

Climate Change as Market Failure

Basic source of market failure: **Externality of producing emissions**

- Every firm can emit carbon dioxide (as by-product of production)
- Emissions cause global warming and climate damages that reduce welfare
- Emitters do not factor in the damages they cause

➔ More emissions than socially optimal

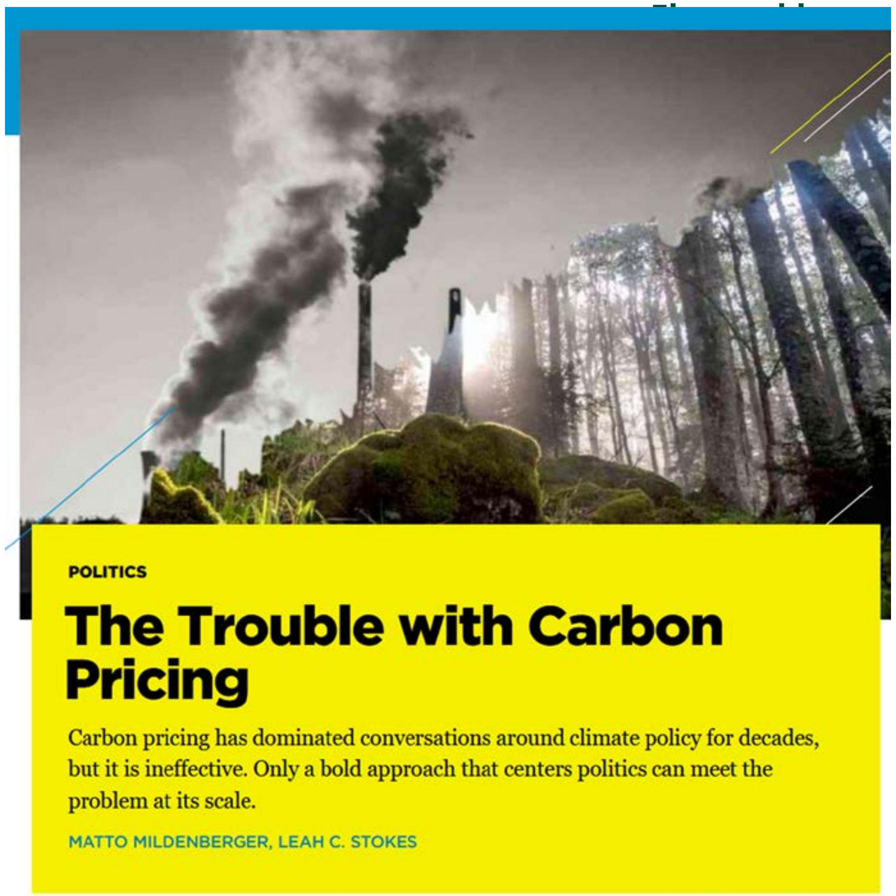
➔ There exist a Pareto-improvement which can make everybody better of if less carbon is emitted

Carbon Pricing vs. Other Policies

Hochschule
für nachhaltige Entwicklung

Typical arguments against carbon pricing

- Carbon pricing has played a minor role compared to other policies
- If at all, existing carbon pricing schemes have achieved marginal emission reductions
    - But no break-through technology, no innovation, no investment
- By contrast, Renewable energy subsidies were successful
- Heated debates about the right policy (in academia but also in the public)
- Key evaluation criteria:
    - Effectiveness
    - Efficiency
    - Equity
    - Political feasibilty



Source: http://bostonreview.net/science-nature-politics/matto-mildenberger-leah-c-stokes-trouble-carbon-pricing

P I K

Summing Up

Hochschule
für nachhaltige Entwicklung
Eberswalde

- **In the economic perspective: crucial questions for policy evaluation are**
  - what is (are) the underlying market failures
  - how does a policy address these
  - what are the efficiency gains (or costs) of this policy
  - what are the distributional effects
- **In a broader perspective, key evaluation criteria are**
  - **Environmental effectiveness**: are emissions reduced?
  - **Static cost effectiveness**: are short-term emission reductions achieved at least cost?
  - **Dynamic cost effectiveness**: are long-term emission reductions achieved at least cost (taking innovation and investment into account)?
  - **Distributional impacts**: on population groups, firms, etc.
  - **Feasibility**: administrative requirements, political support

PIK

Make the polluter pay

Hochschule
für nachhaltige Entwicklung
Eberswalde

1. Internalizing the climate externality
   a) **Voluntary mitigation & bargaining**
   b) Carbon pricing
   c) Subsidies
   d) Standards
   e) Comparison

P I K

Voluntary mitigation: The Kantian perspective

Hochschule für nachhaltige Entwicklung Eberswalde

Kantian approach

- Categorical Imperative abridged: „For an action to be moral, it must be that I would be willing to make the maxim (principle) that motivates the action a universal law (i.e. a principle to be followed everywhere and always by rational agents)"

→ Everyone should reduce emissions voluntarily?

→ Probably: yes

- Challenges

Knowing about climate change

- (Initially) limited choices: technology and and infrastructure context for individual action – restricting consumption as main – very costly – individual reduction option
- High individual costs relative to negligible benefits of individual action
- …overall, a pretty high moral standard that few individuals appear to pass (I don't)

PIK

Bargaining: The Coase Theorem

- Ronald Coase (1960): *The Problem of Social Cost*
  - Chicago Law School

- The idea (Coase Theorem)
  - Under certain conditions, parties trade and reach the efficient outcome – without state intervention
  - Not even Coase thought the Coase theorem applies on most cases

- Conditions
  - Well-defined property rights
  - Limited transaction costs
  - No free-rider problem (collective action problem)

Ronald Coase (1910 – 2013), Nobel Laureate 1991

*The free rider problem is the burden on a shared resource that is created by its use or overuse by people who aren't paying their fair share for it or aren't paying anything at all.

Make the polluter pay

1. Internalizing the climate externality

   a) Voluntary mitigation & bargaining

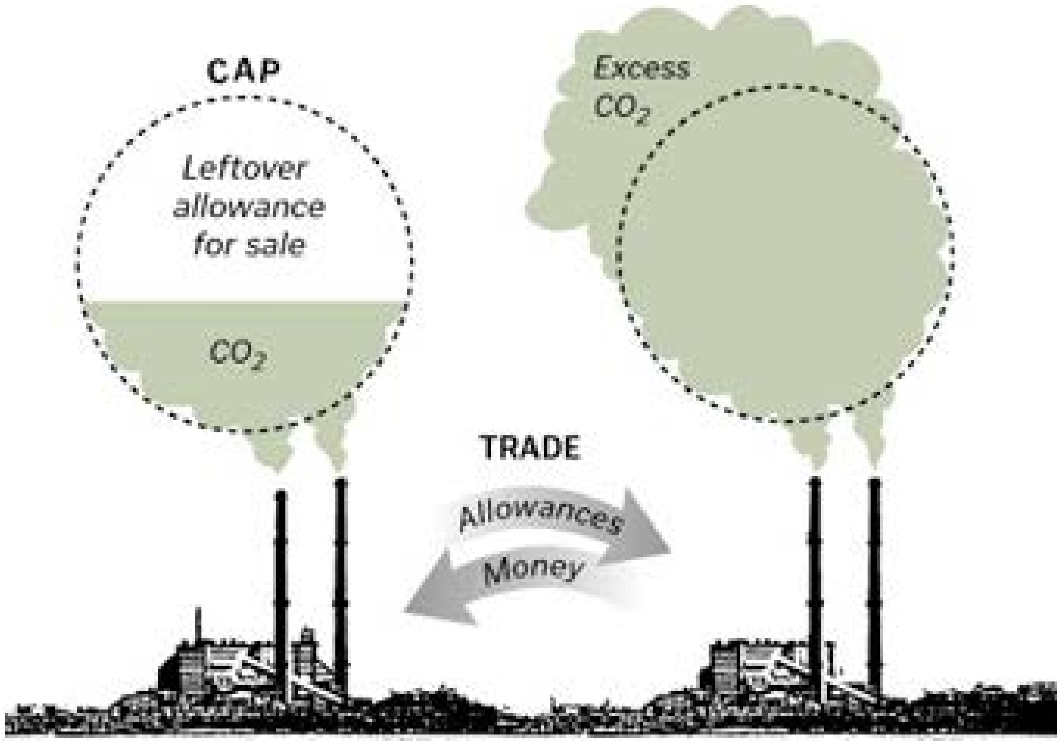
   b) **Carbon pricing**

   c) Subsidies

   d) Standards

   e) Comparison

Carbon Trade



Börsenhandel (Sekundärmarkt)

ICE ENDEX

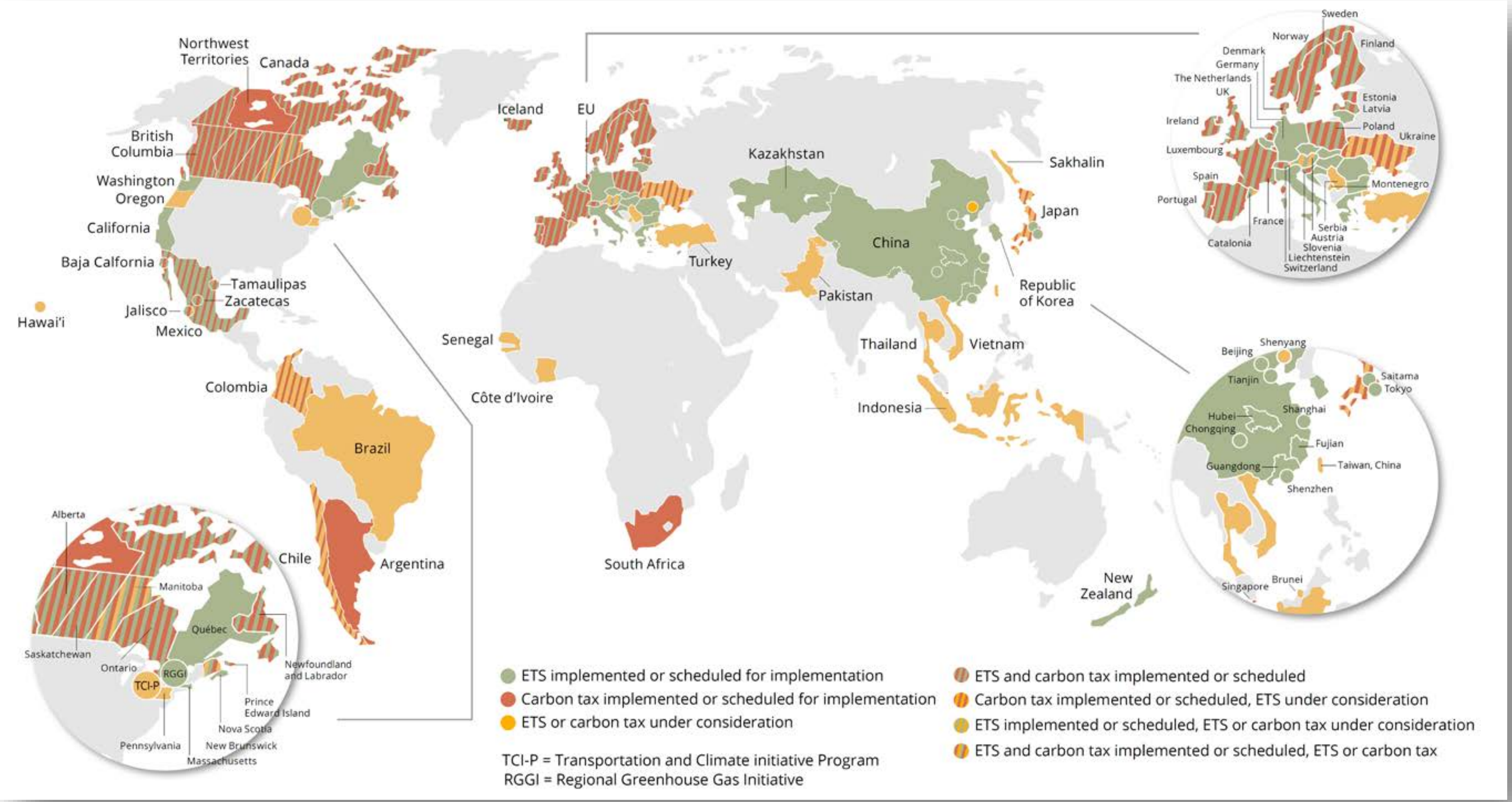
EUA Daily Future

CONTRACT	LAST	TIME(GMT)	% CHANGE	VOLUME
FUTURES TODAY	62.480	9/29/2021 7:05 AM	0.000	31

INTRADAY | 3 MONTHS | 1 YEAR | 2 YEARS | LAST UPDATE TIME: 09-29-2021 7:51 AM GMT

Countries with carbon pricing in place or scheduled

Hochschule für nachhaltige Entwicklung Eberswalde



World Bank 2021

PIK

ETS: Emissions Trading System

Greenhouse gas emissions: internalization

Internalization: put a price tag on emissions

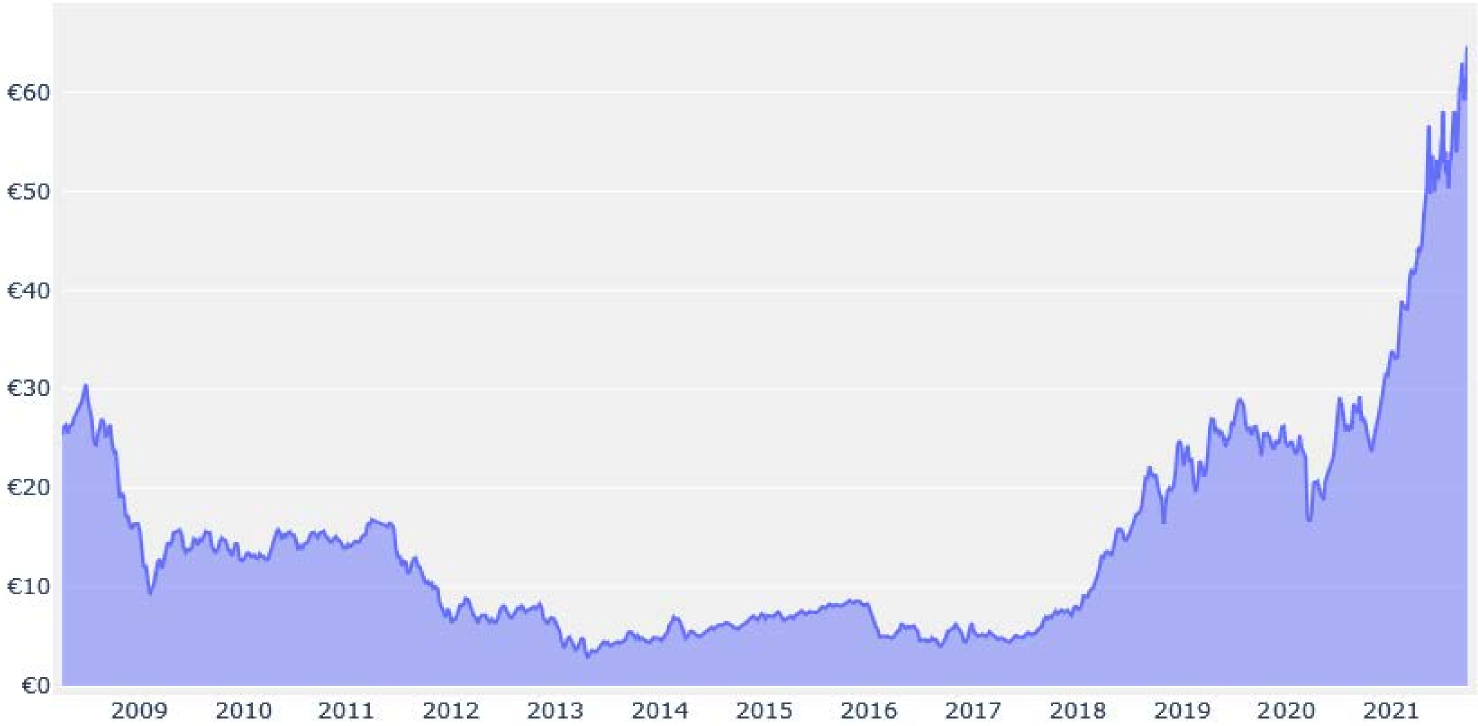
- With the additional price, the utility factors in the negative effects on others
- Consequently, it will emit less

Price should correspond to the damage done (external cost)

- Then, private and social incentives are aligned
- The privately optimized quantity of emissions resembles the planner quantity

Price of certificates/credits: Indicator for functionality

Prices in EU-ETS



https://sandbag.be/index.php/carbon-price-viewer/

Textbook "Environmental Economics":

- the lower the demand / abatement costs, the lower the price
- low prices = low demand -> no problem

Textbook "Transformation":

- Low prices = low incentives to reduce emissions ➝ **big problem**

2008: Financial crisis reduces demand for certificates

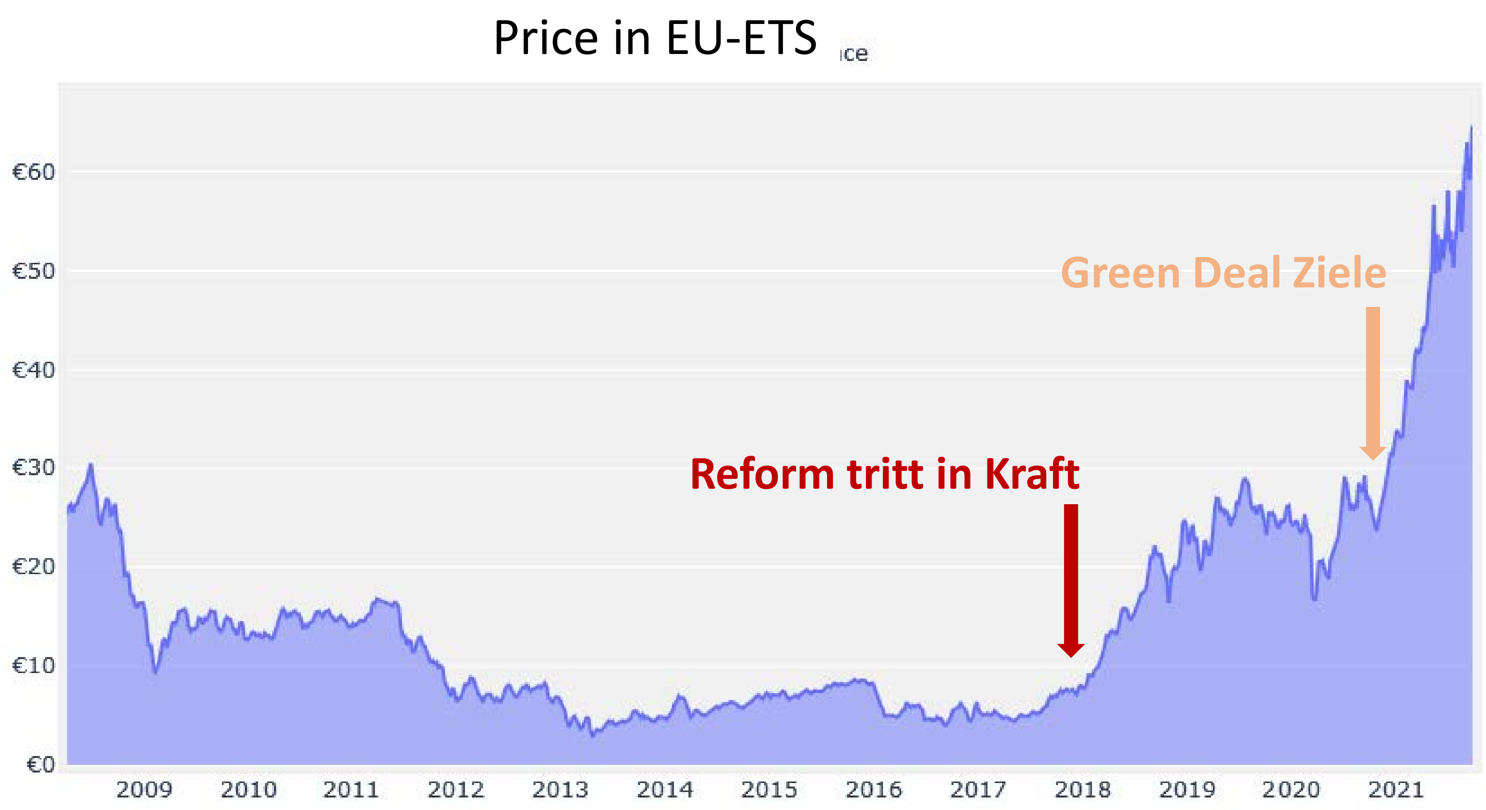
Hochschule
für nachhaltige Entwicklung
Eberswalde

Prices in EU-ETS

https://sandbag.be/index.php/carbon-price-viewer/

2018: Reform of ETS for Phase IV (2021-2030)

Hochschule
für nachhaltige Entwicklung
Eberswalde



https://sandbag.be/index.php/carbon-price-viewer/

- *New deal 2023*
- *Market participants are already pricing in future cancellation (cf. also Green Deal Dec. 2020).*

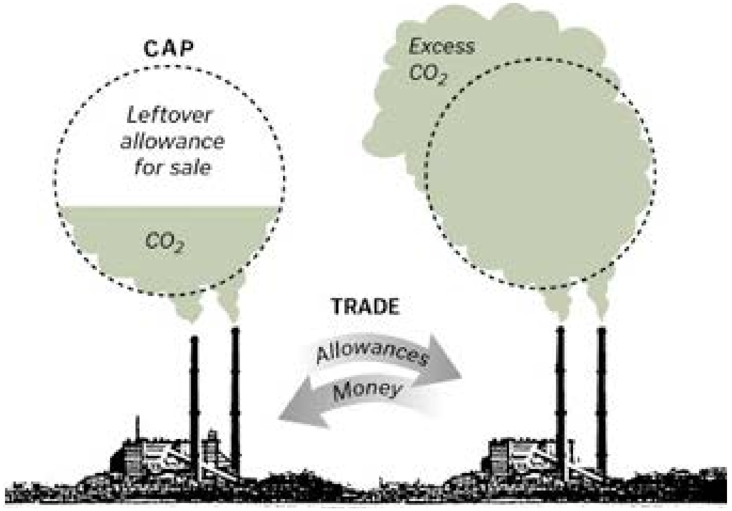
Cap-and-trade schemes in three steps

Hochschule
für nachhaltige Entwicklung
Eberswalde

1. **Create property rights**
   - Create rights to pollute through legislation
   - Before: anyone could emit

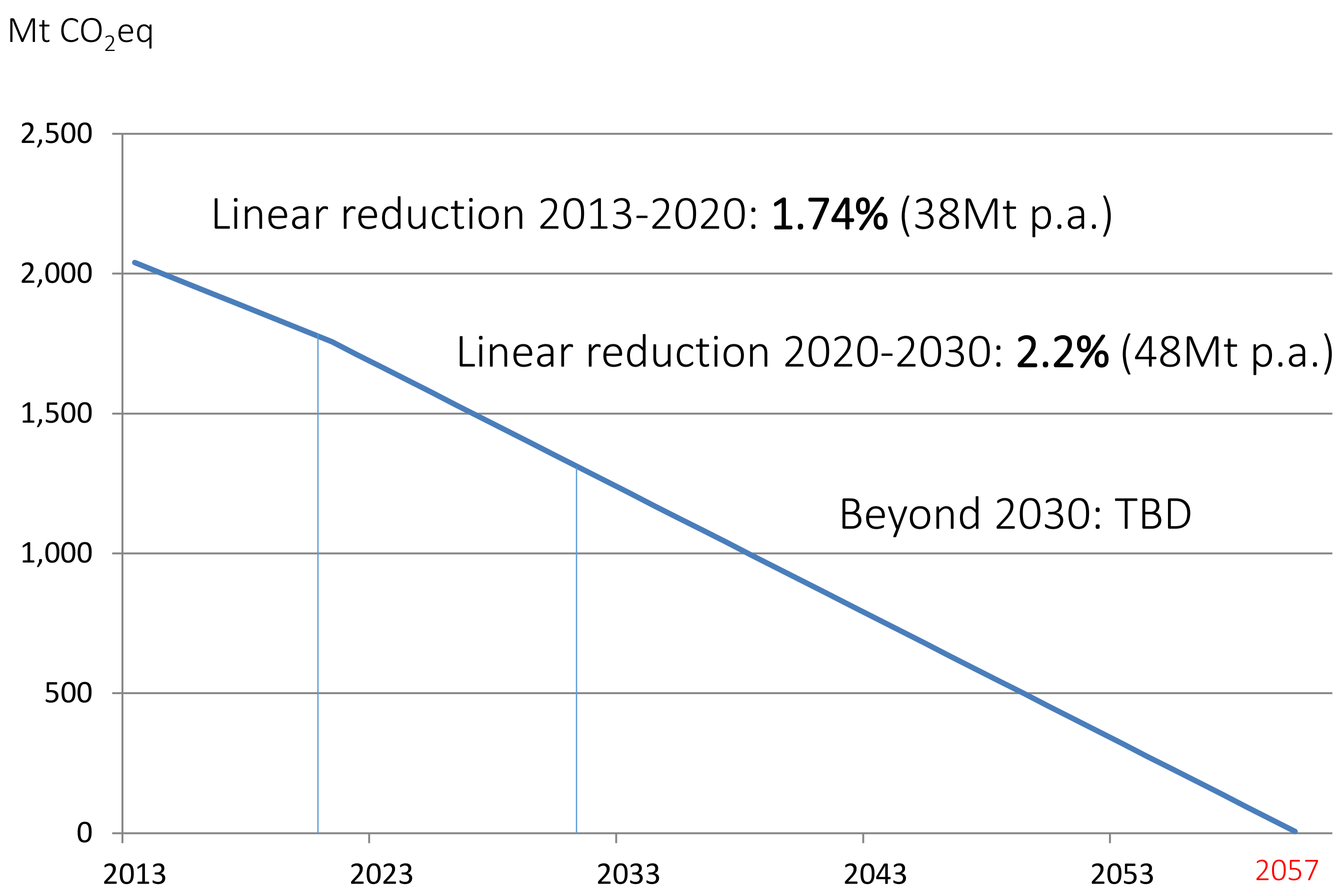
2. Set a cap
   - Government sets an overall limit on emissions (“cap” or “budget”)

3. Allow for trading
   - Firms can sell or buy permits from other firms at the marketplace
   - Governments distribute permits for free or sell them to emitting parties
   - The permit price that emerges from the transaction is the price on emissions



P I K

EU ETS cap and mitigation pathway (in principle)



MCC-PIK assessment informing German Climate Cabinet (18.7.2019)

https://bit.ly/2GrMXU3

"The goal is a uniform carbon price across all sectors. Emissions must be cut at unprecedented speed. Therefore, economies need to ensure efficiency of mitigation pathways and minimize costs. Emissions should be reduced where doing so is cheapest and most innovative potential can be tapped."

(Page 14)

"A cross-sectoral single price should become the core instrument of climate policy. Yet dynamic incentives of carbon pricing can be distorted by market or policy failures. Therefore, a carbon price path should be complemented by sector-specific policy instruments and measures that specifically correct these failures. "

(Page 17)

Impact of CO2-price increase on German households

Hochschule für nachhaltige Entwicklung Eberswalde

Energieträger	Einheit	Preis Privathaushalte (2015-2018)	Preisanstieg bei CO_2-Preis 50 Euro/tCO_2	Preisanstieg bei CO_2-Preis 130 Euro/tCO_2
Benzin	Cent/Liter	135,19	14,10	36,66
Diesel	Cent/Liter	117,44	15,77	41,00
Heizöl*	Cent/Liter	58,13	8,23	33,09
Erdgas*	Cent/kWh	6,25	0,42	2,15
Braunkohle*	Cent/kWh	7,50	1,99	5,38
			Klimadividende	
Vollständige Rückerstattung	Euro/Person und Jahr		98	265
Rückerstattung bei Stromsteuersenkung	Euro/Person und Jahr		66	233

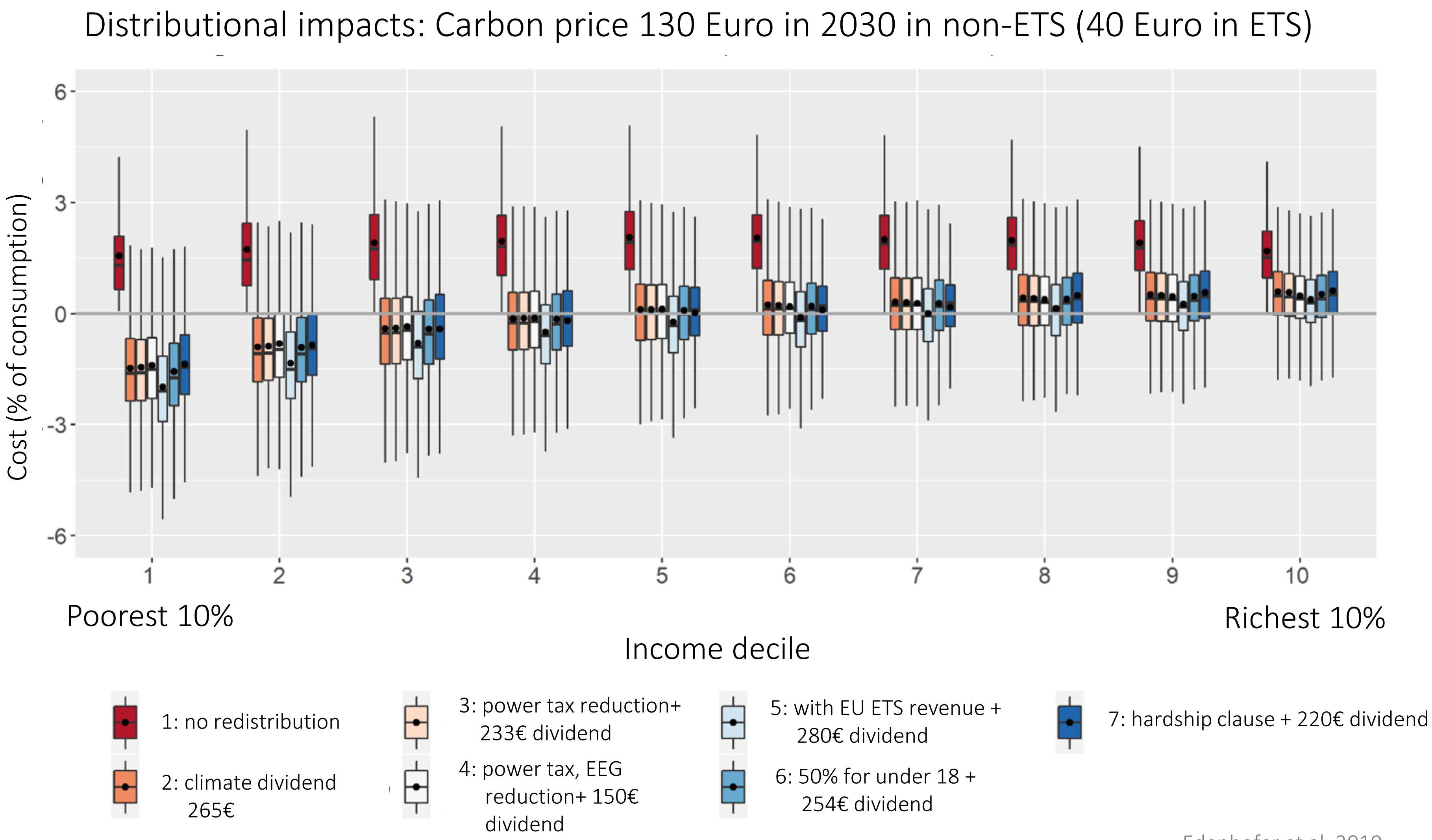
Preise für Privathaushalte, inkl. Mehrwertsteuer. Der Preisanstieg bei Erdgas bezieht sich auf den handelsüblichen oberen Heizwert.
*Für den Preisanstieg bei Heizöl, Erdgas und Braunkohle wird der CO_2-Preis mit bestehenden Energiesteuern verrechnet (harmonisierter CO_2-Preis)

The trick: everybody gets the same amount of money back!

Source: MCC-PIK (2019).

PIK

Revenue recycling options and distributional impacts



Edenhofer et al. 2019

Agenda

Hochschule
für nachhaltige Entwicklung
Eberswalde

1. Internalizing the climate externality

   a) Voluntary mitigation & bargaining

   b) Carbon pricing

   c) **Subsidies**

   d) Standards

P I K

Internalizing the climate externality using subsidies

Hochschule für nachhaltige Entwicklung Eberswalde

Idea: Instead of taxing dirty technologies, subsidize clean technologies

- Often appears politically more attractive – diffuse losers, concentrated winners
- Make clean tech competing with dirty tech economically more attractive
- Up to the point where dirty tech eventually leaves the market
- Does not actually internalize the climate externality – polluter doesn‘t pay

Examples:

- Monetary payments & tax breaks for deployment of renewable and energy efficiency technologies (solar panels, wind turbines, electric vehicles, home insulation, …)
- Monetary payments for phasing-out of GHG emitting technologies (e.g. coal power plant shutdown, cash-for-clunkers, …)
- Monetary payments, tax breaks, state-funded organizations for basic clean tech research & development

PIK

Challenges

Problems of using subsidies to internalize GHG externalities:

- Government require information about least cost clean technologies and subsidize right technologies at right level – otherwise too much/little deployment, some options not considerd
- No incentive to reduce consumption of GHG emitting products other than substituting away
- Rebound effect: Subsidizing clean energy incentivizes additional (cheap) energy consumption

Let the polluter pay

Hochschule
für nachhaltige Entwicklung
Eberswalde

1. Internalizing the climate externality
   a) Voluntary mitigation or bargaining
   b) Carbon pricing
   c) Subsidies
   d) **Standards**
   e) Comparison

P I K

Standards (rules, laws)

The idea

- Ban, limit or otherwise regulate harmful activity directly

Command-and-control instruments

- Also “direct regulatory instruments” or “prescriptive regulation”
- Very common form of environmental regulation

A broad and heterogeneous group of polices

- Input control: ban / moratorium on fossil fuel mining
- Output control: no firm can emit more than X tons of pollutant Z
- Bans/limits: ban on incandescent light bulb, limits on the rating of vacuum cleaners
- Standards: vehicle fuel efficiency standards, efficiency requirements for buildings
- Technology control: requirement to use a particular method or technology, e.g., catalytic converters in cars, “scrubbers” or CCS in coal-fired power plants
- Directives to state-owned enterprises (SOEs): e.g. mandate reducing coal power plant CO_2 emissions, enhance production of renewable energy

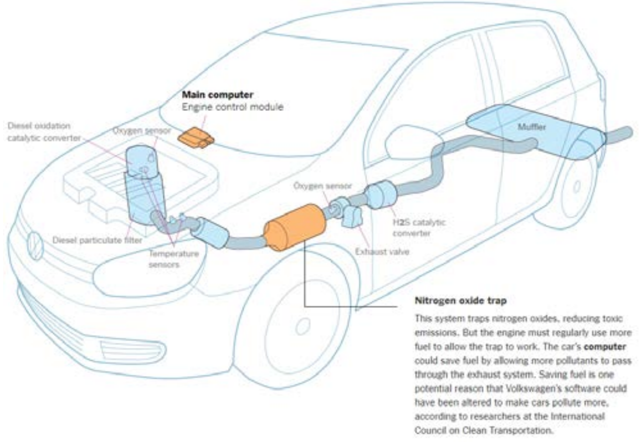
Standards: pro’s and con’s

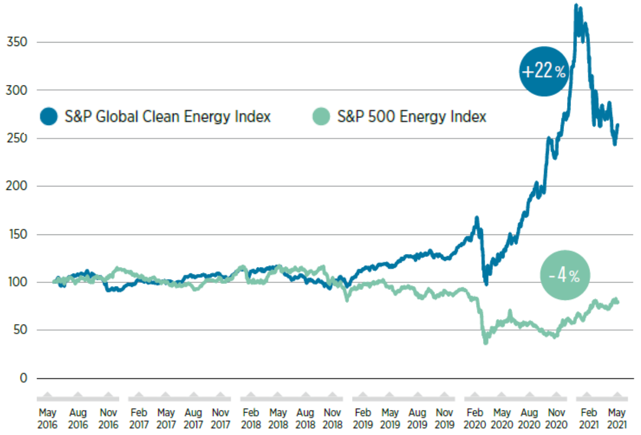
- Across the bord judgment of such a broad group of policies is difficult
  - Let’s try anyway
- Pro: sometimes easier to monitor
  - Installation of catalytic converters in cars is easier to verify than actual emissions while driving
- Pro: can be infused with market elements to resemble price-based instruments
  - For example, tradable renewable portfolio or vehicle performance standards
- Con: requires substantial knowledge on the part of the regulator
  - Firms have heterogeneous costs
  - Information asymmetry: firms have an incentive to hide private costs
- Con: might lack dynamic incentives
  - Can stifle innovation if locking in an existing technology (but can also be well-designed)

Tempting human ingenuity

Hochschule
für nachhaltige Entwicklung
Eberswalde

- Bans trigger efforts to avoid them
  - Building standards make people try to find ways to sneak around
  - Fuel efficiency standards for cars have lead to massive efforts to cheat
  - Cars are optimized to perform on driving cycles, rather than real-world perfomance
- Prices mean profit opportunities
  - Price incentives create profit opportunities
  - “Do good and become rich”





Comparison of policy instruments for reducing GHG emissions

Hochschule für nachhaltige Entwicklung Eberswalde

	Carbon Pricing	Subsidies	Standards
Environmental effectiveness	High - depends on stringency & design (coverage, credibility, ...), price elasticities	Medium – no direct incentive to reduce emissions, depends on stringency & design	High – depends on stringency & design (coverage, ...)
Static cost-effectiveness	High – harmonized marginal abatement costs, depends on coverage	Low – heterogeneous marginal abatement costs, depends on coverage and design	Low – heterogeneous marginal abatement costs, depends on coverage and design (flexibility)
Dynamic cost-effectiveness	Medium – depends on credibility of long-term price signal, foresight of economic actors	Medium – depends on government incentivizing „right“ technologies, stringency, coverage	Medium – depends on government incentivizing „right“ technologies, stringency, coverage
Progressive distributional impacts	High - Revenue recycling enables targeting distributional outcomes	Medium - depends on context – targeting distributional outcomes can be challenging	Medium - depends on context – targeting distributional outcomes can be challenging
Political feasibility	Medium - context-specific, often challenging	High - tend to be widely accepted (at stringency levels in the past)	High - tend to be widely accepted (at stringency levels in the past)

P I K

Takeaways

- From the climate economics perspective, GHG emissions are an externality to be internalized
- Economists almost virtually universally agree carbon pricing is the best instrument to do the job
- Other instruments (subsidies, standards) less suited because they require government information and face rebound effects
- Multiple instruments are required even in the economics perspective
- Rationale: Additional market (and possibly government) failures
- One instrument per failure – calibrate carefully, which is challenging
- Cost-effectiveness enables maximizing emission reductions and minimizing distributional conflict

MCC-PIK assessment informing German Climate Cabinet (18.7.2019)

https://bit.ly/2GrMXU3

"The goal is a uniform carbon price across all sectors. Emissions must be cut at unprecedented speed. Therefore, economies need to ensure efficiency of mitigation pathways and minimize costs. Emissions should be reduced where doing so is cheapest and most innovative potential can be tapped."

(Page 14)

"A cross-sectoral single price should become the core instrument of climate policy. Yet dynamic incentives of carbon pricing can be distorted by market or policy failures. Therefore, a carbon price path should be complemented by sector-specific policy instruments and measures that specifically correct these failures. "

(Page 17)

Impact of CO2-price increase on German households

Hochschule für nachhaltige Entwicklung Eberswalde

Energieträger	Einheit	Preis Privathaushalte (2015-2018)	Preisanstieg bei CO_2-Preis 50 Euro/tCO_2	Preisanstieg bei CO_2-Preis 130 Euro/tCO_2
Benzin	Cent/Liter	135,19	14,10	36,66
Diesel	Cent/Liter	117,44	15,77	41,00
Heizöl*	Cent/Liter	58,13	8,23	33,09
Erdgas*	Cent/kWh	6,25	0,42	2,15
Braunkohle*	Cent/kWh	7,50	1,99	5,38
			Klimadividende	
Vollständige Rückerstattung	Euro/Person und Jahr		98	265
Rückerstattung bei Stromsteuersenkung	Euro/Person und Jahr		66	233

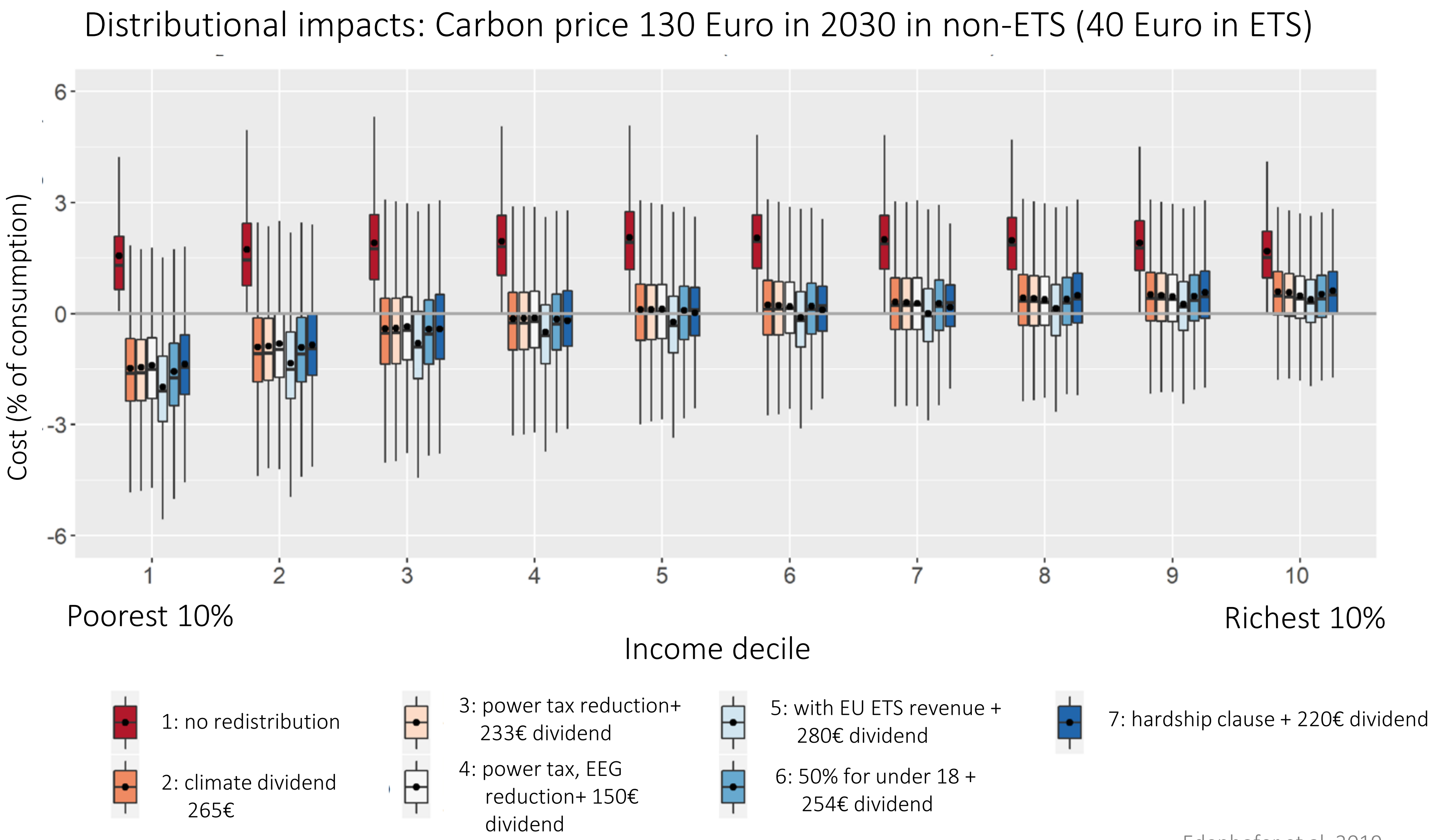
Source: MCC-PIK (2019).

Preise für Privathaushalte, inkl. Mehrwertsteuer. Der Preisanstieg bei Erdgas bezieht sich auf den handelsüblichen oberen Heizwert.
*Für den Preisanstieg bei Heizöl, Erdgas und Braunkohle wird der CO_2-Preis mit bestehenden Energiesteuern verrechnet (harmonisierter CO_2-Preis)

The trick: everybody gets the same amount of money back!

PIK

Revenue recycling options and distributional impacts



Edenhofer et al. 2019

Mitigation and adaptation

- Despite mitigation efforts, climate change will continue
- We are in the midst of climate change
- The number and intensity of climate extremes is on the rise
- => We have to adapt!

Ideal are measures combining mitigation and adaptation

Adaptation in cities

Smart cities world

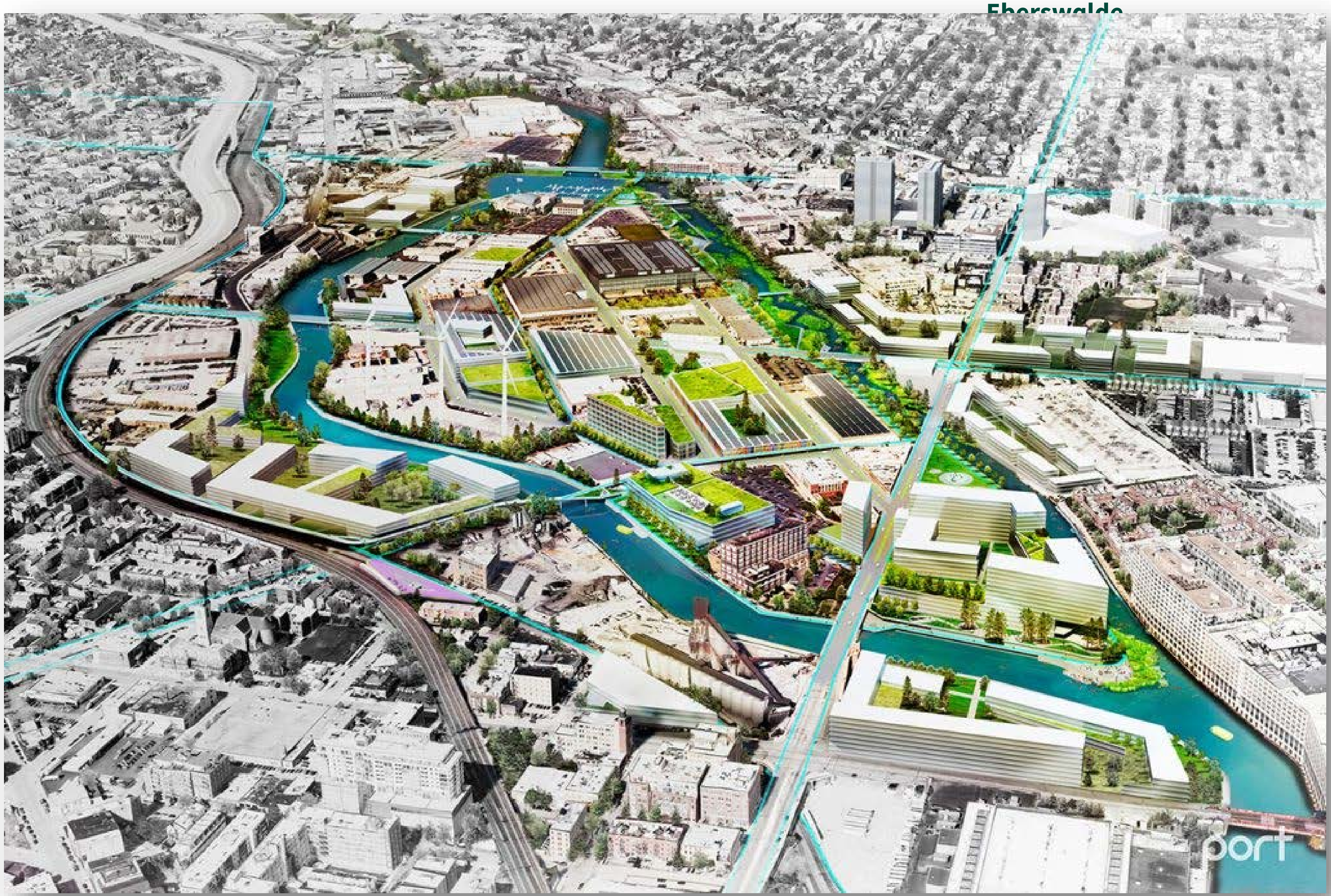
Adaptation in cities - Examples

Sponge city/urban district in Berlin
Infiltration leads to groundwater recharge and prevention of flash floods

Green roofs for cooling and production
https://unhabitat.org/programme/city-resilience-profiling-programme

Adaptation in cities - Examples

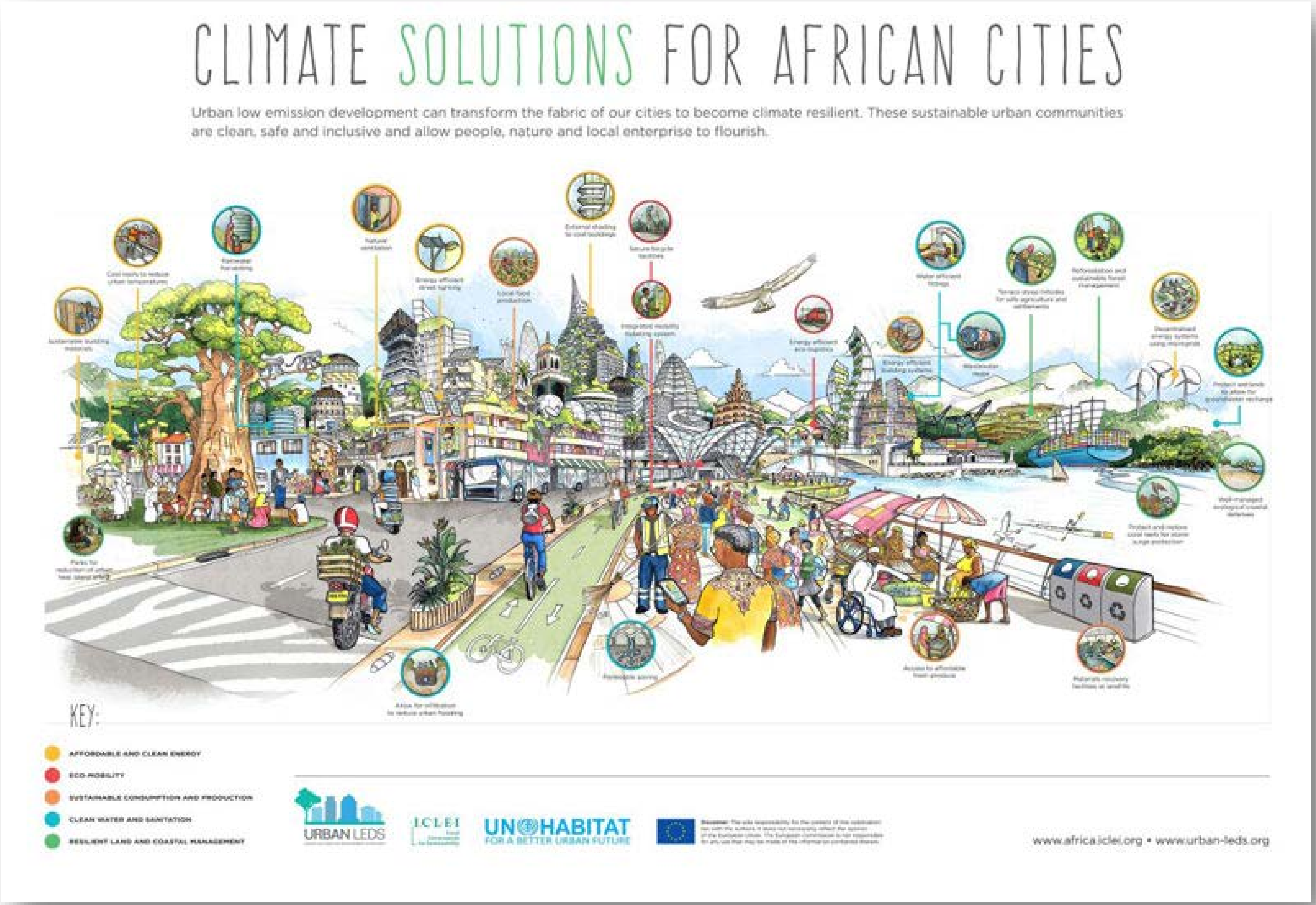
Hochschule
für nachhaltige Entwicklung
Eberswalde



https://environment.princeton.edu

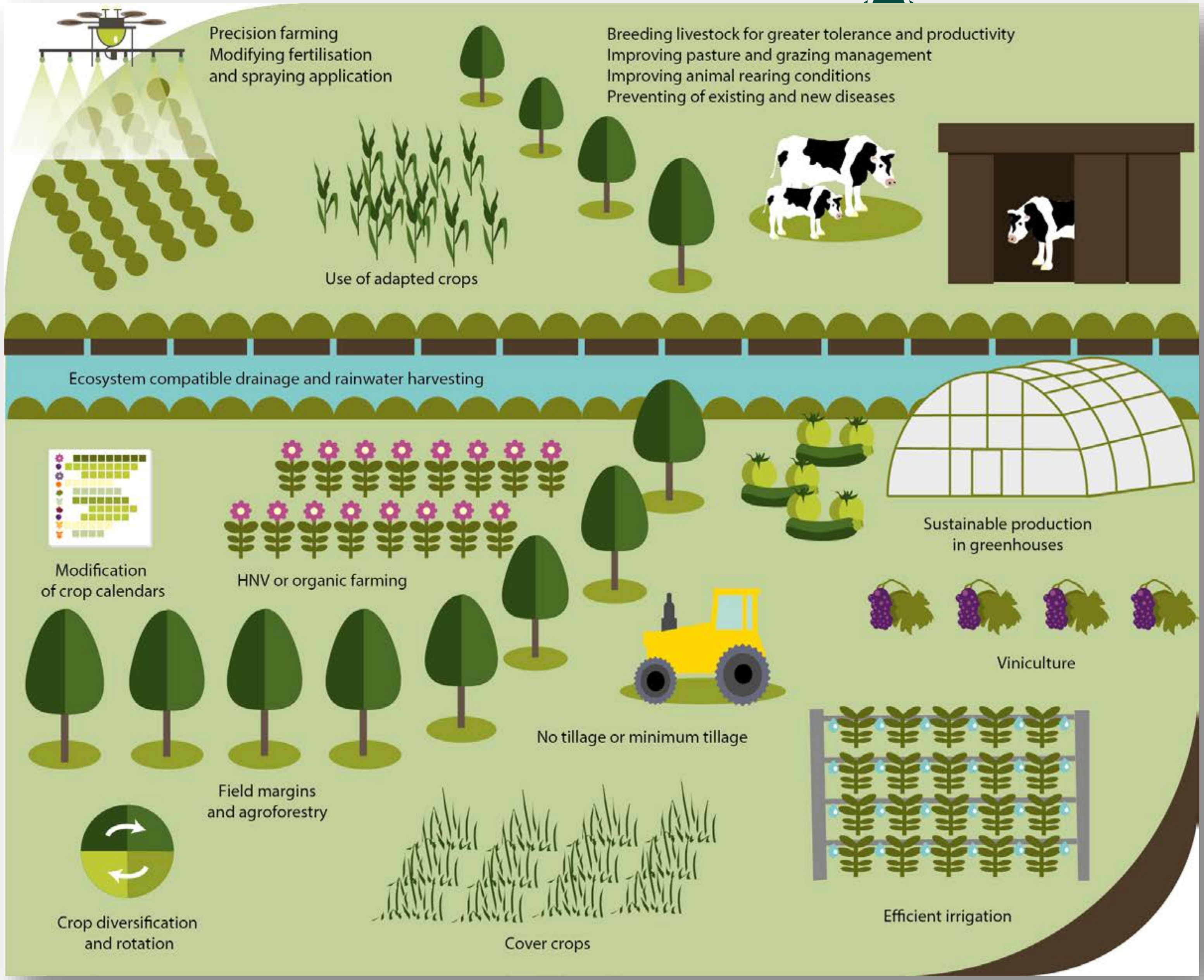
PIK

Adaptation in cities



https://www.connective-cities.net

Adaptation in agriculture

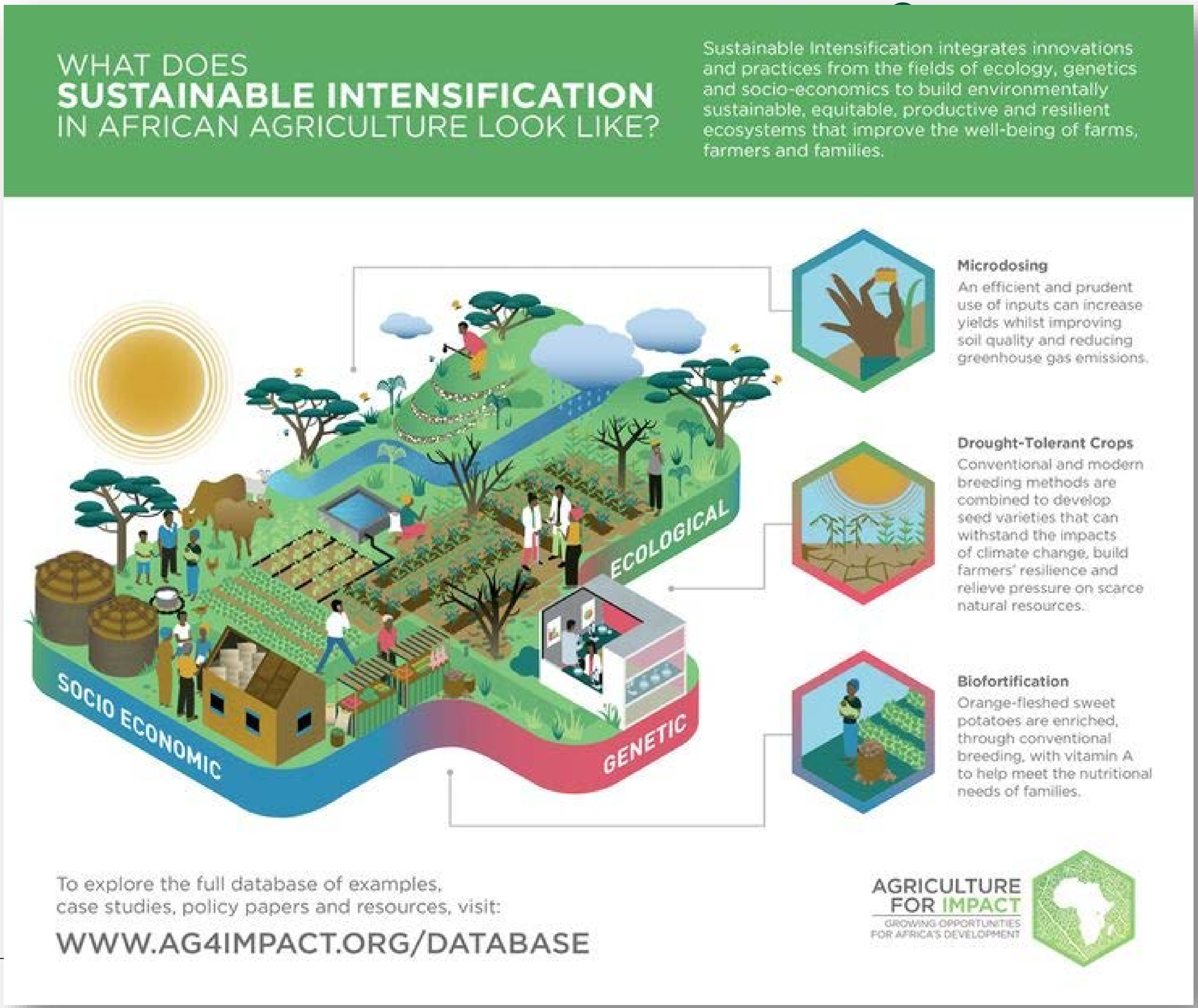


EEA: European Environmental Agency

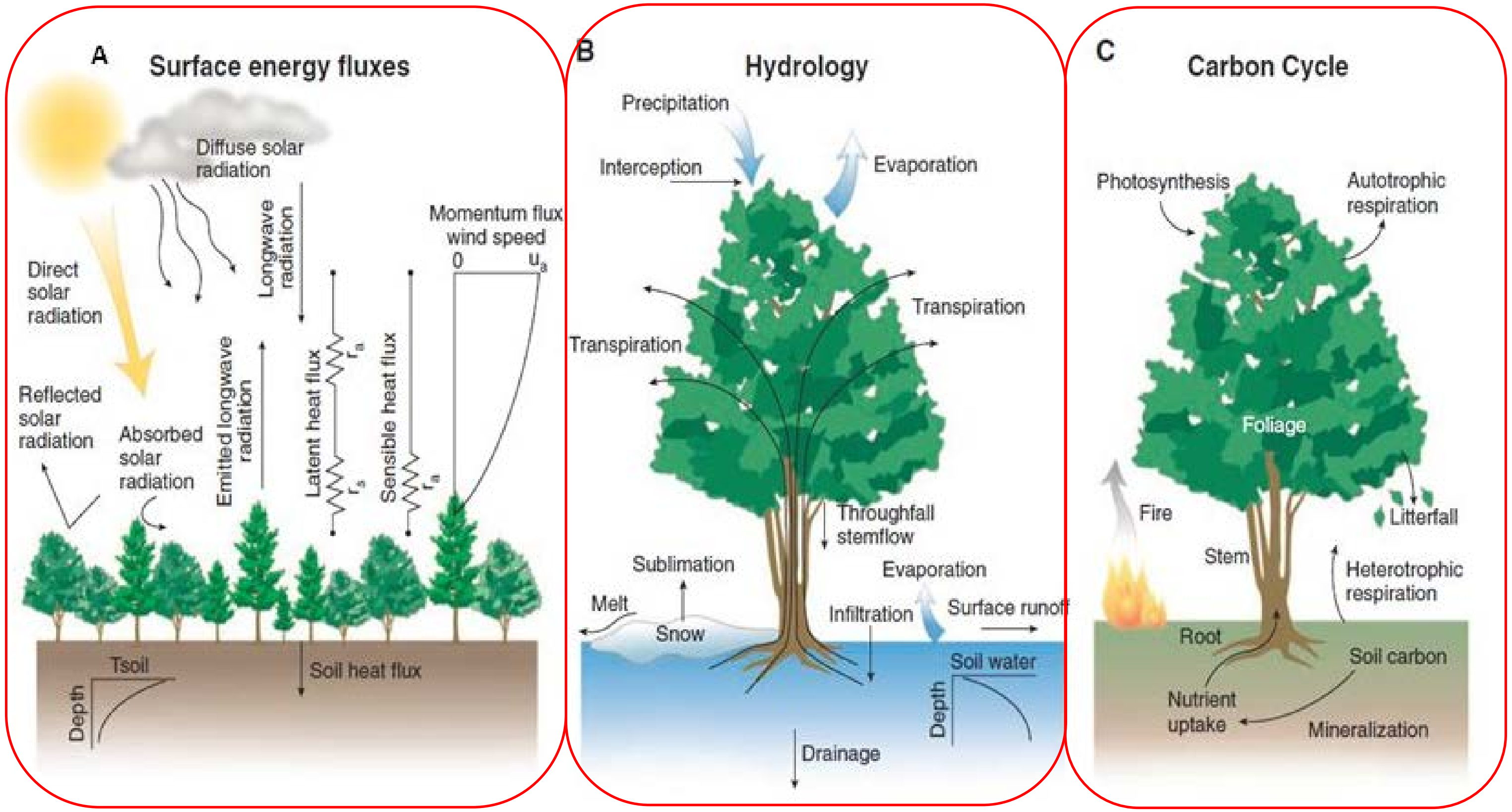
Adaptation in agriculture

LIFE AgriAdapt project

Adaptation in agriculture

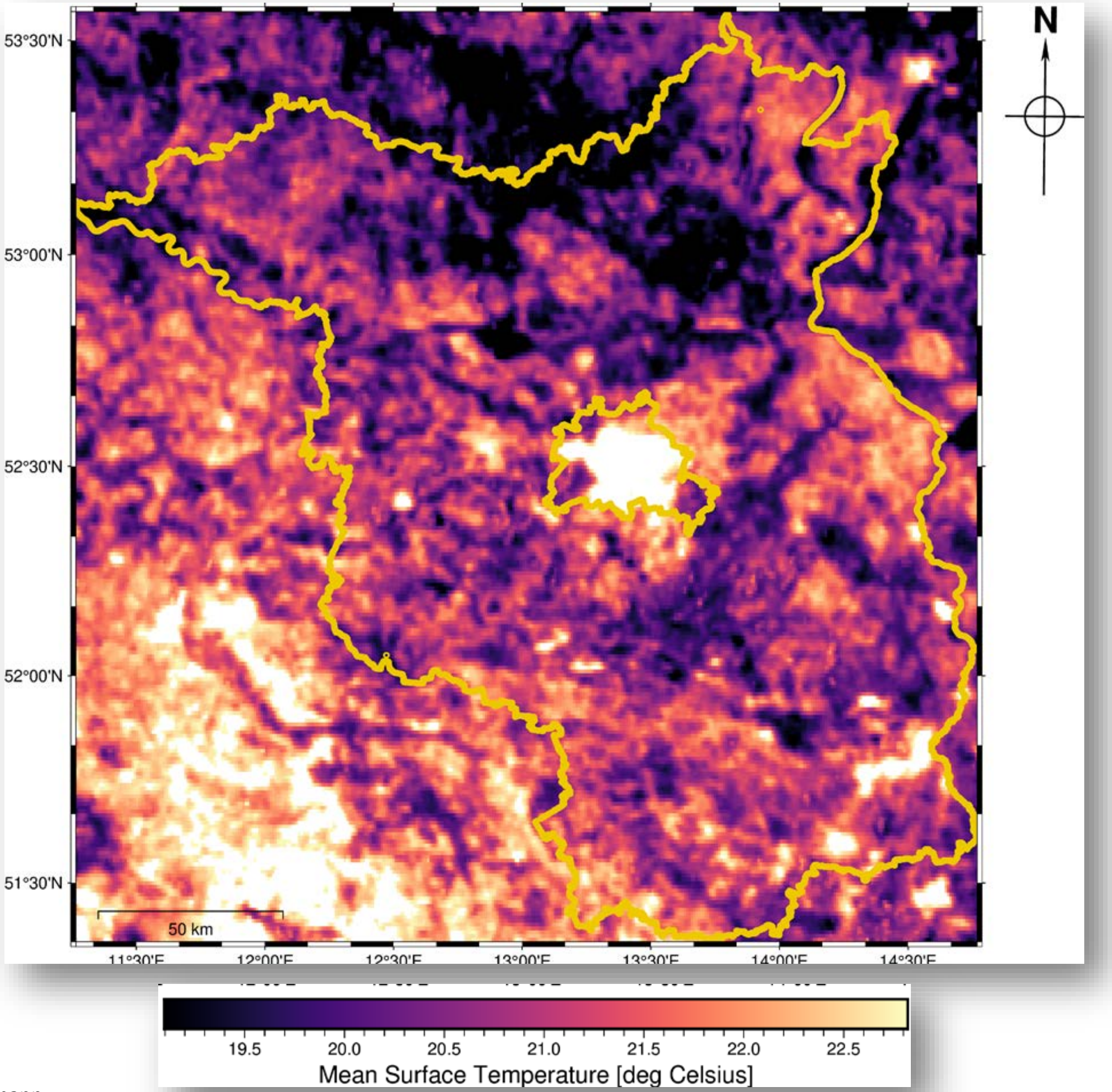


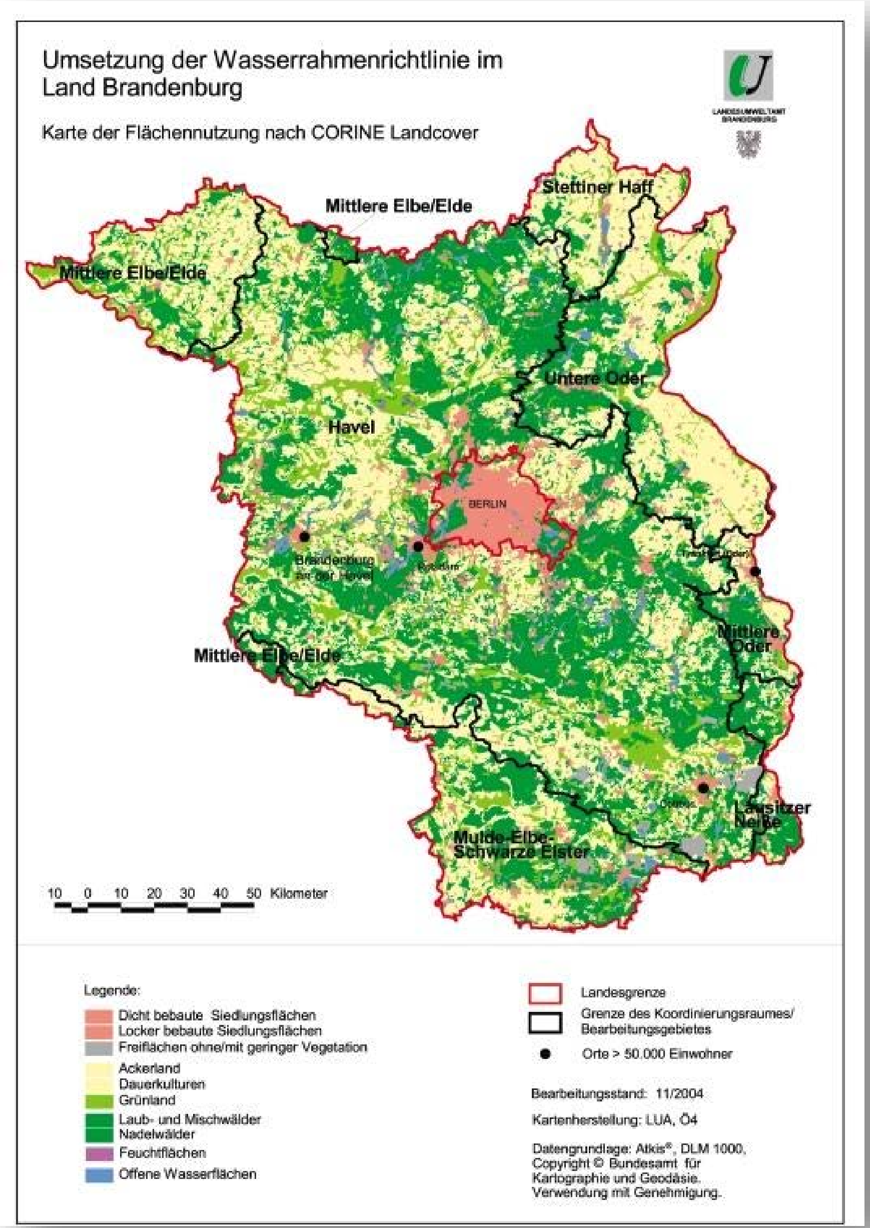
Adaptation and mitigation: the role of vegetaton



Source. Bonan et al. 2008

Thermal photo (Landsat, August)



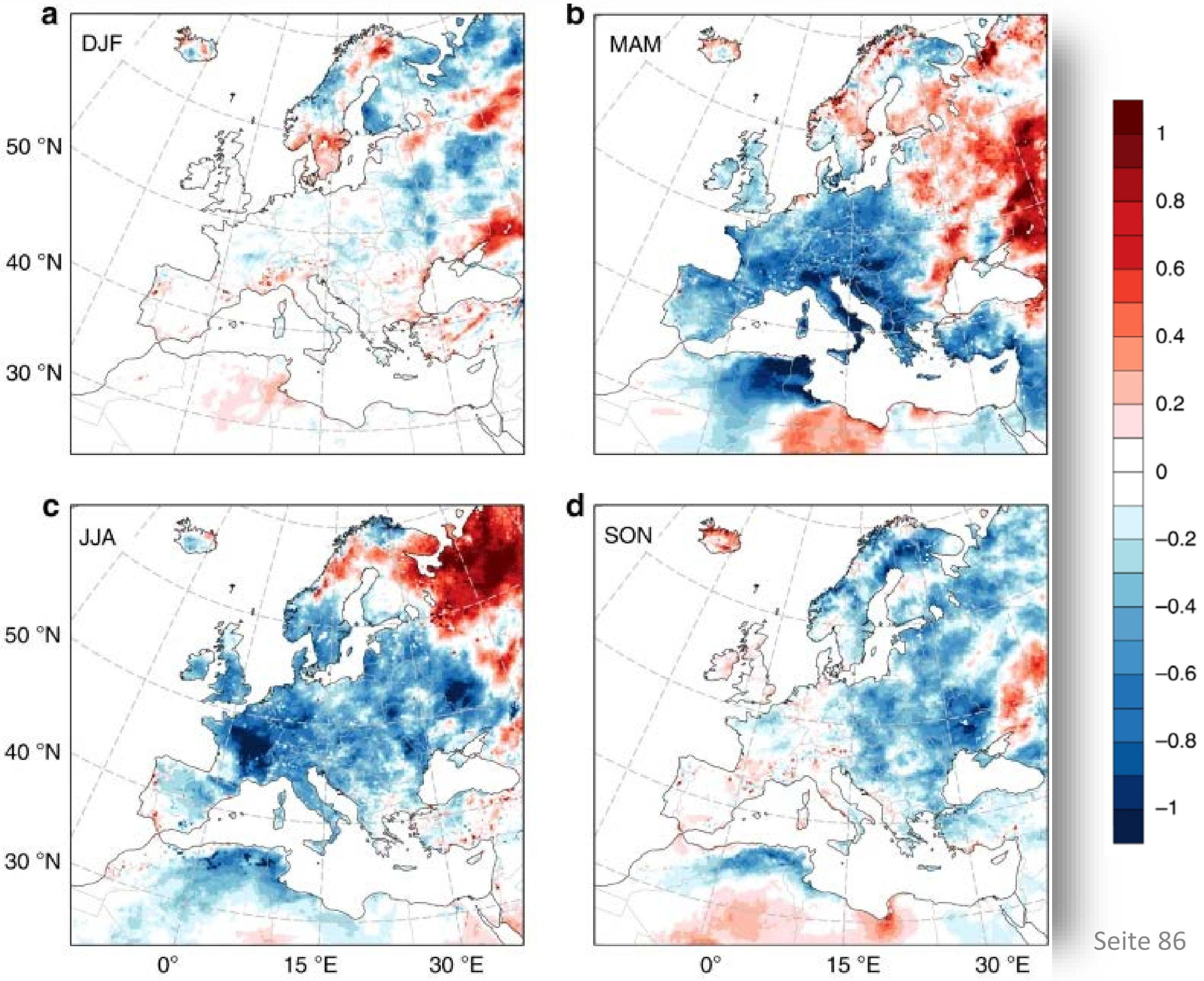


Predominant regional biophysical cooling from recent land cover changes in Europe (Huang et al. 2020, *Nature Communications*)

From 1992 to 2015, approximately 25 Mha of agricultural land was left abandoned. **Declines in agricultural land mostly occurred in favor of forests (15 Mha, 7 Mha of net gain) and urban settlements (8 Mha).**

Two simulations with the land cover in 1992 and 2015 are performed and the resulting relative differences in 2-m air temperature and surface air humidity investigated.

Regional climate model WRF (Weather Research and Forecasting model)



Hochschule für nachhaltige Entwicklung Eberswalde

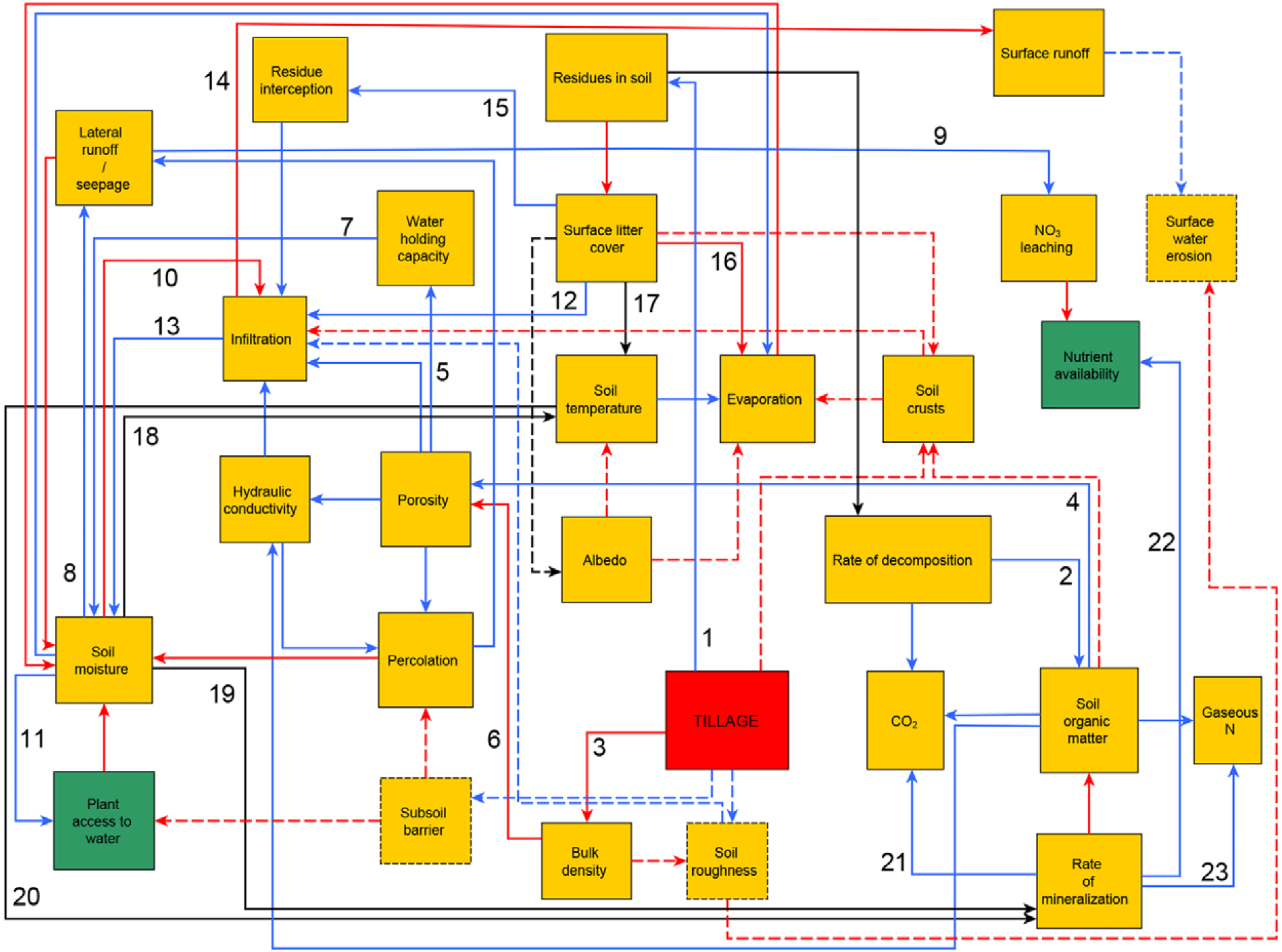
How should a landscape look like / be composed to be climate resilient and still providing basic ecosystem services such as water, food and protection?

-> climate landscapes?

PIK

Management for climate mitigation

Hochschule für nachhaltige Entwicklung Eberswalde



P I K

Lutz et al. 2019

Suggestions for presentations

1. Smart mitigation in the energy sector
2. Geo-engineering: pros and cons
3. Adaptation and mitigation in the water sector
4. Adaptation and mitigation in the agricultural sector
5. Adaptation and mitigation in the forest sector
6. Adaptation and mitigation across sectors
7. Climate landscapes

Thanks!

Hochschule
für nachhaltige Entwicklung
Eberswalde

Tomorrow we meet in the front of building A62:

https://www.pik-potsdam.de/en/institute/contact/where

P I K