Climate Economics for Engineers

ENV-724 (Thalmann/Vielle/Vöhringer), Session 1, 23 Sept. 2020

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Overview

23.09	Economic activity as a source of greenhouse gases, climate scenarios	Frank Vöhringer
30.09	Impacts of climate change: valuation and uncertainty	Philippe Thalmann
07.10	Impacts of climate change: net costs (aggregation, discounting)	Frank Vöhringer
14.10	Adaptation to climate change	Marc Vielle
21.10	Mitigation: abatement measures, cost curves, innovation	Frank Vöhringer
28.10	Cooperation: mitigation as a public good, international climate policy	Frank Vöhringer
04.11	Instruments for climate policy	Philippe Thalmann
11.11	Swiss climate policy	Philippe Thalmann
18.11	Solar radiation management: economics and governance	Frank Vöhringer
02.12	Final exam	all

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Overview for today

- round of introductions
- topics for the presentations on December 2nd
- IPCC = Intergovernmental Panel on Climate Change
  - publications and publication process
  - how they deal with uncertainty
  - some statements
- sources of greenhouse gases
- introduction to the mitigation game
- climate scenarios / emissions scenarios

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Presentations

- final session
  - Dec 2nd
  - 12:15-16:00
  - 10 minutes presentation + 5 minutes discussion per person
- next steps
  - Propose a topic by e-mail to frank.voehringer@epfl.ch by Monday, September 28th, noon.
  - You will receive feedback on your topic by one of the teachers.
  - Provide a draft outline of your presentation by November 3rd the lastest.
  - Contact the supervising teachers with any persistent questions or doubts that you may have.

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Presentation topics

- You could pick
  - a **country**, and analyse (parts of) its climate policy,
  - a specific **climate policy instrument**, and analyse how it works and how it is used,
  - a **sector**, and analyse
    - its contribution to climate change, the evolution of its emissions and what is done to curb these, or
    - how it might be affected by climate change and what is done to mitigate these impacts.
- If you write a dissertation related to climate change: You could pick a topic related to your own research.
- We would like to see some diversity among the topics.
- Whatever topic: It has to be a topic in climate **economics**.

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

What is an "economic" topic? (1)

A possible definition of economics:

> Economics is a social science concerned with the production, distribution, and consumption of goods and services. It studies **how individuals, businesses and governments make choices** about how to allocate resources.

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

What is an "economic" topic? (2)

- Technological development and the costs of technologies are a relevant aspect in economic analysis, but they are only one of many relevant aspects.
- Costs influence choices, but so do many other things:
  - decision makers' preferences, social norms, risk perceptions, degree of rationality in decision-making, strategic interaction
  - incentives, especially policy instruments (e.g. subsidies, taxes, liability rules and other regulations)
  - information and efficient institutions (or their absence) determine whether any regulation, planned allocation, market mechanism etc. will actually work. There are many examples for policies that lack enforcement, especially but not only at the international level.

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

What is an "economic" topic? (3)

- What follows from this?
  - focus on decisions and why they are taken
  - don't forget the demand side
  - distinguish (at least) between producers, regulators and consumers
  - differentiate as closely as possible between different institutions and decision makers (who buys? who sells? who decides on regulations at what territorial scope? who enforces them? etc.)
  - consider policies and study the way they work including the actual incentives they create and the way these incentives are received
  - dive into social science

    among other things, this requires considering multiple criteria and balancing conflicting arguments

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Examples of possible topics

- Countries:
  - The economics of Chinese climate policy.
- Instruments:
  - The Swiss emissions trading system and its interaction with other climate policy instruments.
- Sectors (mitigation):
  - The economics of forest protection.
- Sectors (adaptation):
  - The economics of insurance markets against weather extremes.

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

The IPCC

- IPCC = Intergovernmental Panel on Climate Change
- founded in 1988 by UNEP and WMO, Secretariat in Geneva
- Nobel Peace Prize in 2007
- objective: provide a clear scientific view on the current state of knowledge in climate change and its impacts
- policy-relevant, but not policy-prescriptive
- Working Groups
  - I: scientific aspects of the climate system and climate change
  - II: vulnerability of socio-economic and natural systems to climate change, consequences of climate change, adaptation
  - III: limiting greenhouse gas emissions, other mitigation options
- www.ipcc.ch

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

The IPCC: Main publications

- Assessment reports (1990, 1995, 2001, 2007, 2013/14)
  - By working group + synthesis report
  - Summaries
    - Technical summaries
    - Summaries for policymakers
- Special reports, e.g.
  - Oceans and cryosphere
  - Climate change and land
  - Global warming of 1.5°C
  - Adaptation to extreme events
  - Renewable energy sources
  - Carbon capture and storage
  - Technology transfer
  - Aviation
- Technical papers, background material, presentations

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

IPCC writing and review process

Scoping

The outline is drafted and developed by experts nominated by governments and observer organizations

Approval of Outline

The Panel then approves the outline

Nomination of authors

Governments and observer organizations nominate experts as authors

Government and Expert Review - 2nd Order Draft

The 2nd draft of the report and 1st draft of the Summary for Policymakers (SPM) is reviewed by governments and experts

Expert Review - 1st Order Draft

Authors prepare a 1st draft which is reviewed by experts

Selection of authors

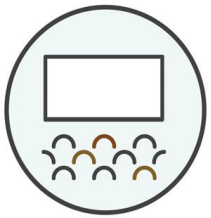
Bureaux select authors

Final draft report and SPM

Authors prepare final drafts of the report and SPM which are sent to governments

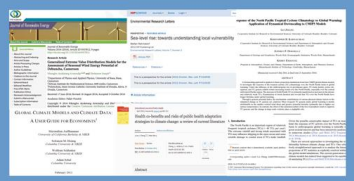
Government review of final draft SPM

Governments review the final draft SPM in preparation for its approval



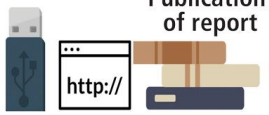
Approval & acceptance of report

Working Group/Panel approves SPMs and accepts reports



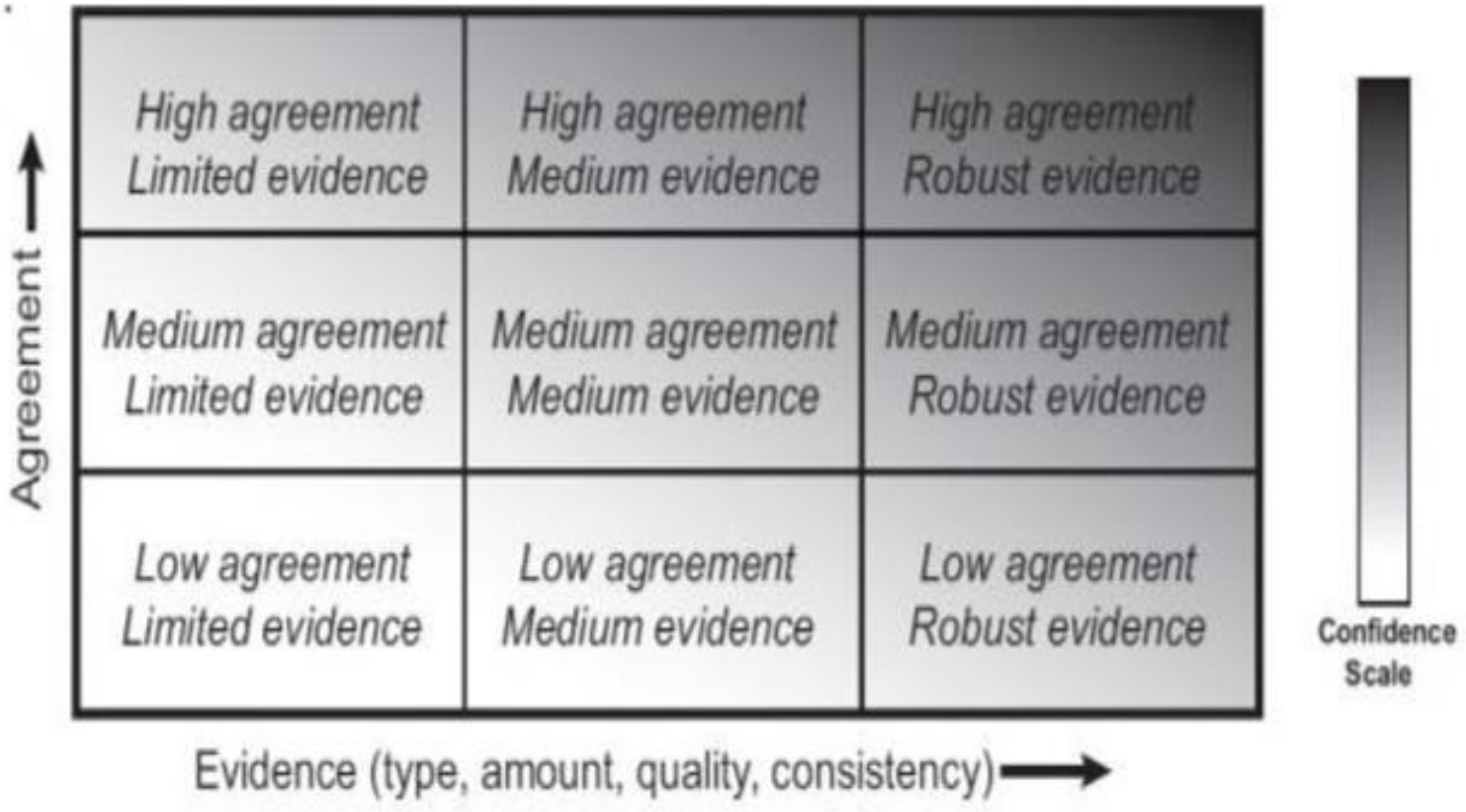
© images: www.ipcc.ch/AC6copyright.pdf

Peer reviewed and internationally available scientific technical and socio-economic literature, manuscripts made available for IPCC review and selected non-peer reviewed literature produced by other relevant institutions including industry



Publication of report

IPCC confidence scale



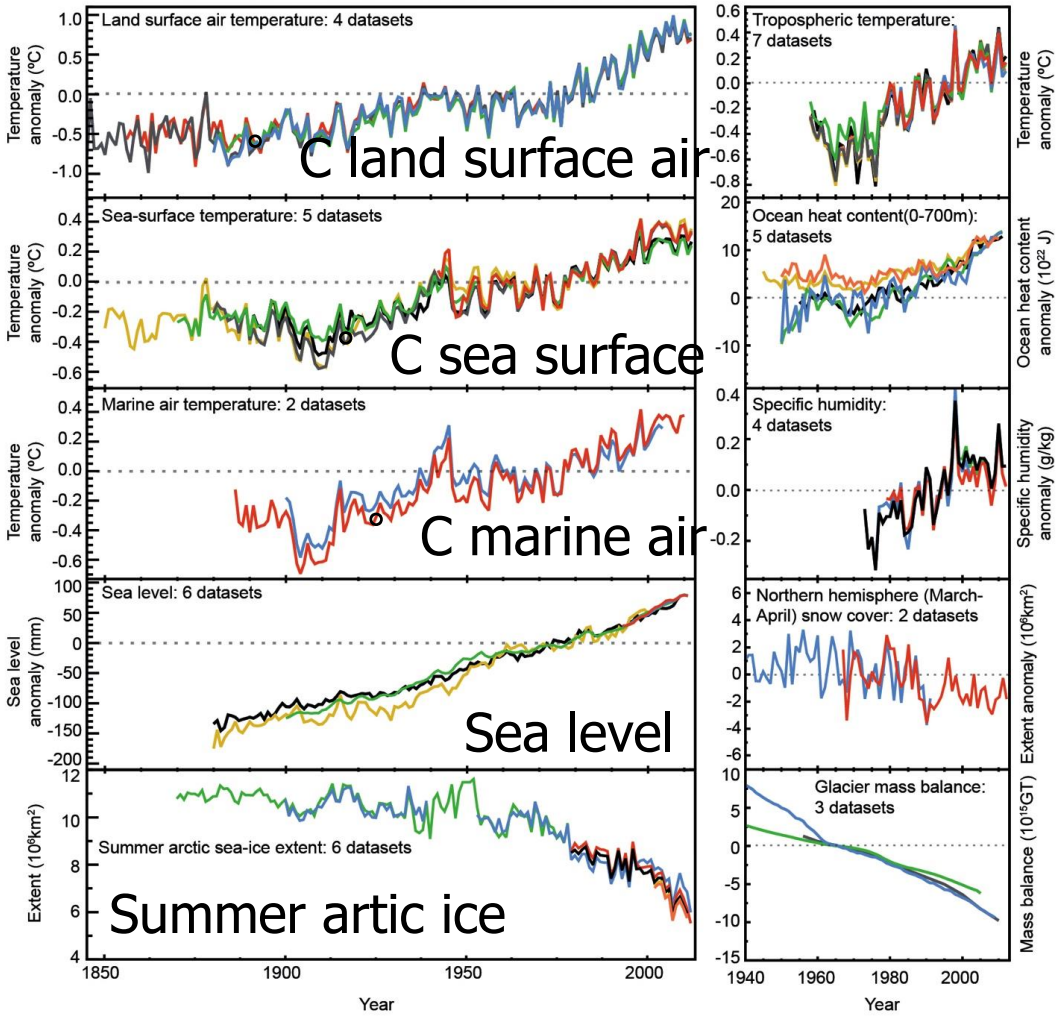
IPCC likelihood terminology

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Climate change

- « Warming of the climate system is unequivocal »
  - IPCC 2013



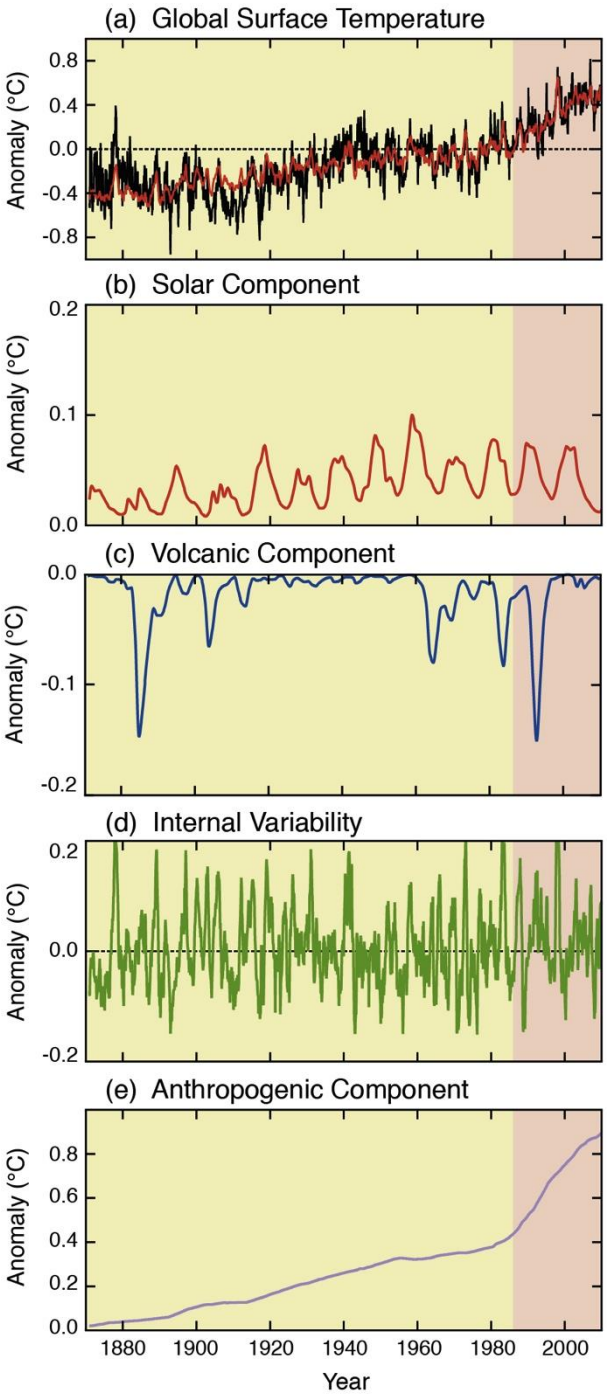
IPCC, WG I, AR5, 2013

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

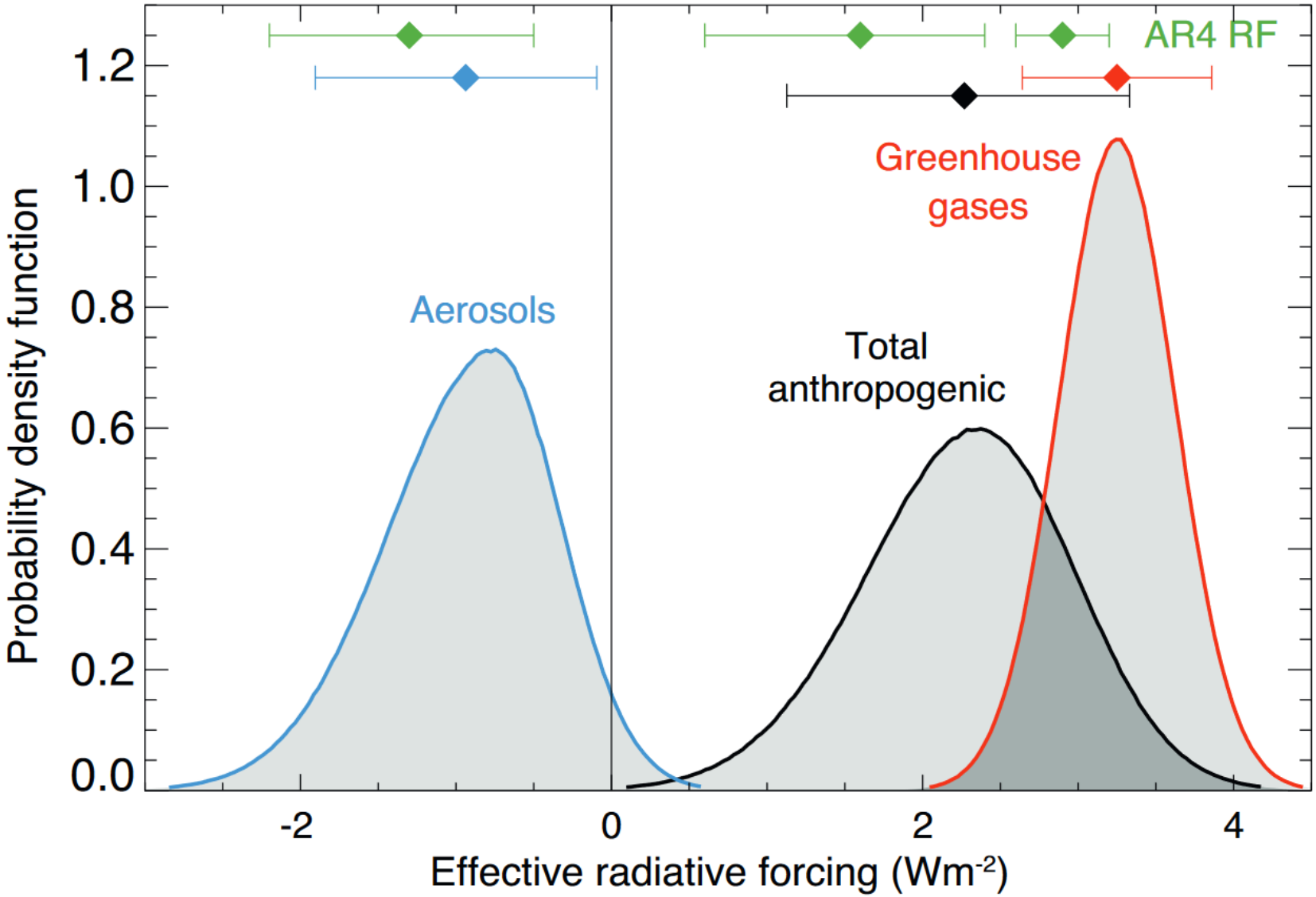
Climate change forcings

- « It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century»
  - IPCC 2013



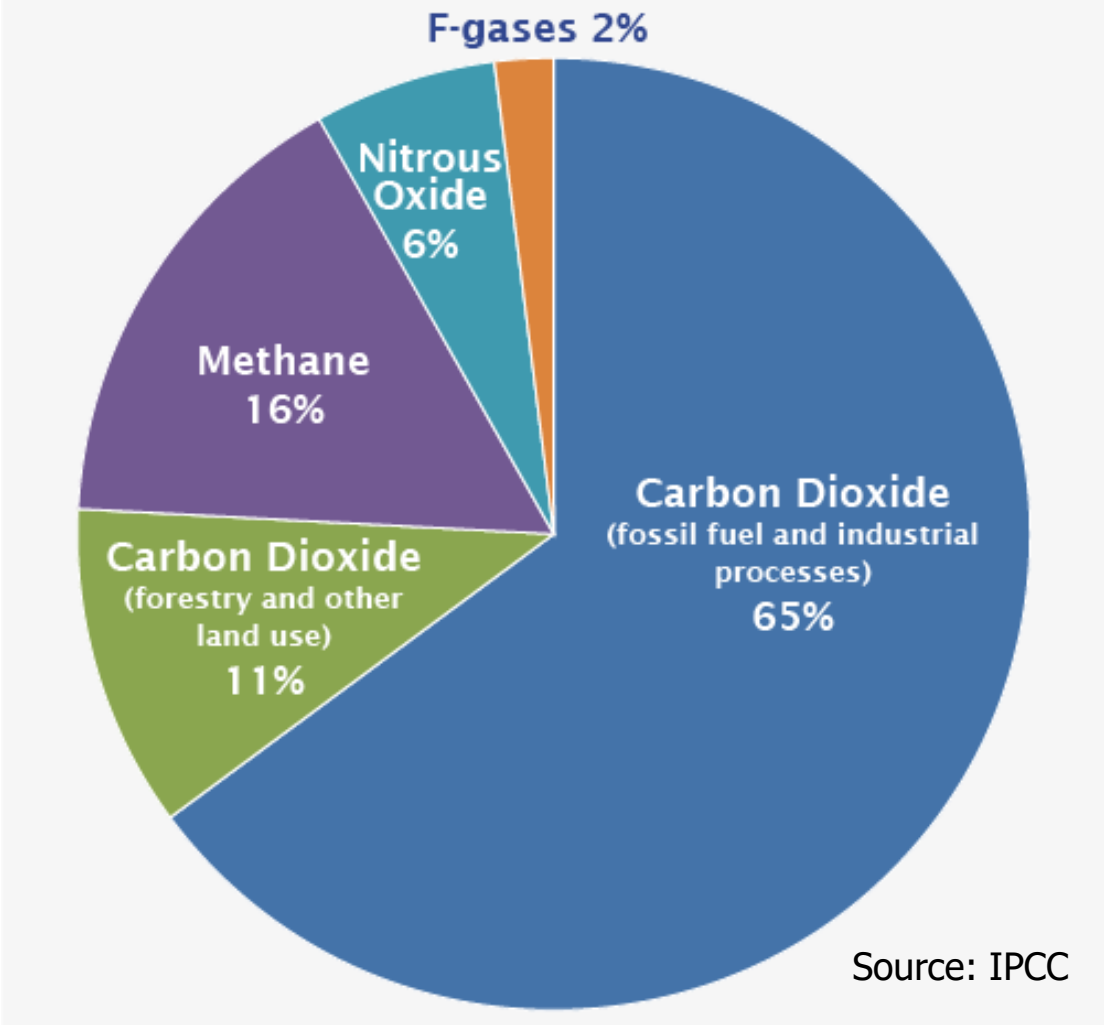
IPCC, WG I, AR5, 2013

Climate models and the human influence



IPCC, WG I, AR5, 2013

GHG emission shares in 2010



EPFL
Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Lifetimes and Global Warming Potentials

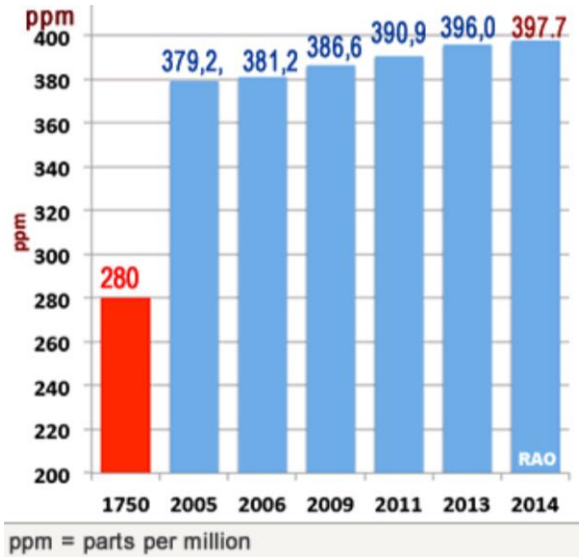
Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4x10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7x10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03x10^{-3}	310	289	298	153

Source: IPCC

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Atmospheric concentrations

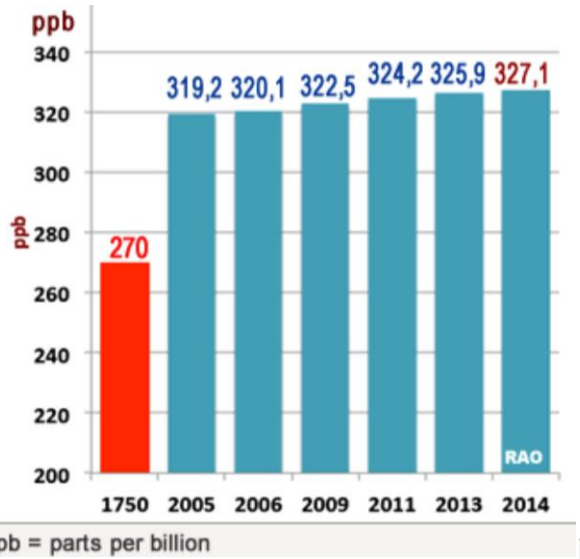
CO_2



ppm = parts per million

latest: 411

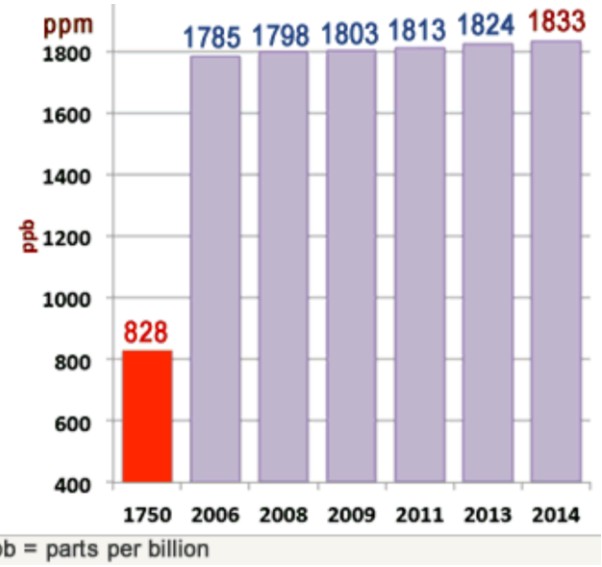
N_2O



ppb = parts per billion

2018: 331

CH_4



ppb = parts per billion

2018: 1850

Source: RAO online based on WMO data

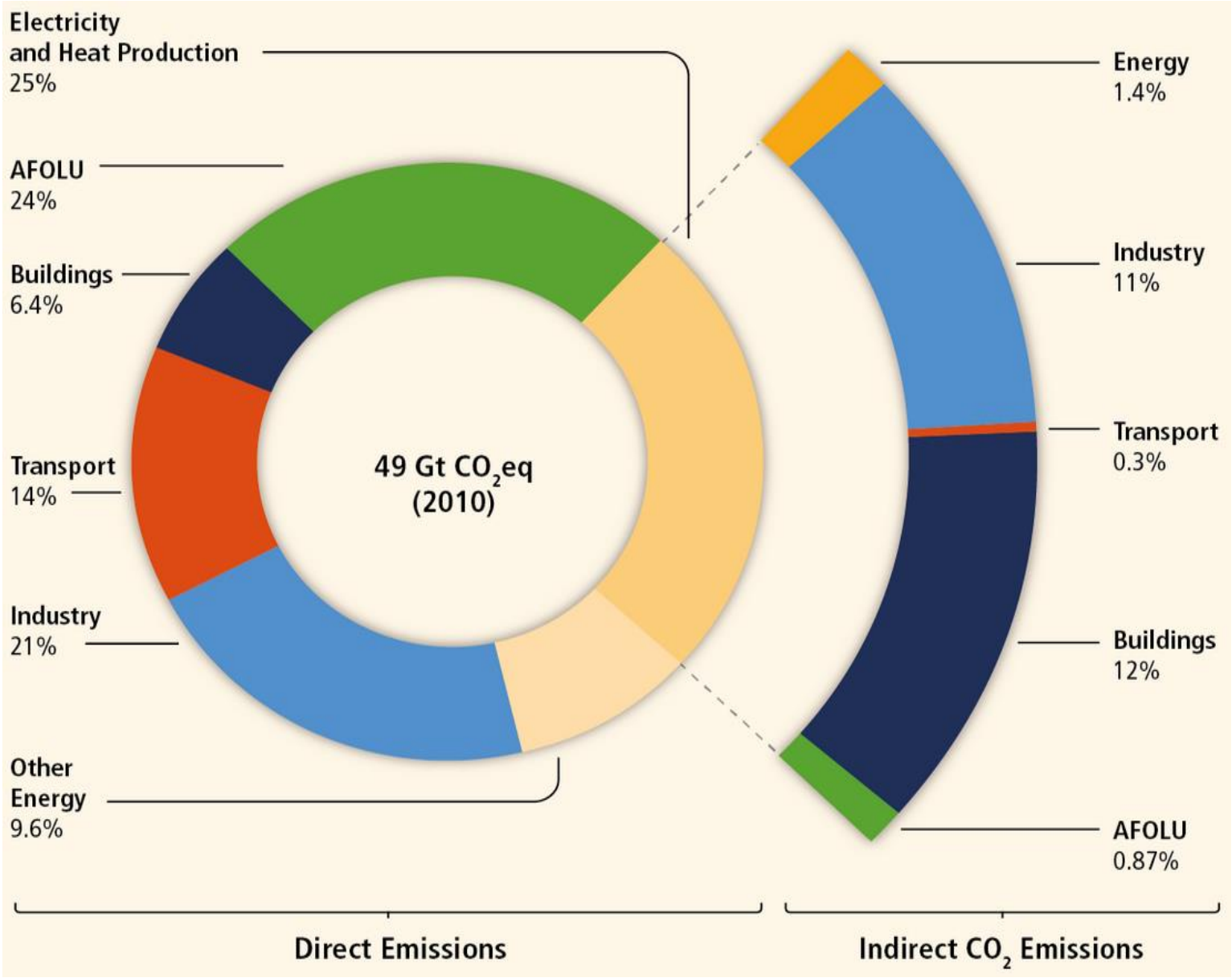
EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4x10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7x10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03x10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	9,990
Halon-1301	$CBrF_3$	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF_3	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF_6	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF_3	740	0.21		12,300	17,200	20,700
PFC-14	CF_4	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C_2F_6	10,000	0.26	9,200	8,630	12,200	18,200

Source: IPCC

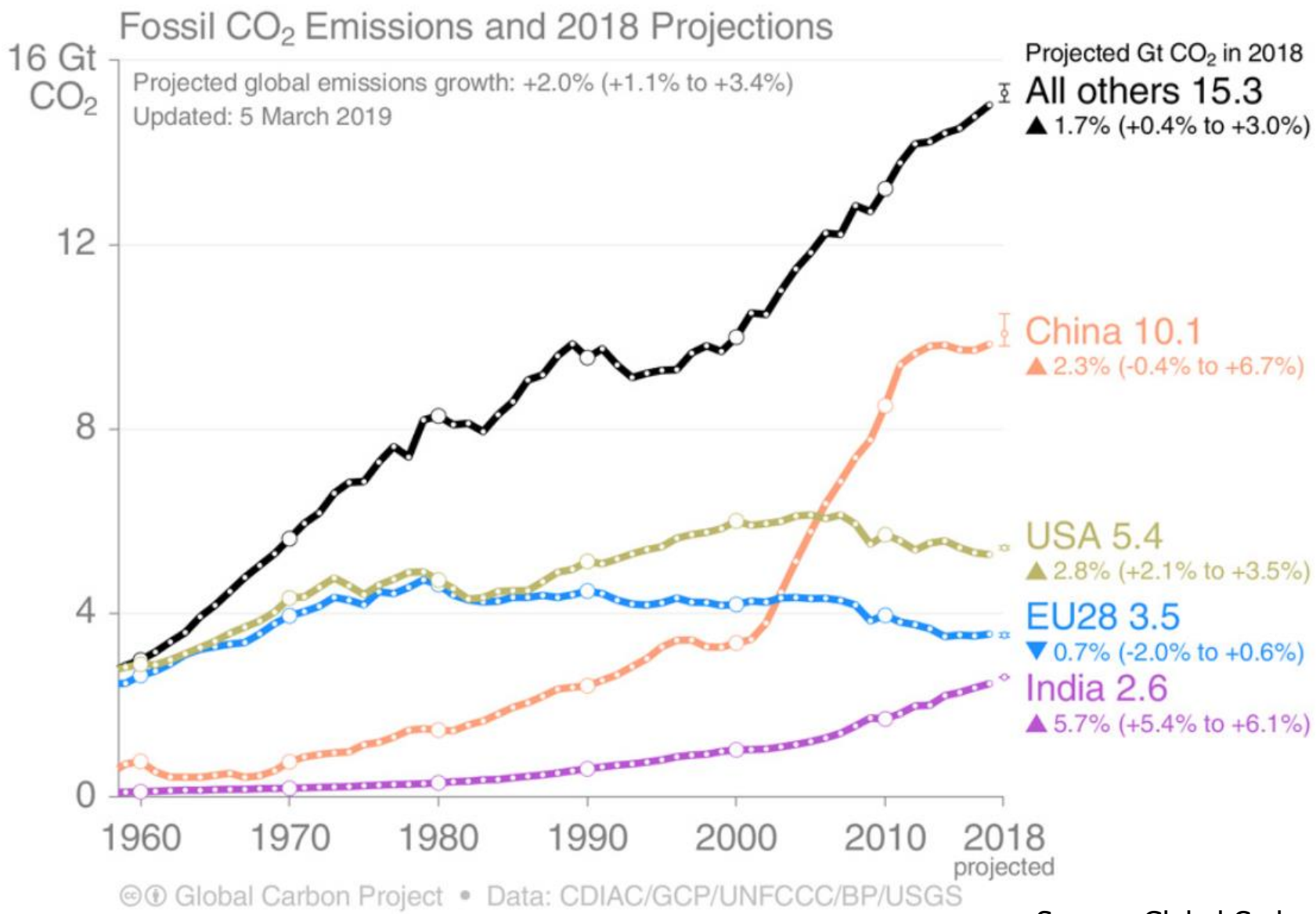
Greenhouse gas emissions
Globally by sector



Source: IPCC

Greenhouse gas emissions

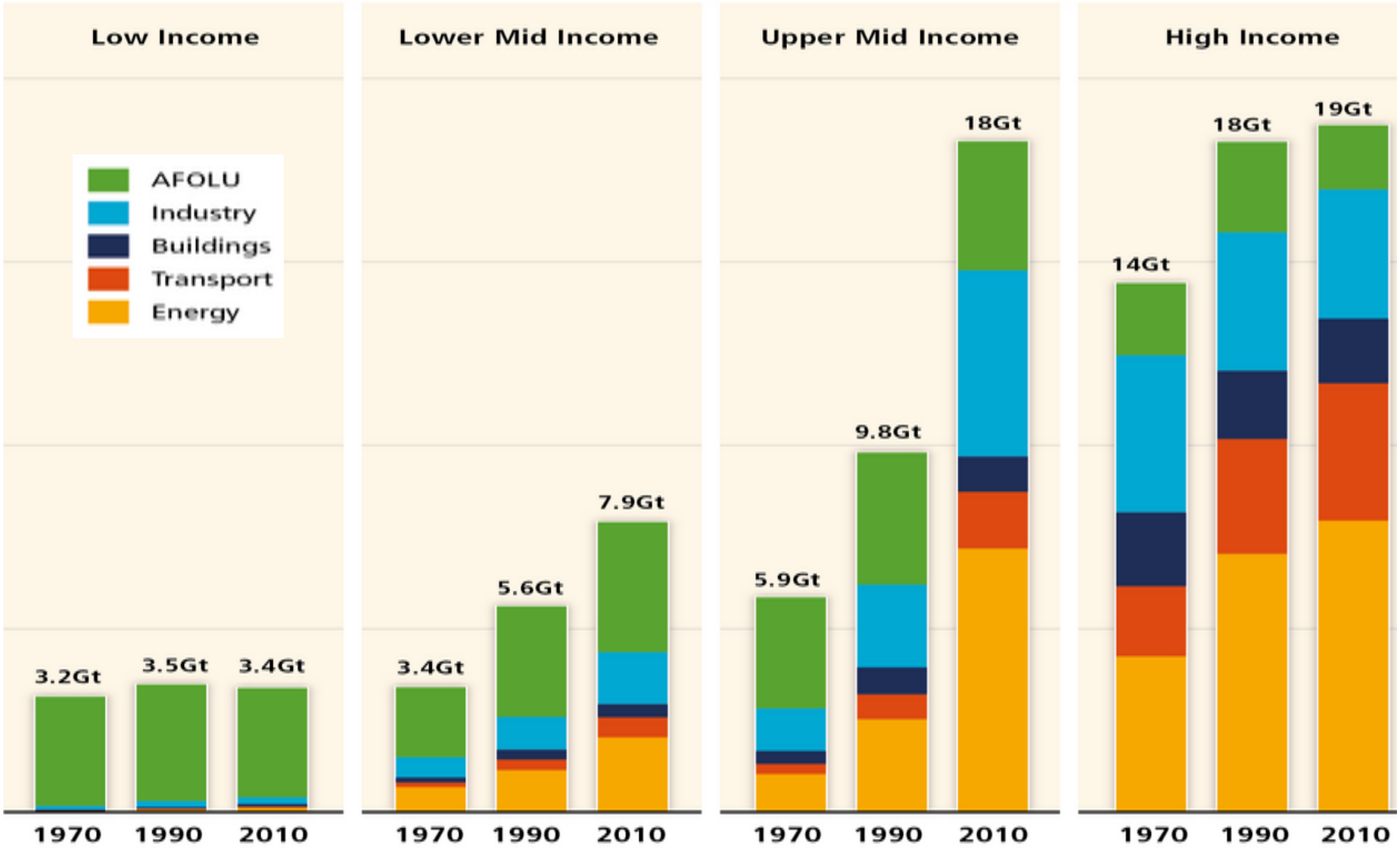
By major emitting countries (CO_2 only)



Source: Global Carbon Project

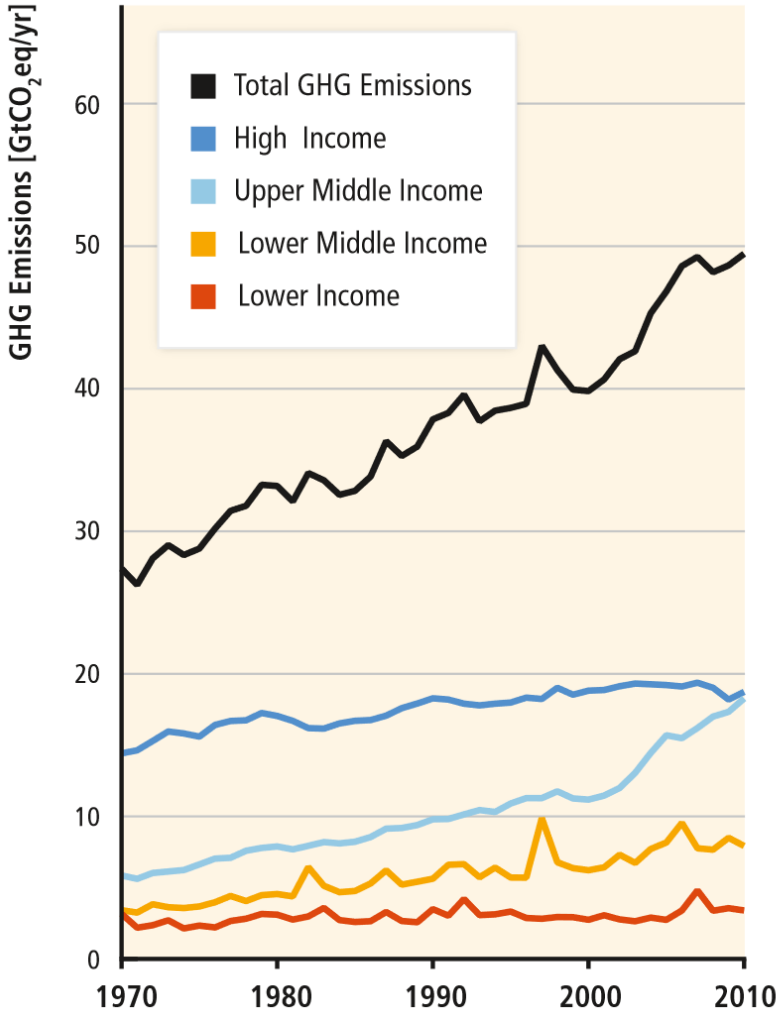
Greenhouse gas emissions

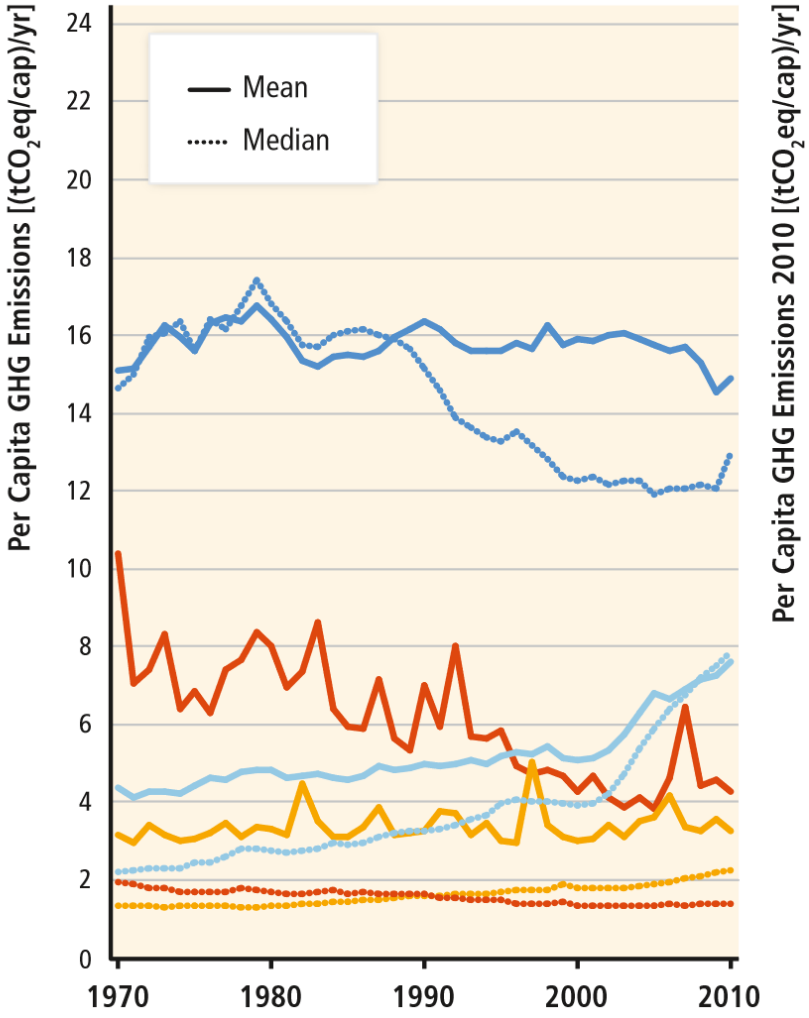
By national income category and sector



Source: IPCC

By income category (total and per capita)



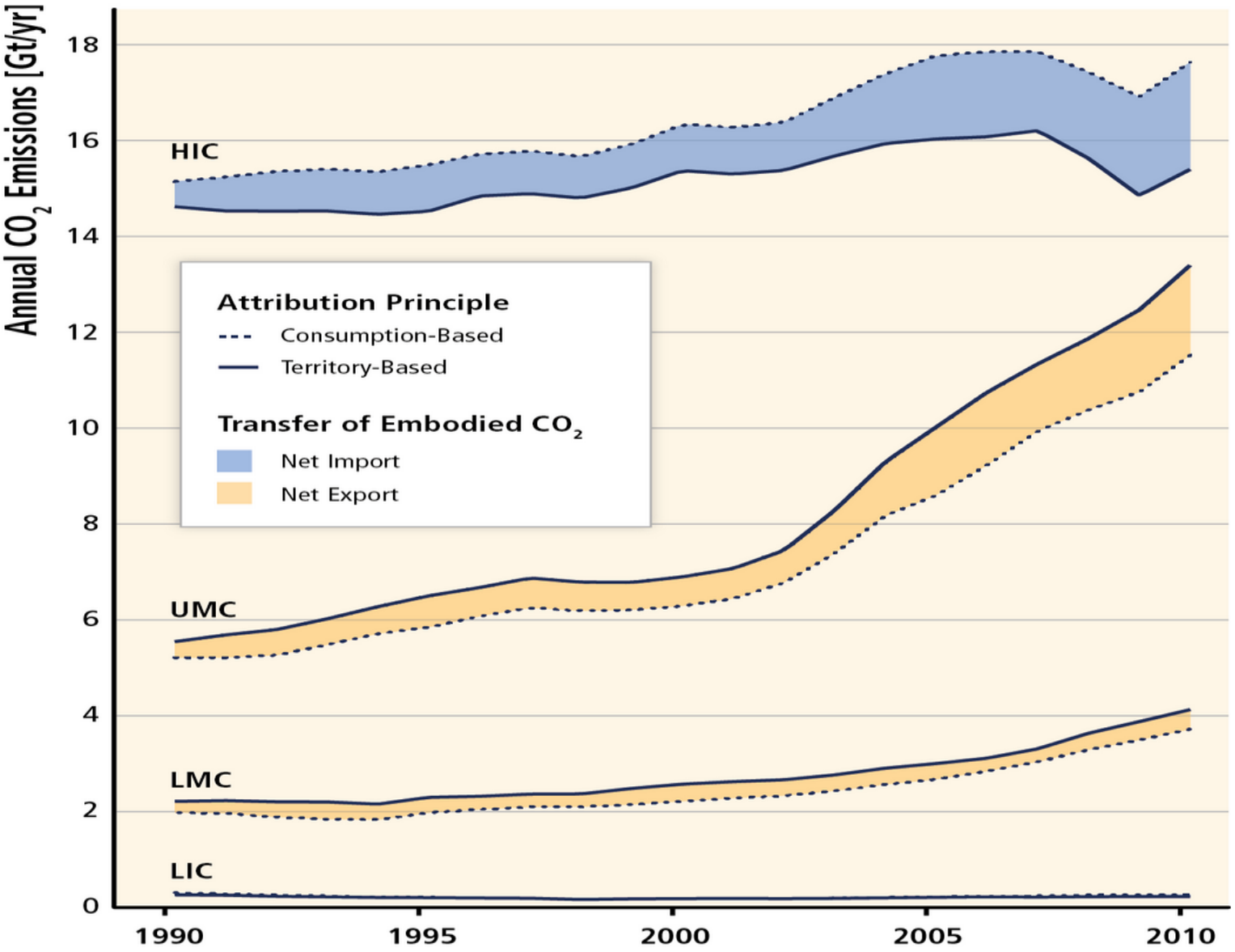


Source:
IPCC 5AR
TS WG3

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

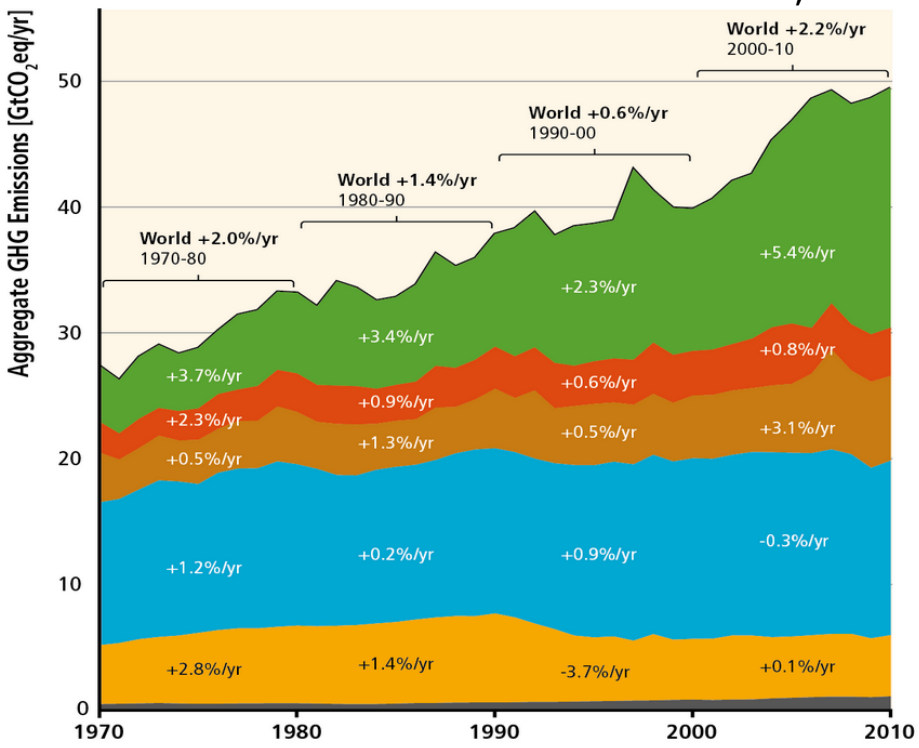
Embodied CO_2

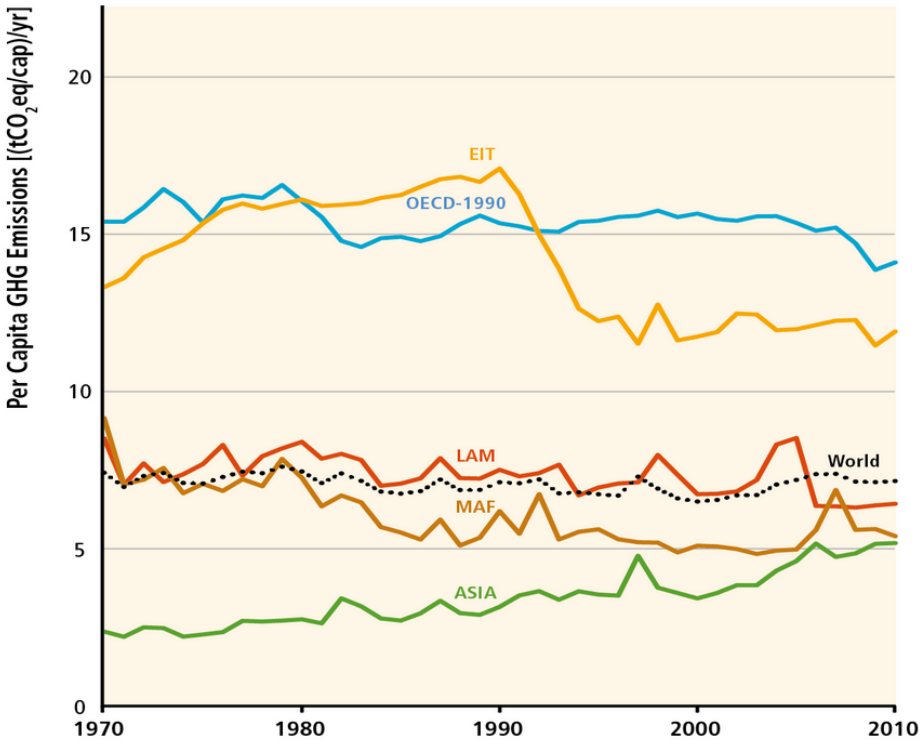


Source: IPCC

By region (total and per capita)

Total in 2018: 51,8 Gt*





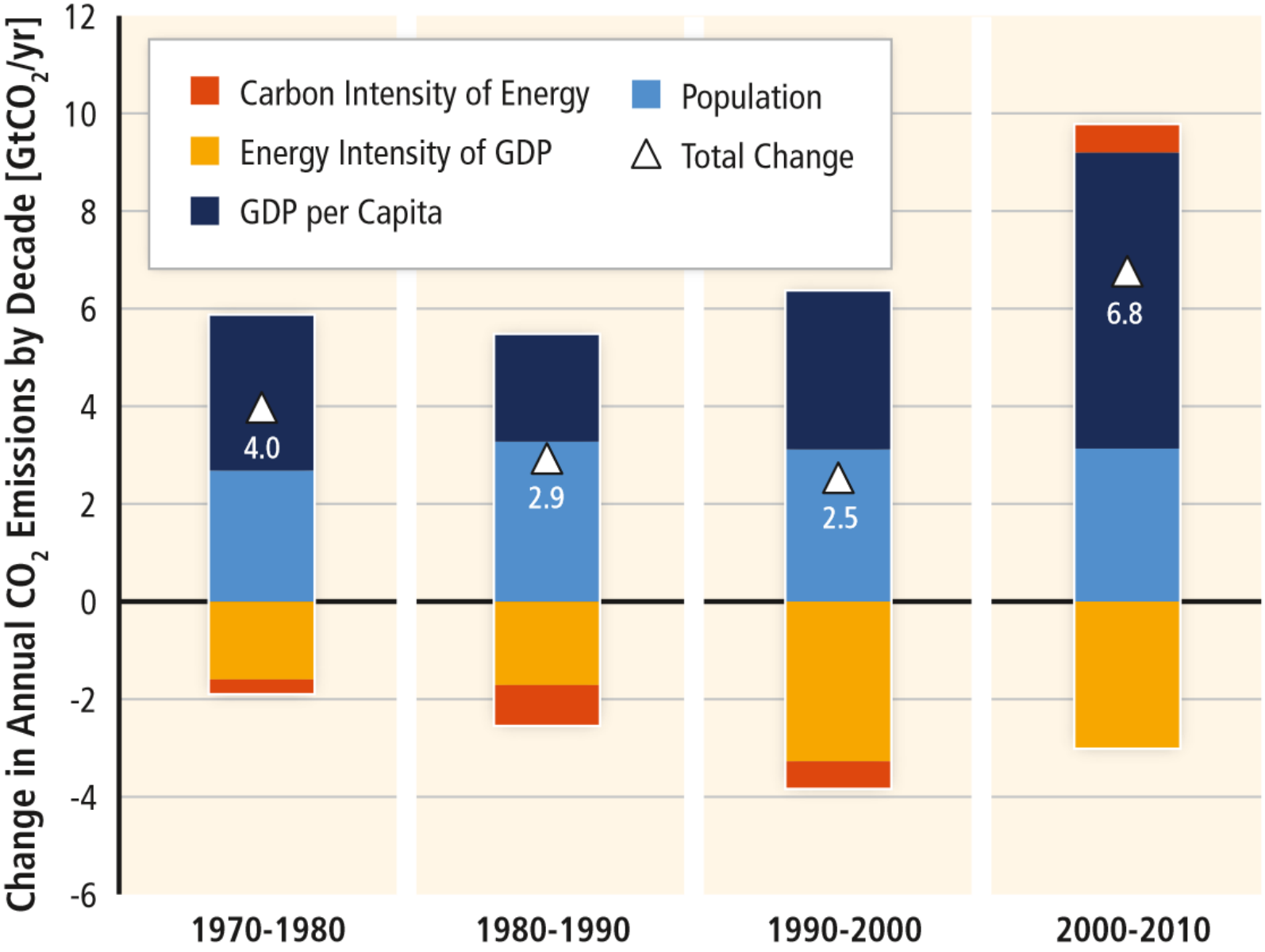
International Transport
Latin America and Caribbean
Asia
Middle East and Africa
Economies in Transition
OECD-1990 Countries
World Average

Source: IPCC
* Source: PBL

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

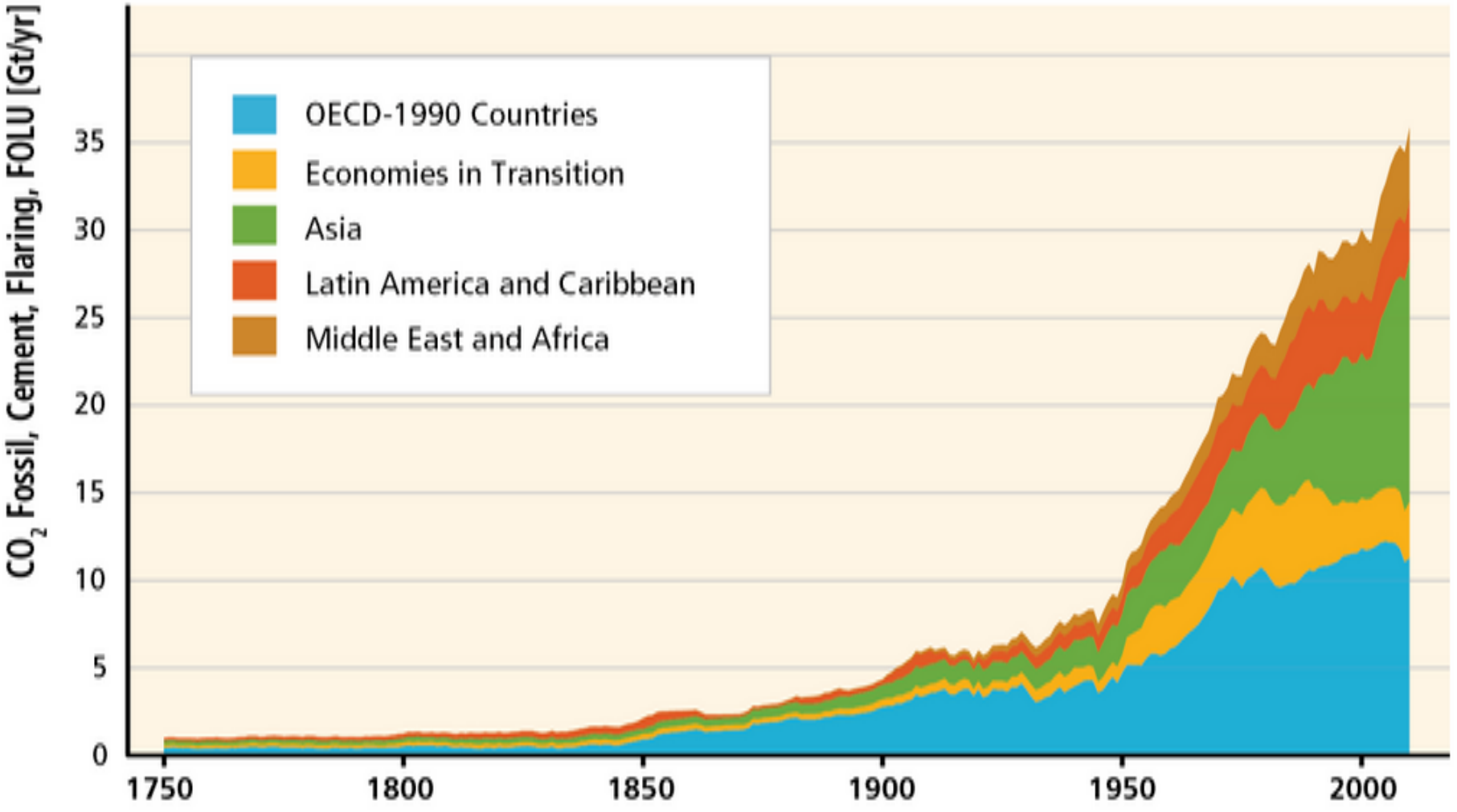
Drivers (decomposition of changes per decade)



Source:
IPCC 5AR
TS WG3

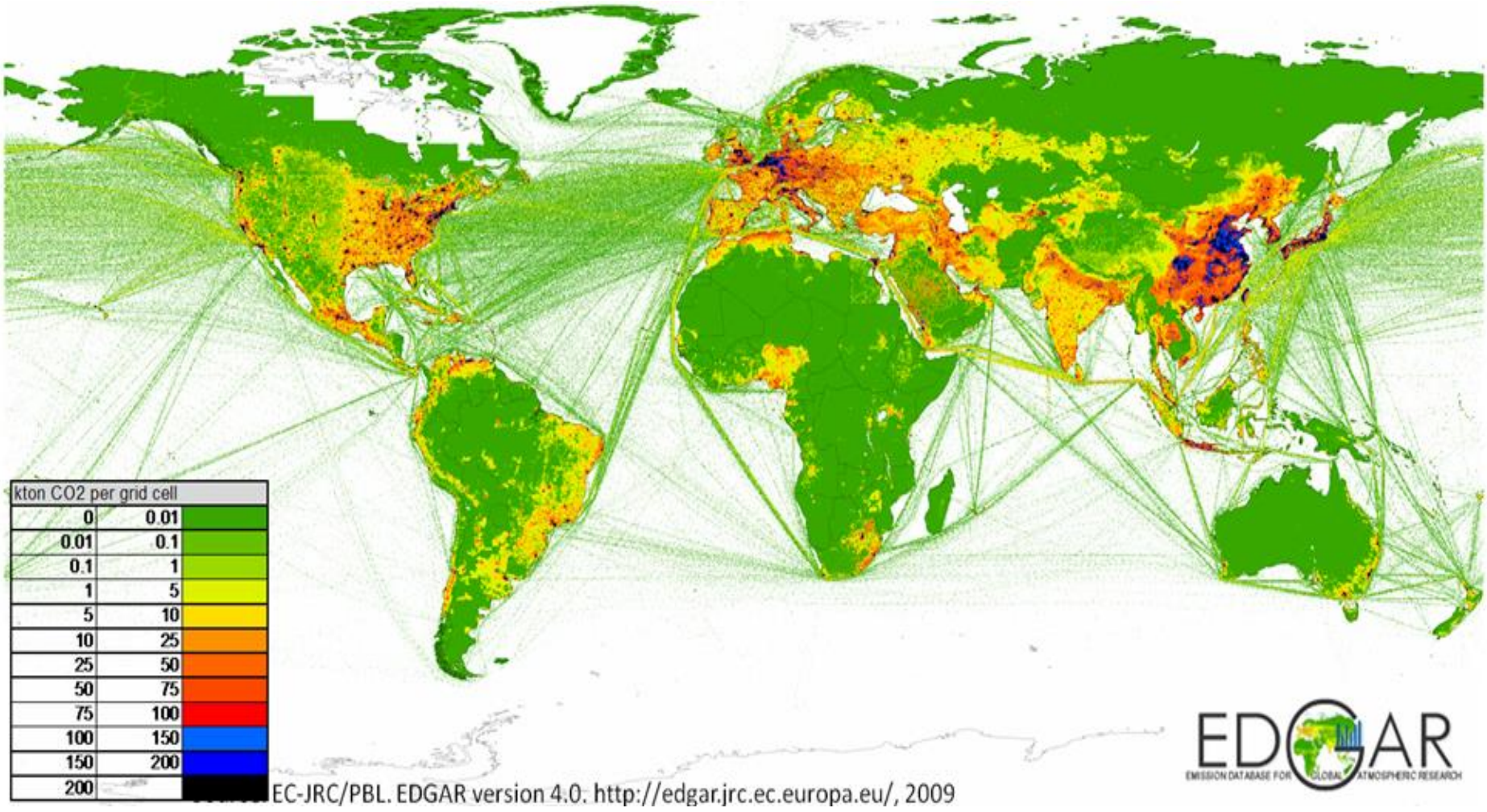
Greenhouse gas emissions

By region (1750-2010, CO_2 only)



Source: IPCC

CO_2 emission density



EPFL

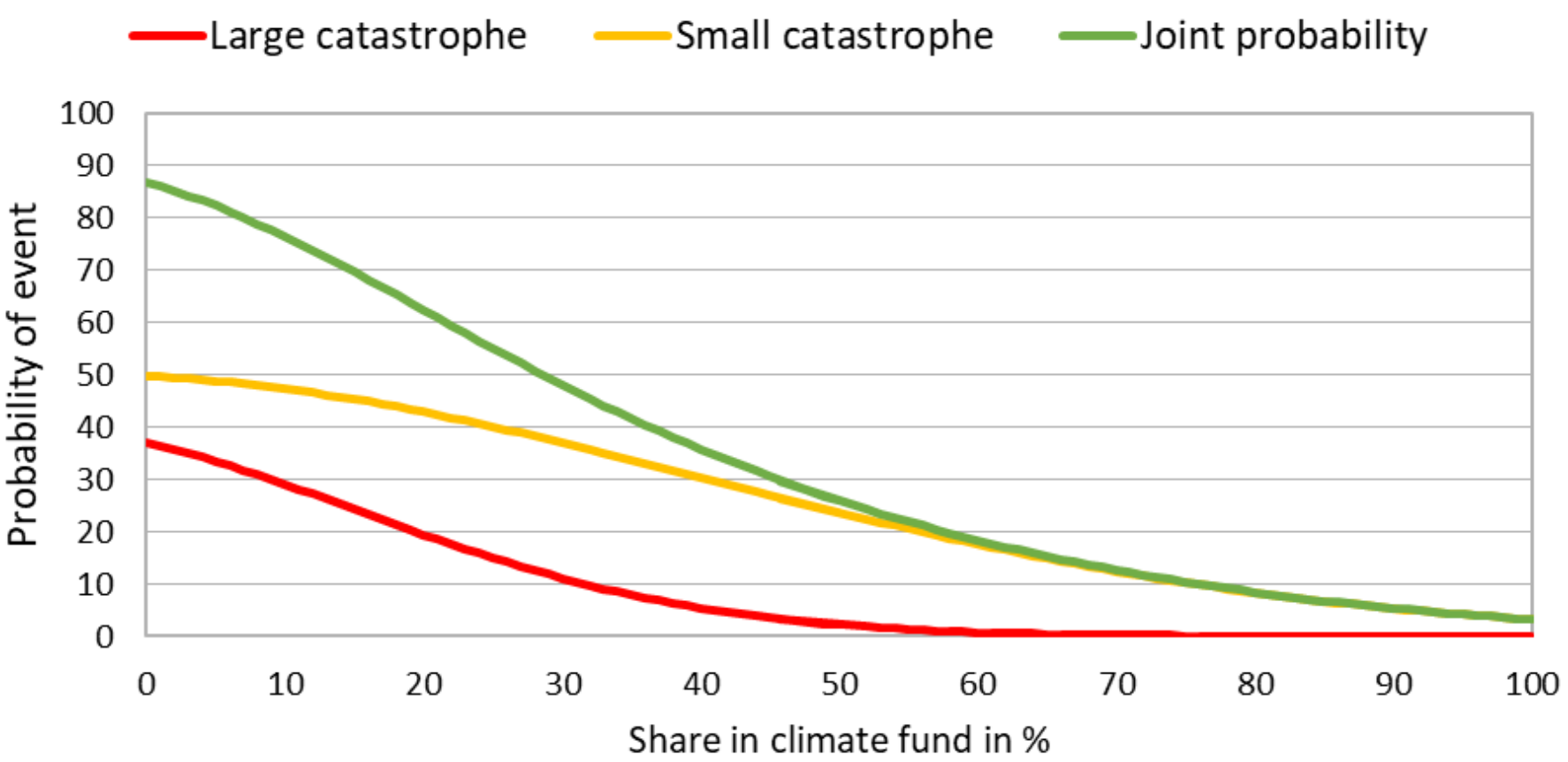
Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

The Mitigation Game

- players choose nicknames
  - make sure to remain incognito
  - players are allocated to groups A or B by lot
- 1 round per session
  - 10 PolyPesos are available per person per round
  - allocation of the PolyPesos by e-mail to the coordinator
- small (virtual?) prizes
  - chosen in the order of the ranking of private accounts
  - may be destroyed by climate catastrophes (small/large)
- mitigation fund
  - payments into mitigation fund reduce the probability of catastrophes
- regulatory uncertainty (events)

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

The Mitigation Game



EPFL

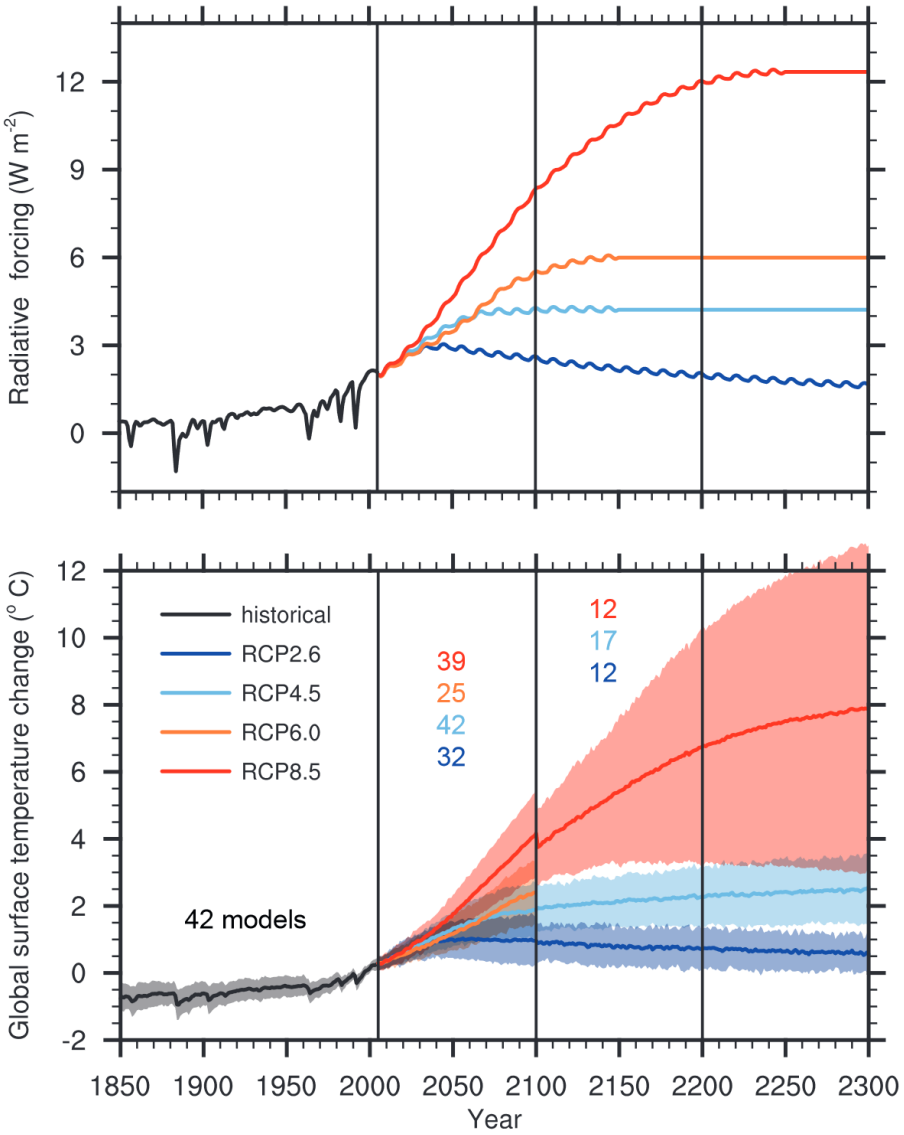
Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

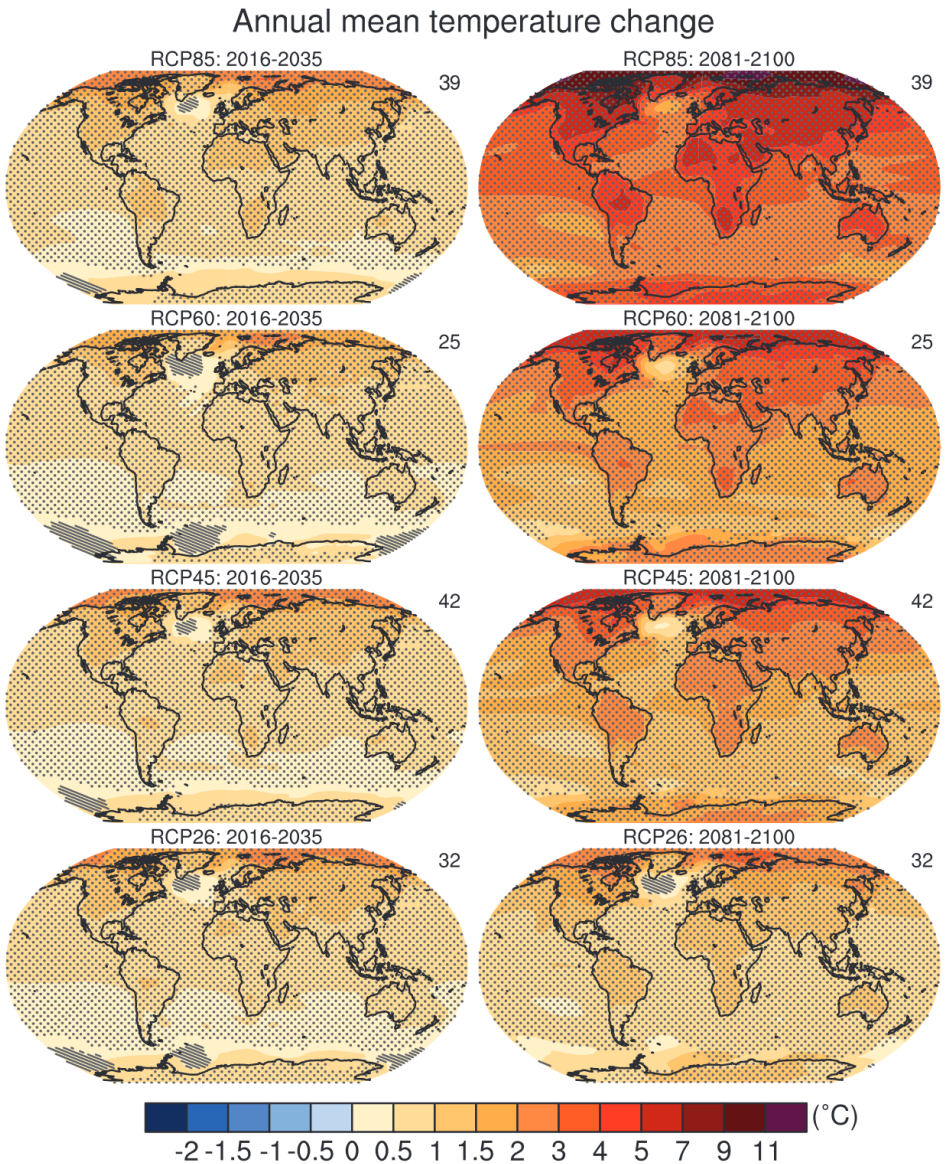
Some history

- IPCC Special Report on Emissions Scenarios (2000)
  - socioeconomic storylines (e.g.: rapid economic growth, sustainability, self-reliance)
  - limited usability – difficult to apply the complete set of storyline assumptions to other models
- IPCC 5th Assessment Report: RCP scenarios
  - Representative Concentration Pathways
  - broad range of possible climate futures
  - numbered according to radiative forcing in W/m^2 in 2100
  - more flexible scenario approach
    - compatible emissions scenarios based on IAMs
    - internally consistent set of socioeconomic assumptions, but open to alternative interpretations

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

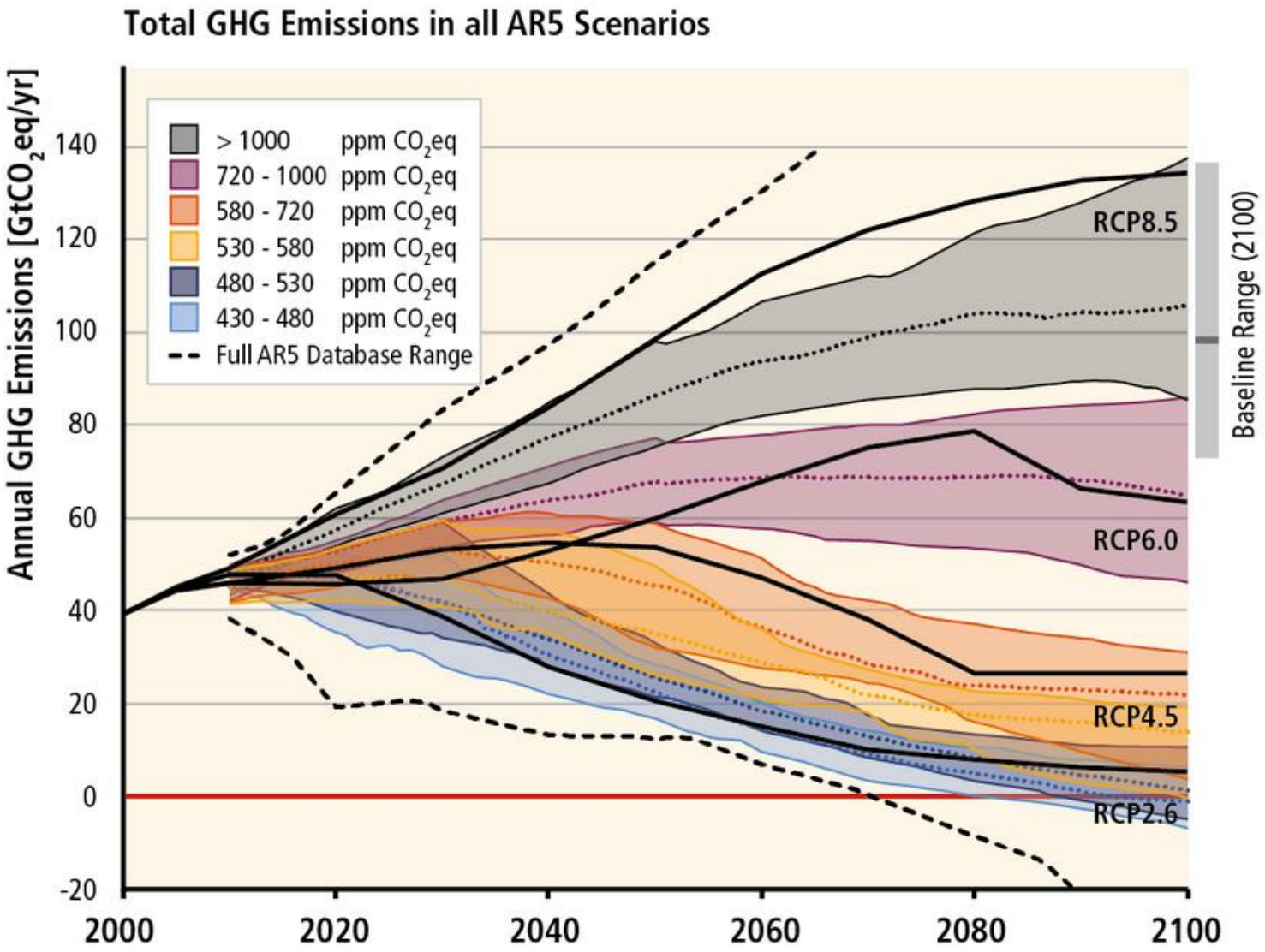
Multi model projections: temperature change





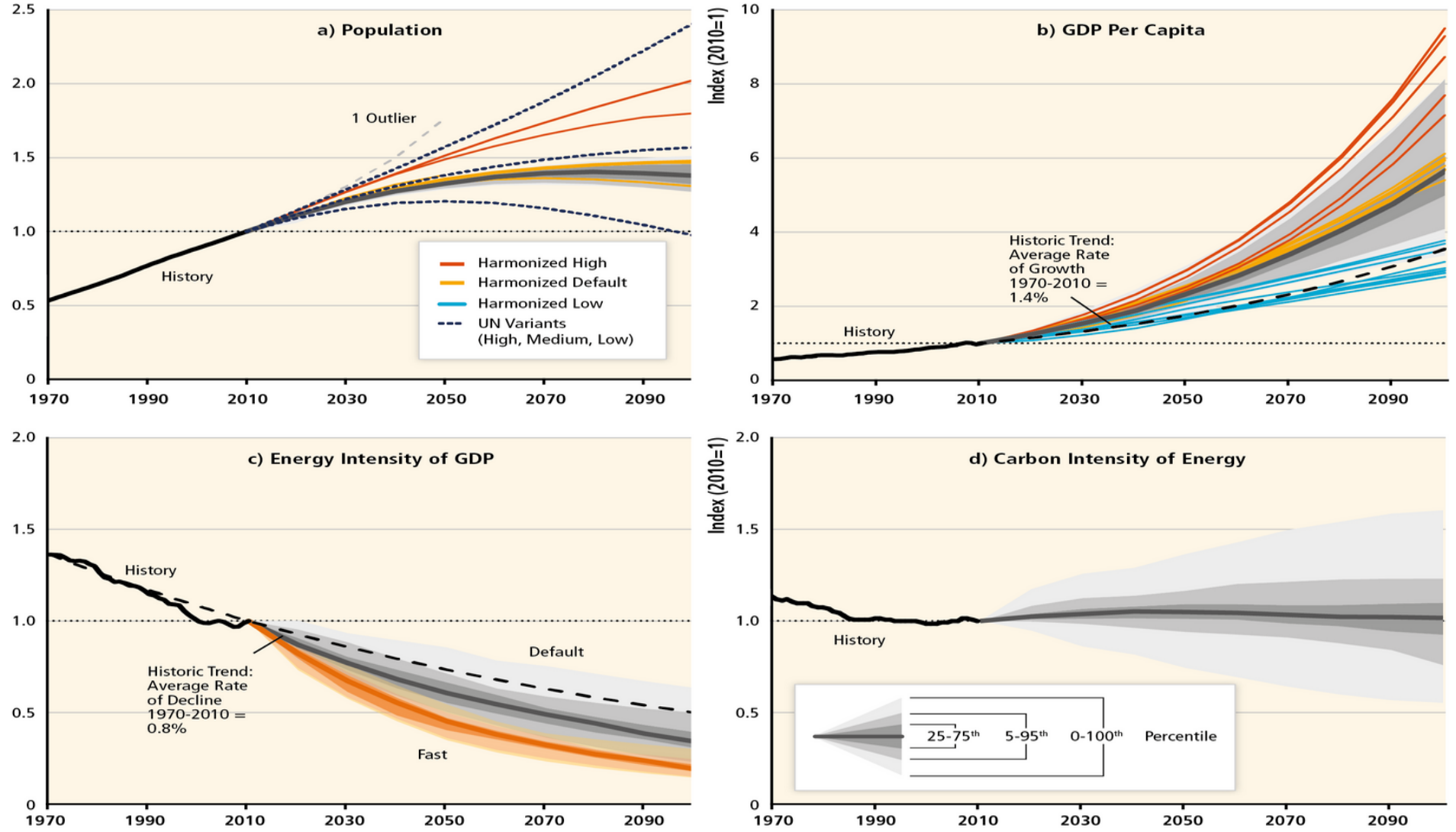
Source: IPCC 5AR

Global GHG emissions scenarios



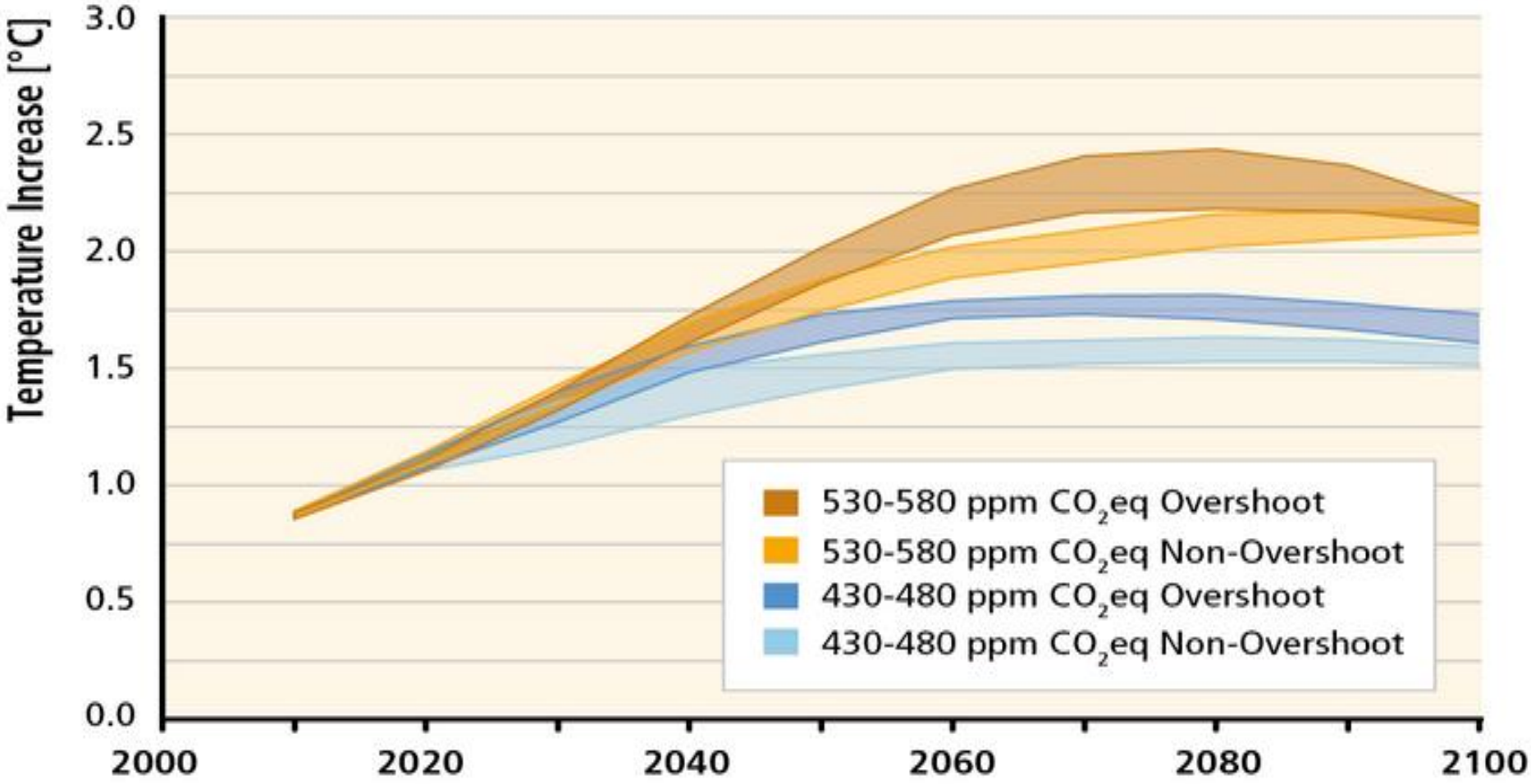
Source: IPCC

Emissions scenarios: economic drivers



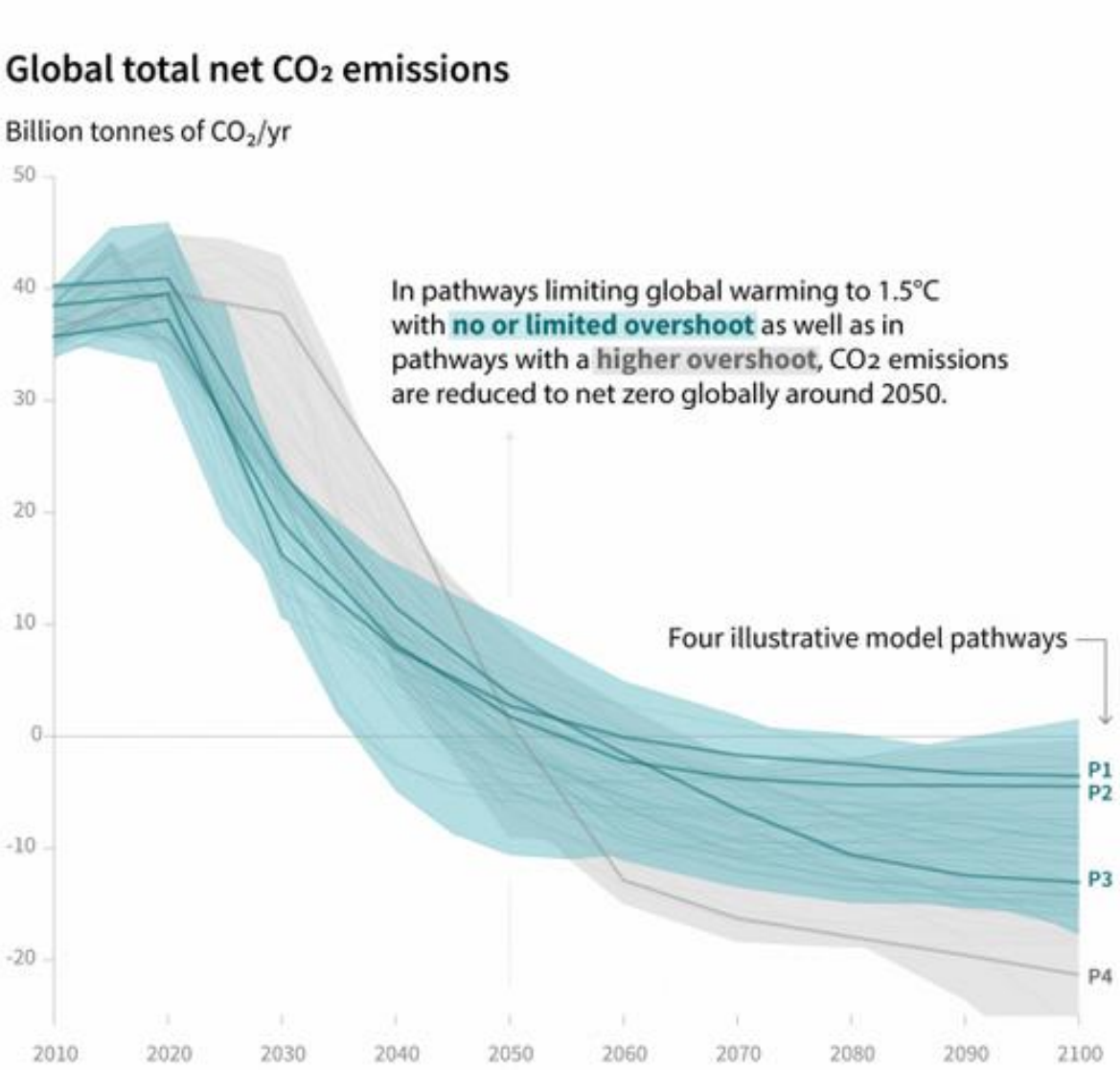
Source: IPCC

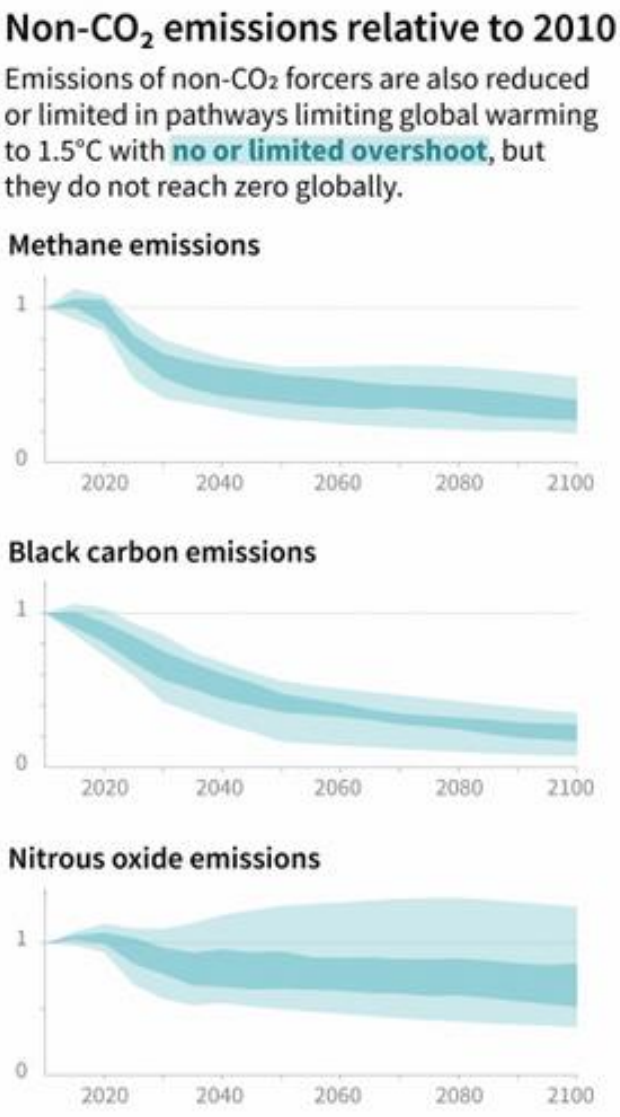
Overshooting



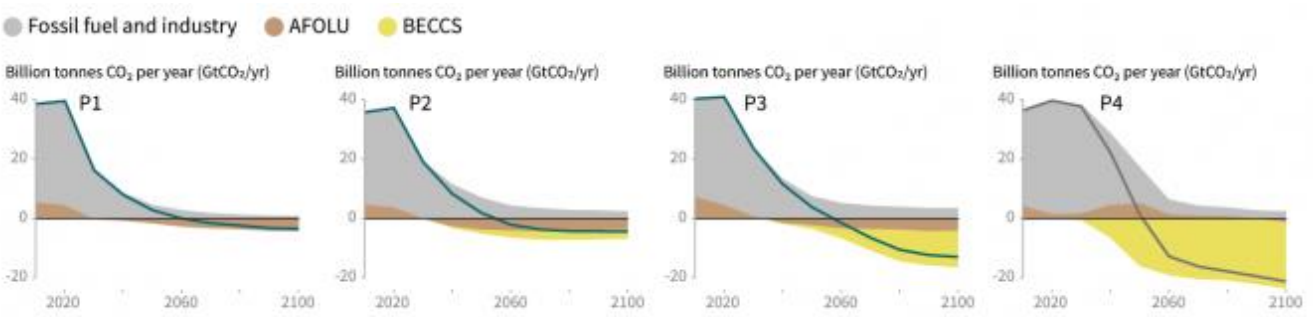
Source: IPCC

Emissions scenarios: 1.5°C





Source: IPCC SR 1.5



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

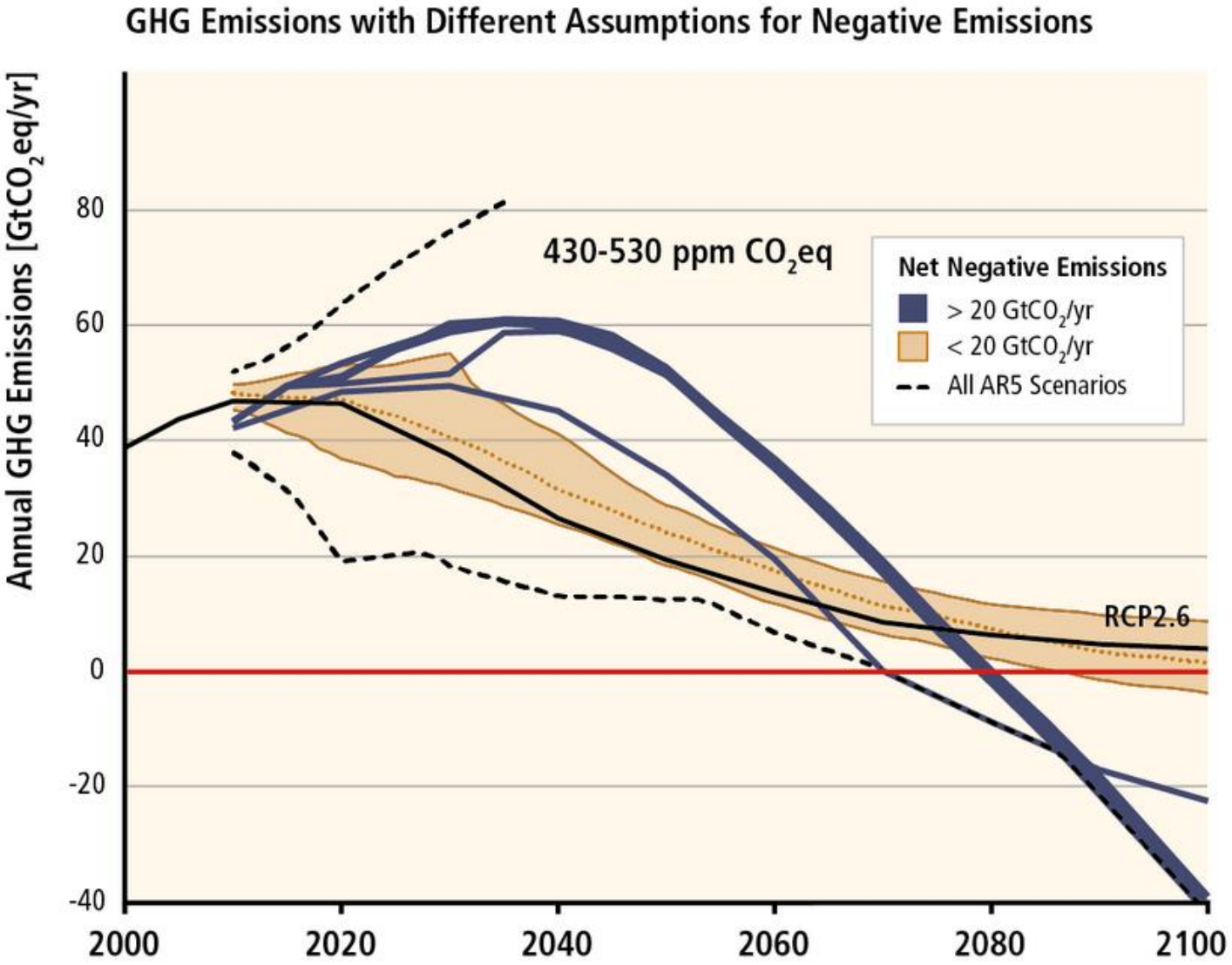
P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-58,-40)
└ in 2050 (% rel to 2010)	-93	-95	-91	-97	(-107,-94)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-51,-39)
└ in 2050 (% rel to 2010)	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12,7)
└ in 2050 (% rel to 2010)	-32	2	21	44	(-11,22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47,65)
└ in 2050 (%)	77	81	63	70	(69,86)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
└ in 2050 (% rel to 2010)	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
└ in 2050 (% rel to 2010)	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
└ in 2050 (% rel to 2010)	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
└ in 2050 (% rel to 2010)	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
└ in 2050 (% rel to 2010)	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(245,436)
└ in 2050 (% rel to 2010)	833	1327	878	1137	(576,1299)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550,1017)
└ of which BECCS ($GtCO_2$)	0	151	414	1191	(364,662)
Land area of bioenergy crops in 2050 (million km^2)	0.2	0.9	2.8	7.2	(1.5,3.2)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-47,-24)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,3)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

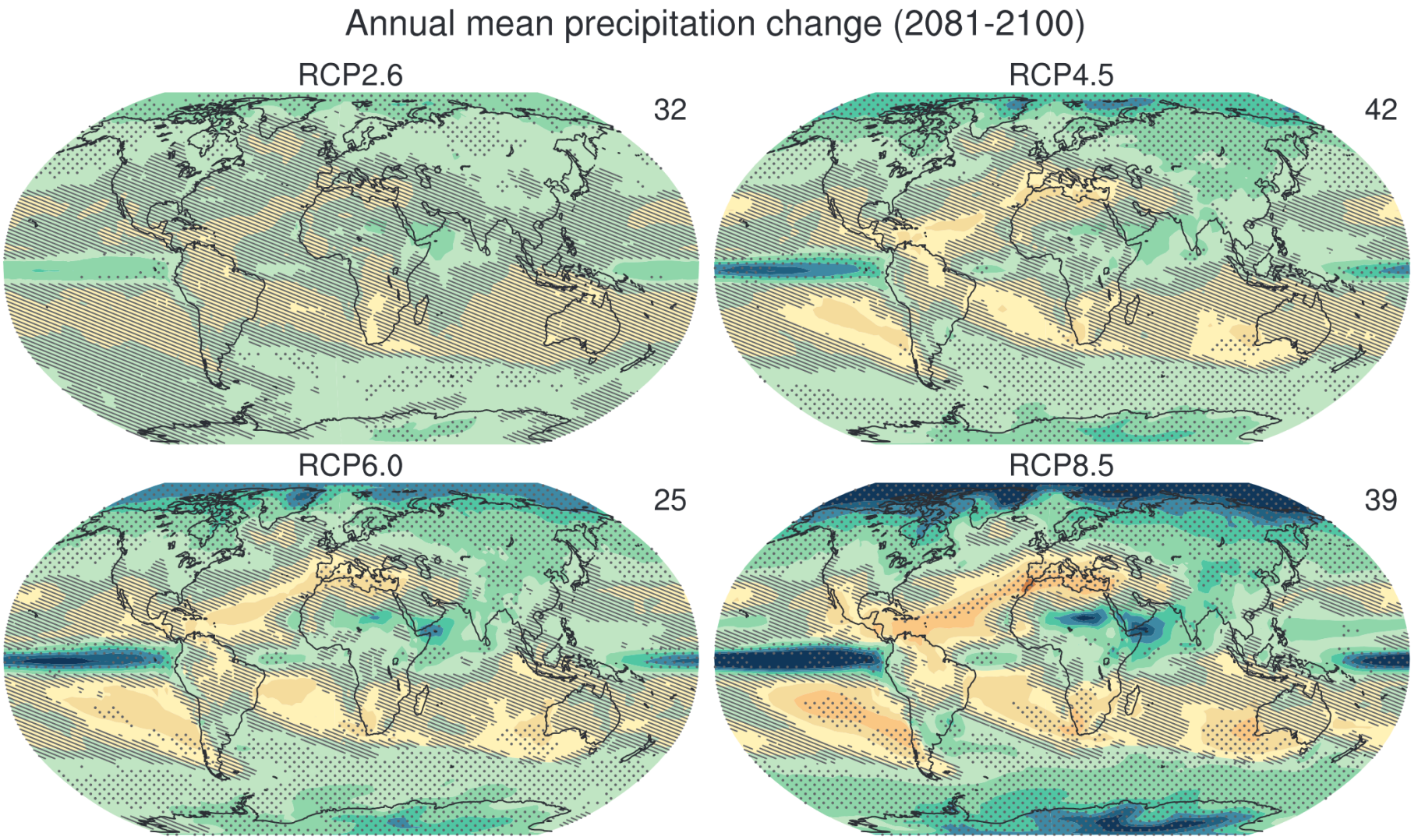
Source:
IPCC SR 1.5

Emissions scenarios: negative emissions



Source: IPCC

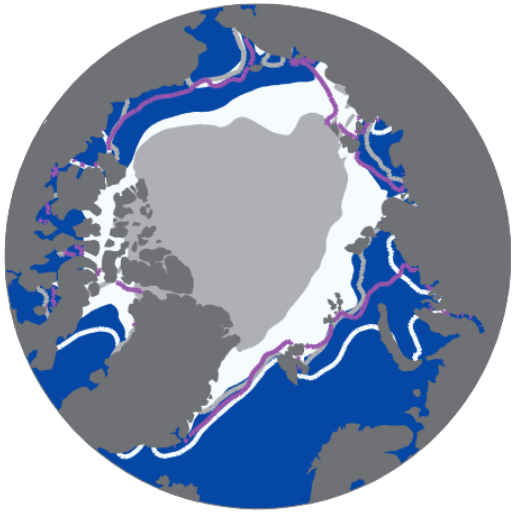
Multi model projections: precipitation change



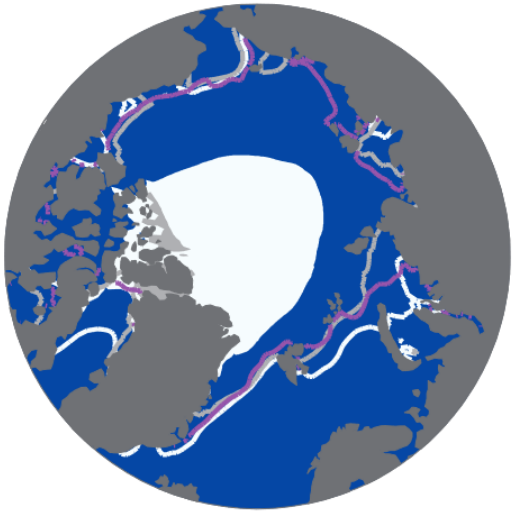
Source: IPCC 5AR

Sea ice extent (2081-2100, September, northern hemisphere)

RCP2.6



RCP6.0

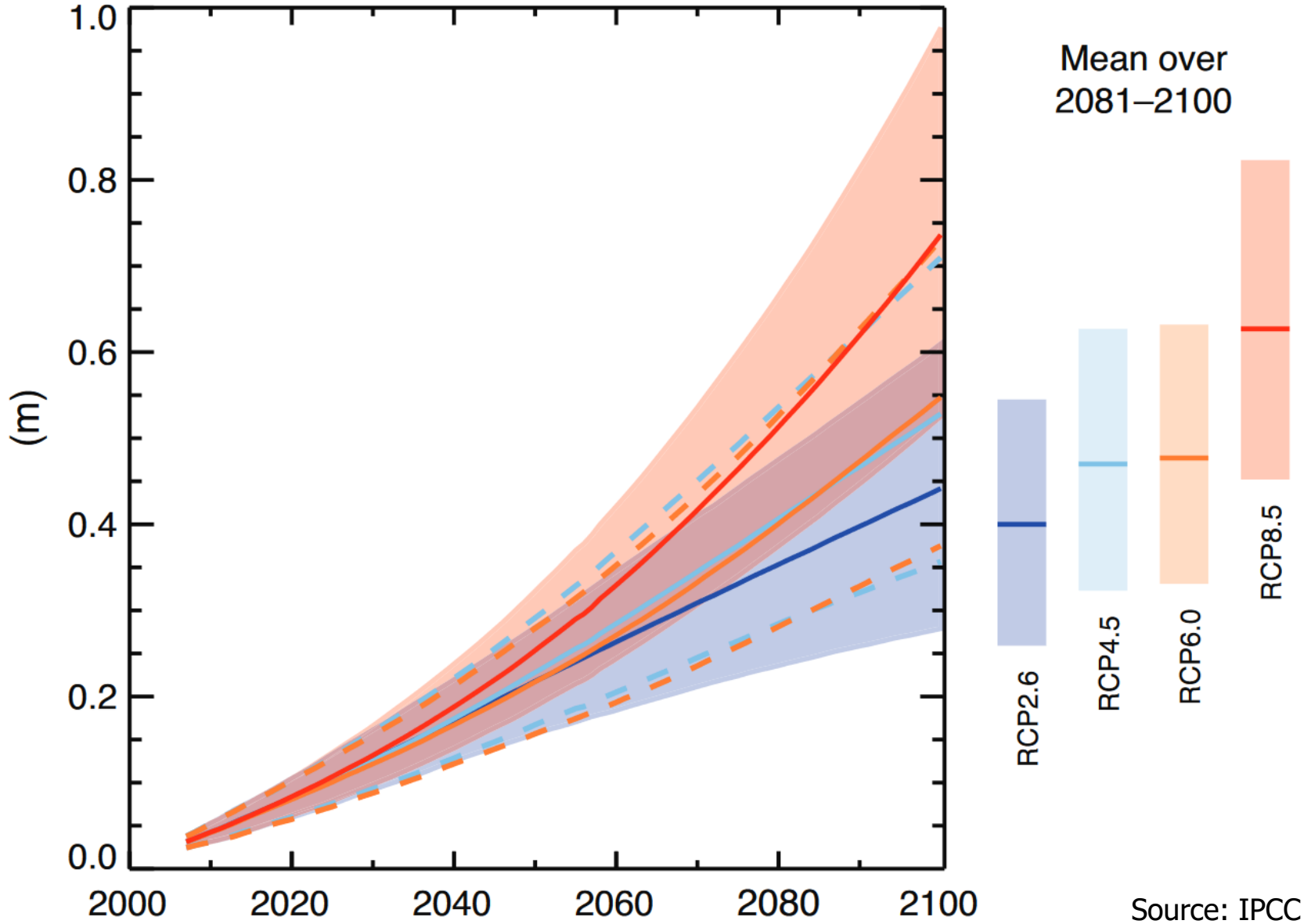


RCP4.5

RCP8.5

Source: IPCC 5AR

Sea level rise (global average)



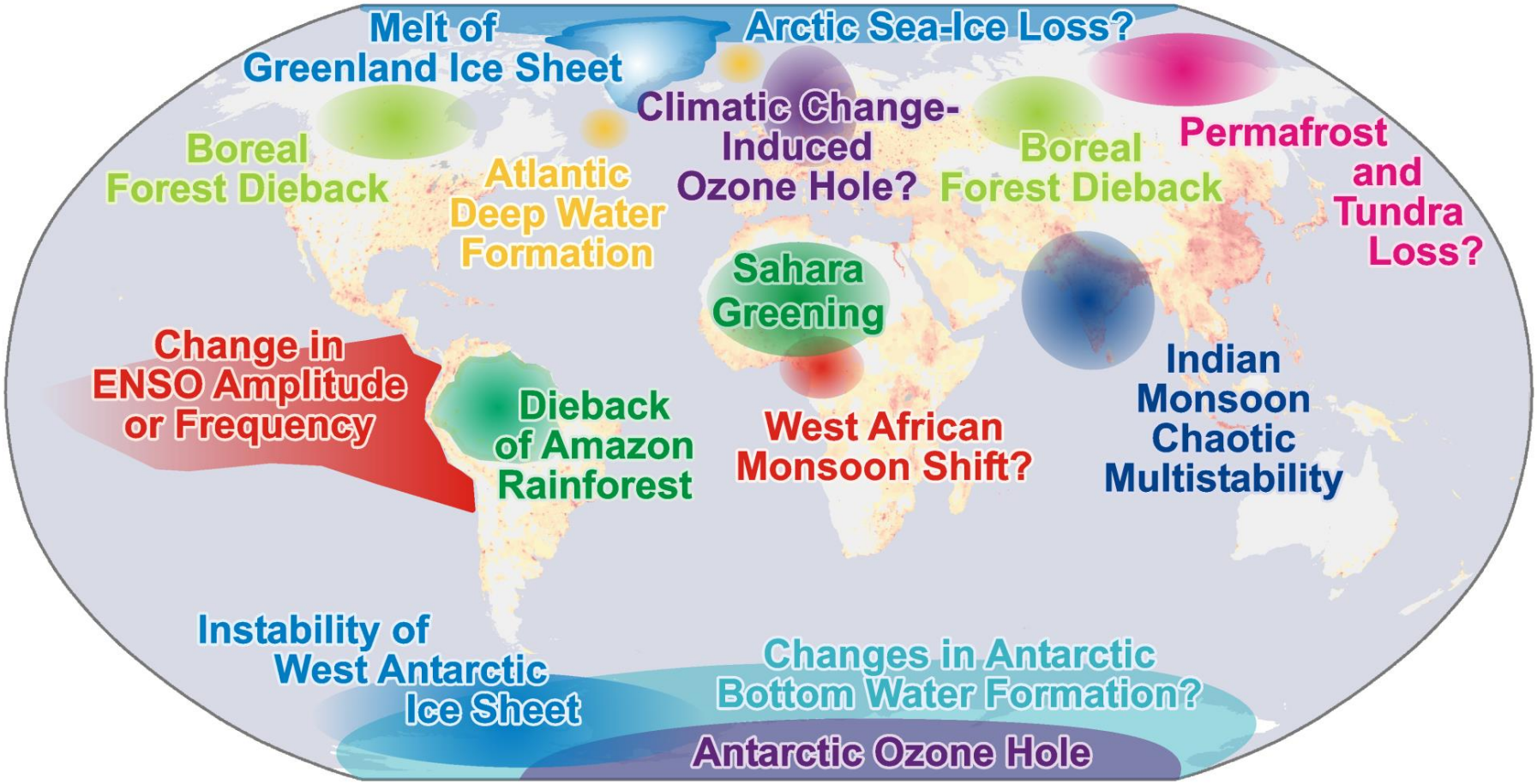
Source: IPCC 5AR

Tipping point

A critical point
at which a tipping element
(a component of the Earth system,
at least sub-continental in scale),
can be switched
– under certain circumstances –
into a qualitatively different state

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Potential tipping elements



Lenton et al.

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Tipping points

Tipping element	Feature of system, F	Control parameter(s), ρ	Critical value(s)*, ρ_{crit}	Global warming*†	Transition timescale*, T	Key impacts
Greenland ice sheet (GIS)	Ice volume (−)	Local ΔT_{air}	$+\sim 3$ °C	+1–2 °C	>300 yr (slow)	Sea level +7 m
West Antarctic ice sheet (WAIS)	Ice volume (−)	Local ΔT_{air}, or less ΔT_{ocean}	$+\sim 8$°C	+3–5 °C	>300 yr (slow)	Sea level +4–6 m
Atlantic thermohaline circulation (THC)	Overturning (−)	Freshwater input to N. Atlantic	+0.1–0.5 Sv	+3–5 °C	∼100 yr (gradual)	Regional cooling, sea level, ITCZ shift
El Niño Southern Oscillation (ENSO)	Amplitude (+)	Thermocline depth, sharpness in EEP	–	+3–6 °C	∼100 yr (gradual)	Drought in SE Asia and elsewhere
Indian summer monsoon (ISM)	Rainfall (−)	Planetary albedo over India	0.5	–	∼1 yr (rapid)	Drought
Sahara/Sahel and WAM	Veg. fraction (+)	Precipitation	100 mm/yr	+3–5 °C	∼10 yr (rapid)	Increased carrying capacity
Amazon rainforest	Tree fraction (−)	Precipitation, dry season length	1100 mm/yr	+3–4 °C	∼50 yr (gradual)	Biodiversity loss, decreased rainfall
Boreal forest	Tree fraction (−)	Local ΔT_{air}	$+\sim 7$ °C	+3–5 °C	∼50 yr (gradual)	Switch of biome

*Numbers given are preliminary as they are the result of a three-fold subjective but informed procedure: (1) selection of workshop participants, (2) assessment by the experts at the workshop, and (3) aggregation of multiple expert opinions by workshop group leaders and authors of this review article.

†Global mean temperature change above present (1980–1999) that corresponds to critical value of control, where this can be meaningfully related to global temperature.

Lenton et al.

Results from literature review and workshop

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Methodological consequences of tipping points

- description and analysis of gradual changes does not suffice
- risk aversion and the precautionary principle (but what is a dangerous interference?)

EPFL

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch

Some conclusions for session 1

- climate change happens on very long time scales
- human economic activity is the dominant cause («extremely likely»)
  - dominant GHG emission sources: energy-related fossil fuel use, agriculture/land use
  - global GHG emissions still rise, especially in high middle income countries
  - per capita emissions are highest where rich people live, especially when accounted on a consumption basis
- uncertainty is highly relevant for climate economic analysis
  - uncertainties in emissions pathways affect climate projections
  - uncertainties in climate projections affect economic analysis
- Paris temperature goals (1.5°C or well below 2°C) require
  - immediate and drastic mitigation action
  - negative emissions

Dr. Frank Vöhringer
ENAC IA LEURE
frank.voehringer@epfl.ch