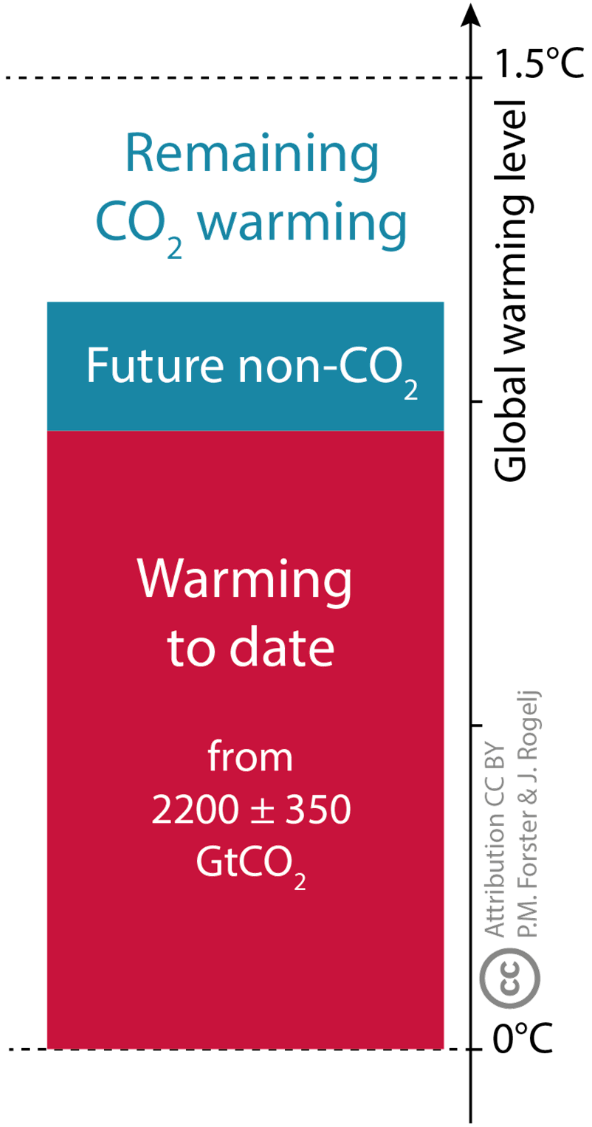
Rapid global transformations towards net zero CO_2 emissions

Keywan Riahi
International Institute for Applied Systems Analysis (IIASA)
riahi@iiasa.ac.at

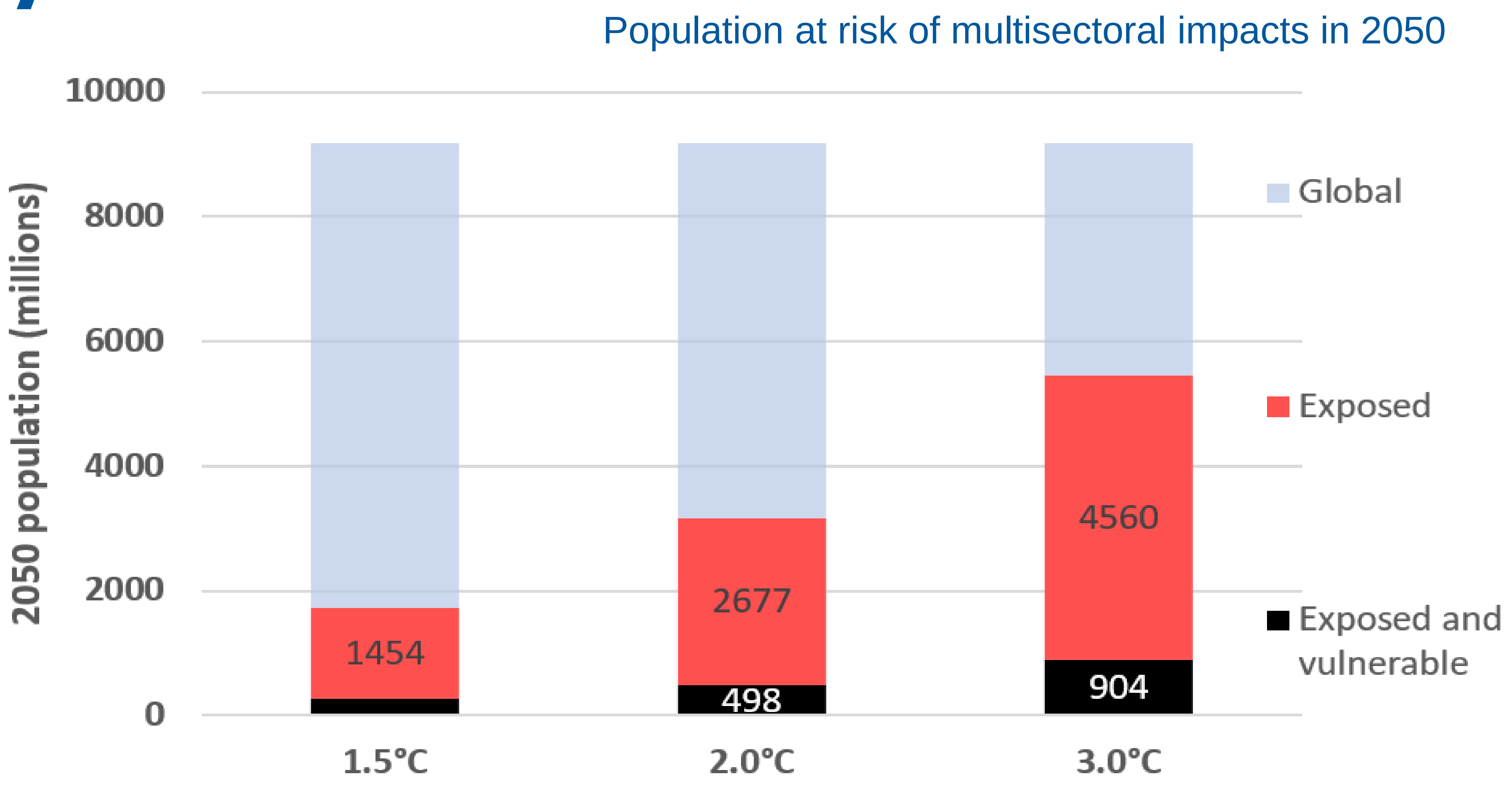
ALPS Symposium, 8 March 2021



Remaining carbon budget for 1.5C

- 580 $GtCO_2$ left (50% chance of 1.5°C)
  420 $GtCO_2$ left (66% chance of 1.5°C)
  +- 250 $GtCO_2$ depends on what is done on non-CO_2
  +- 400 $GtCO_2$ geophysical uncertainty
- Currently, 42 +- 3 $GtCO_2$/yr annually
- 200 $GtCO_2$ budget differences are about 5 year of current emissions and imply roughly a 10 year variation in the mid-century timing of reaching net zero CO_2 emissions.
- Advances in methods and understanding have resulted in a 300 $GtCO_2$ increase since AR5

Why 1.5C?



2010 Poverty in numbers:

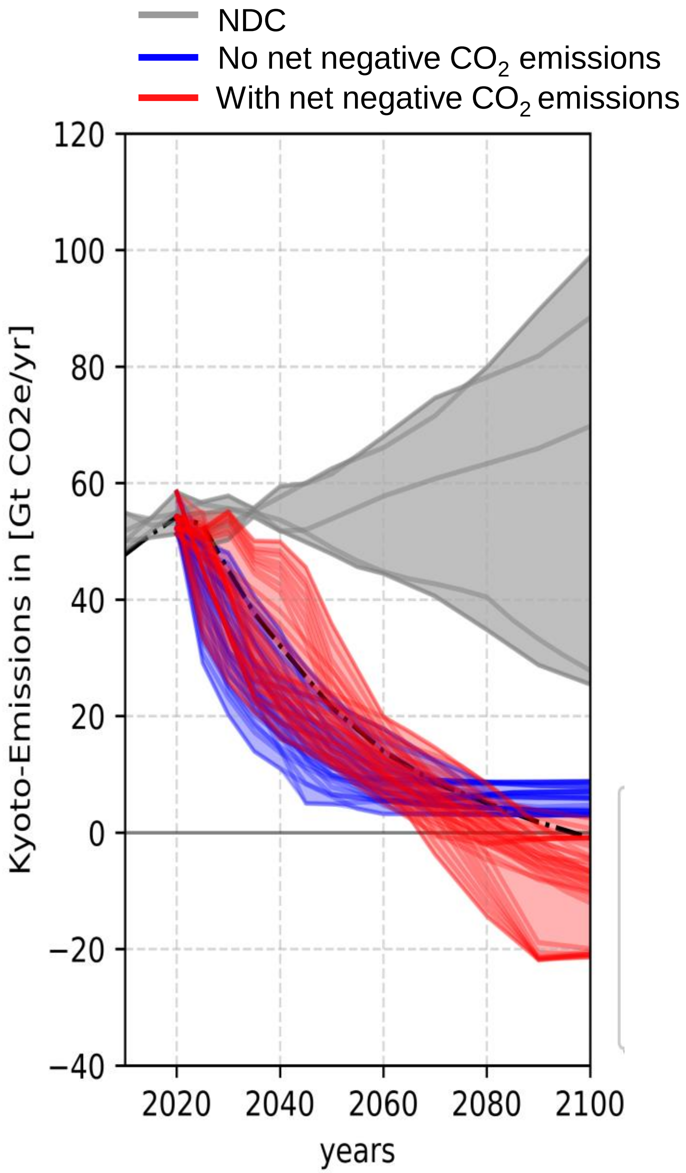
~ 700 million in extreme poverty (<2$/day)

~ 2.2 billion vulnerable to poverty (<10$/day)

Byers et al. (2018, ERL) feeding into the IPCC 1.5C

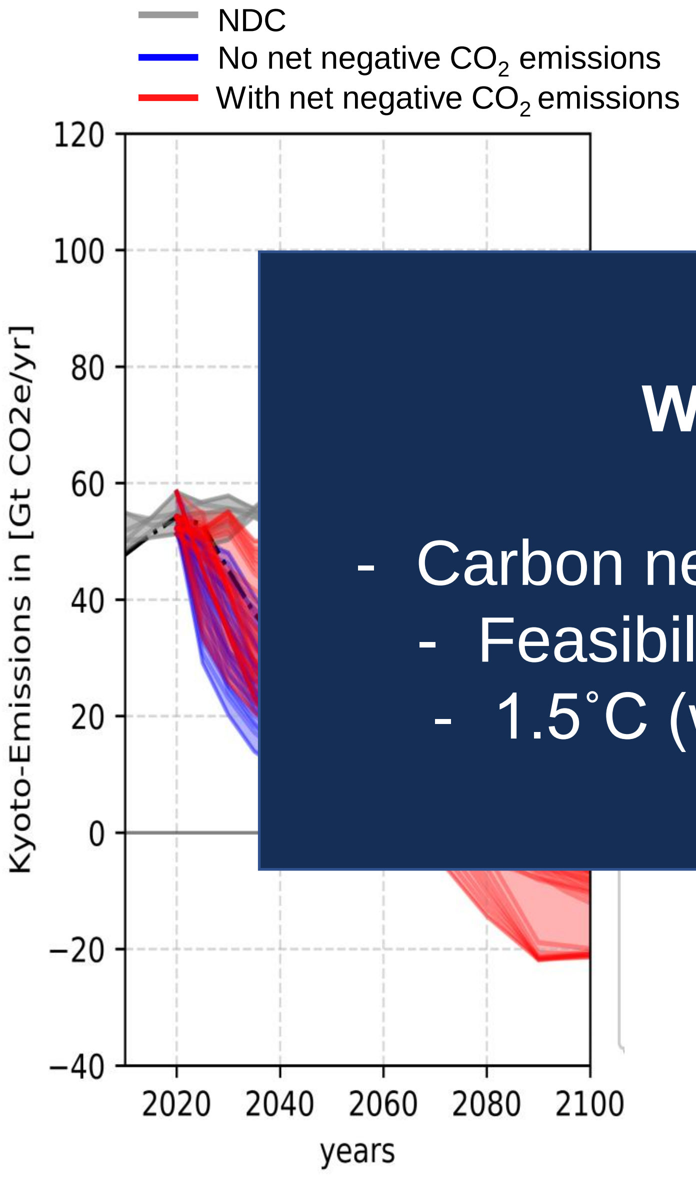
UNIDO IIASA gef GLOBAL ENVIRONMENT FACILITY INVESTING IN OUR PLANET

World GHG Emissions

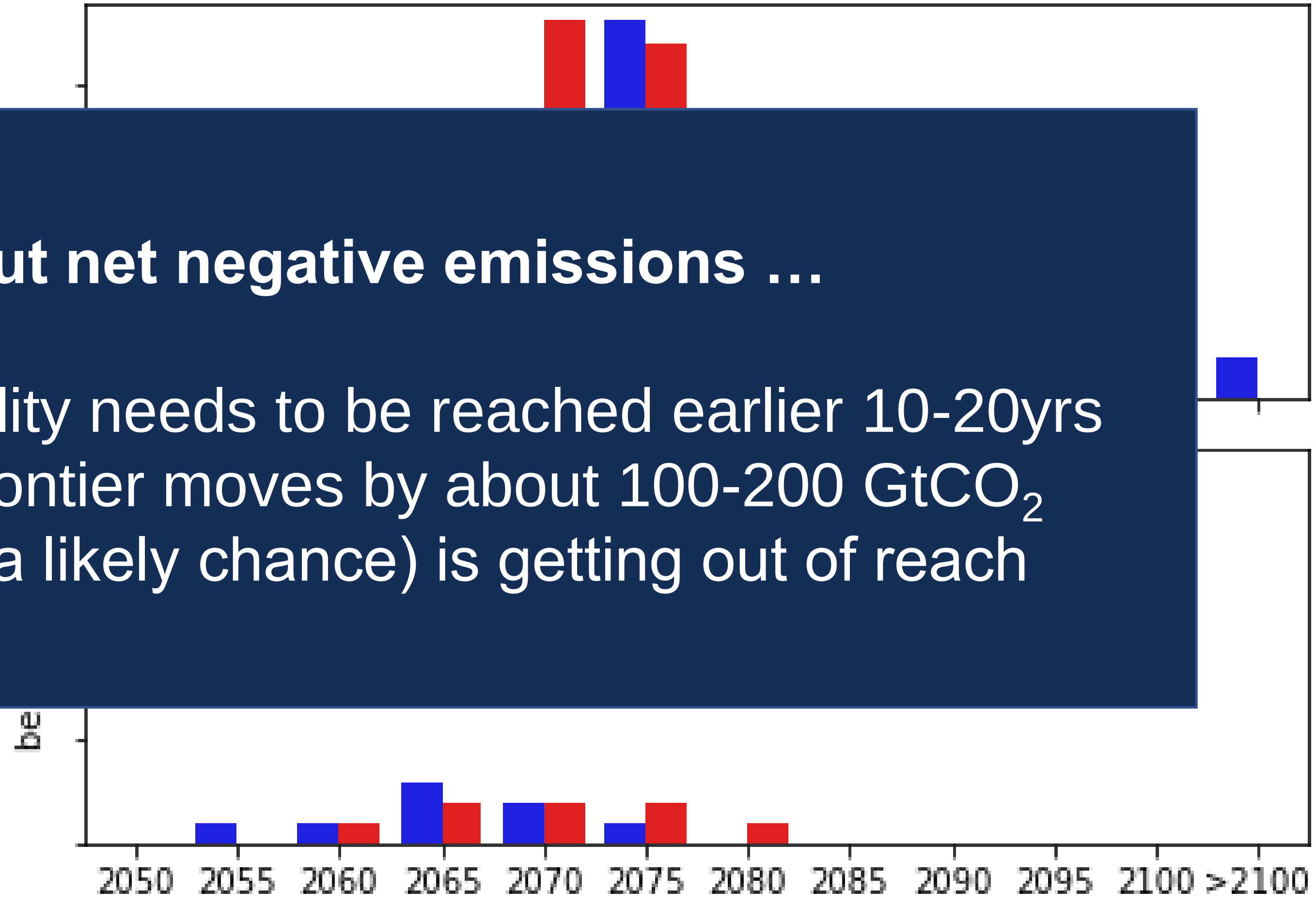


- So far focus on end-of-century scenario design → temperature overshoot
- New scenario design (Rogelj et al, 2019)
- Focuses on the remaining near-term **carbon budget until net zero CO_2** emissions are reached
- Time of net zero is the time when temperature is stabilized (avoiding overshoot)
- Key question is what does it mean to achieve temperature objectives **without net negative emissions and without temperature overshoot**
- **ENGAGE:** Nine global modelling teams

World GHG Emissions



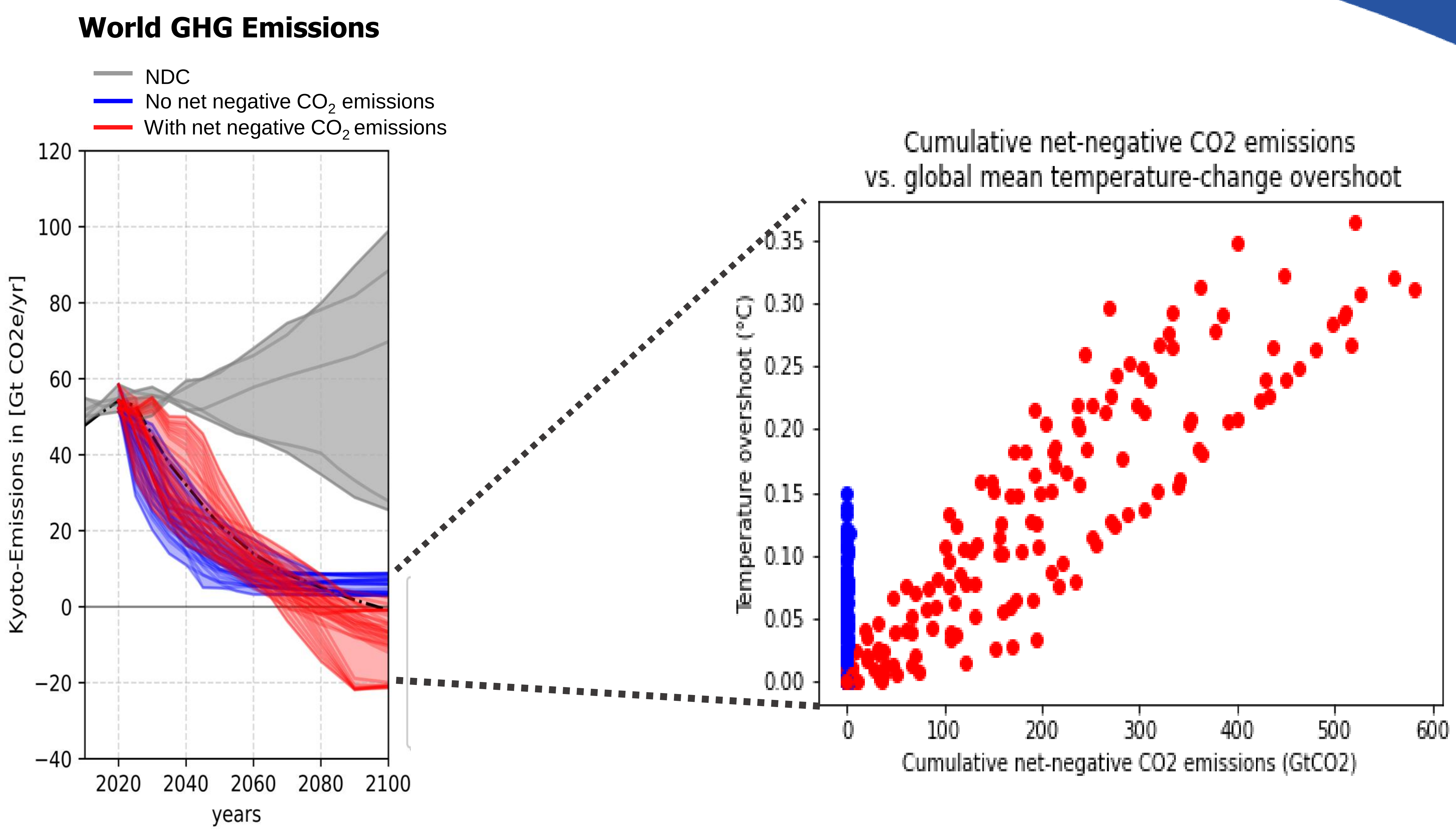
Time when global net zero CO2 emissions is reached



Without net negative emissions …

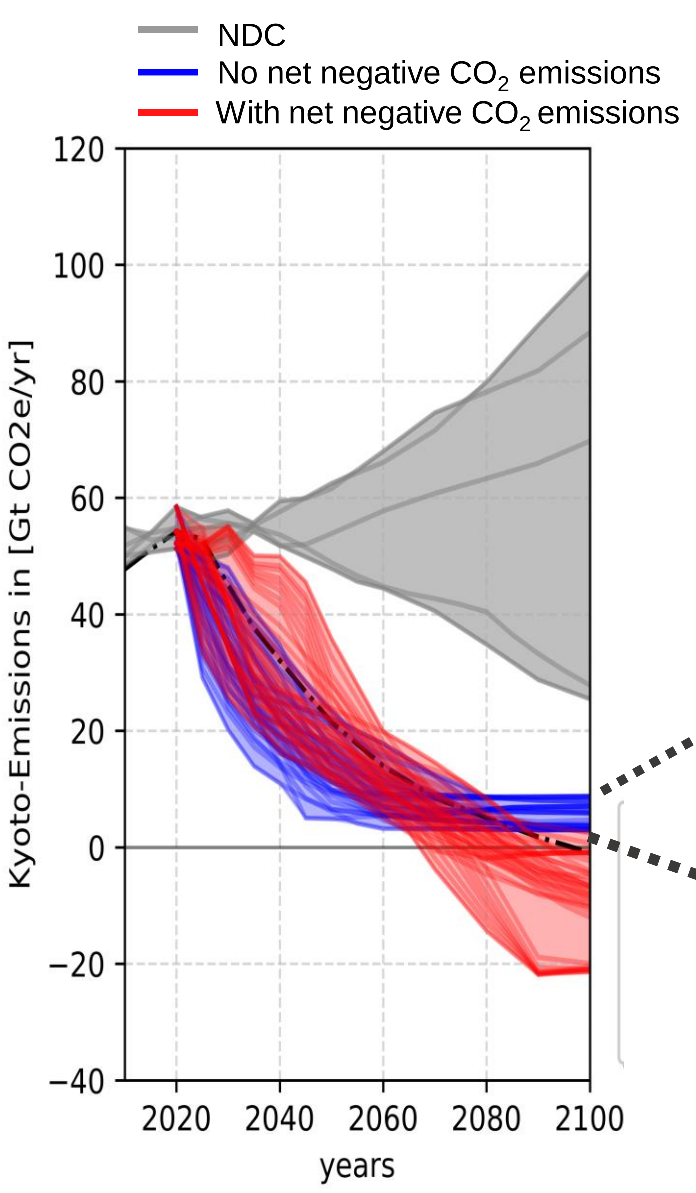
- Carbon neutrality needs to be reached earlier 10-20yrs
- Feasibility frontier moves by about 100-200 $GtCO_2$
- 1.5˚C (with a likely chance) is getting out of reach

IIASA

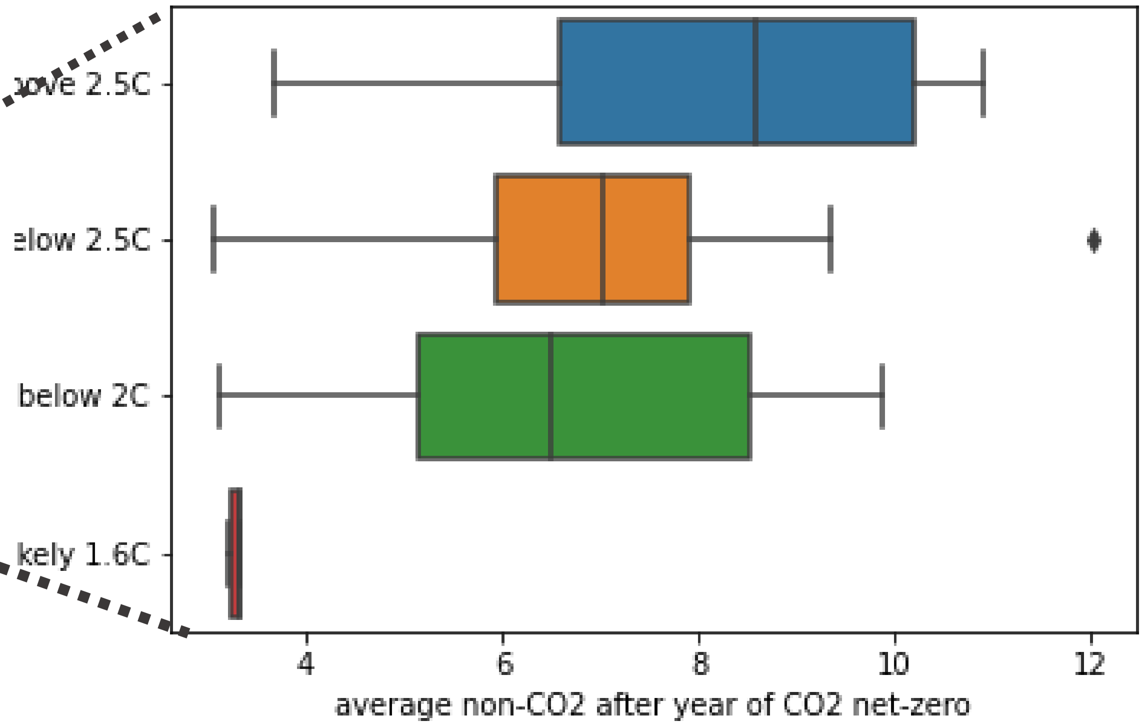

World GHG Emissions
NDC
No net negative CO2 emissions
With net negative CO2 emissions
Kyoto-Emissions in [Gt CO2e/yr]
120
100
80
60
40
20
0
−20
−40
2020
2040
2060
2080
2100
years
Cumulative net-negative CO2 emissions
vs. global mean temperature-change overshoot
Temperature overshoot (°C)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
100
200
300
400
500
600
Cumulative net-negative CO2 emissions (GtCO2)

IIASA

World GHG Emissions

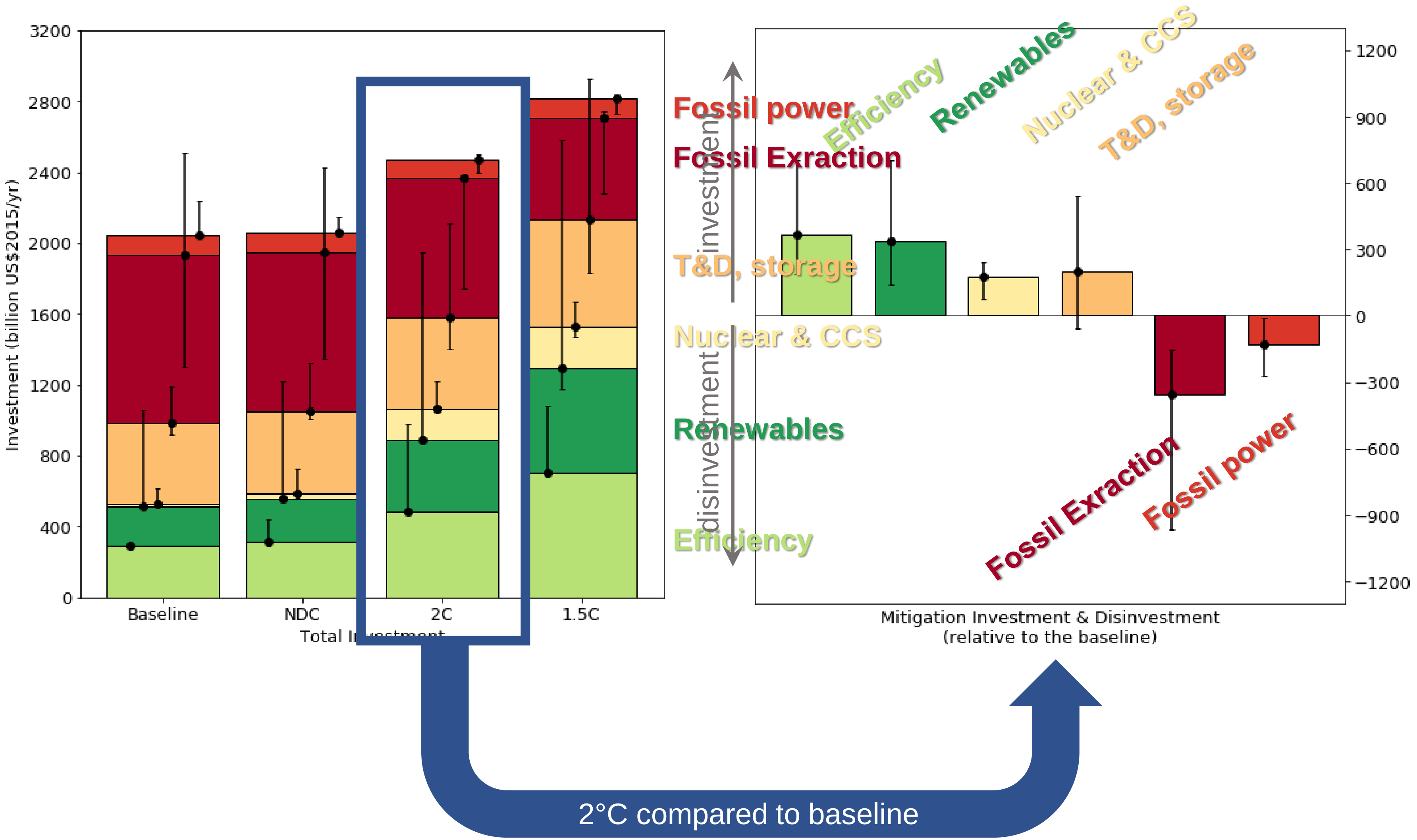


Non-CO2 "tail" emissions consistent with different temperature stabilization levels



Global Investment Portfolios for 1.5 and 2C

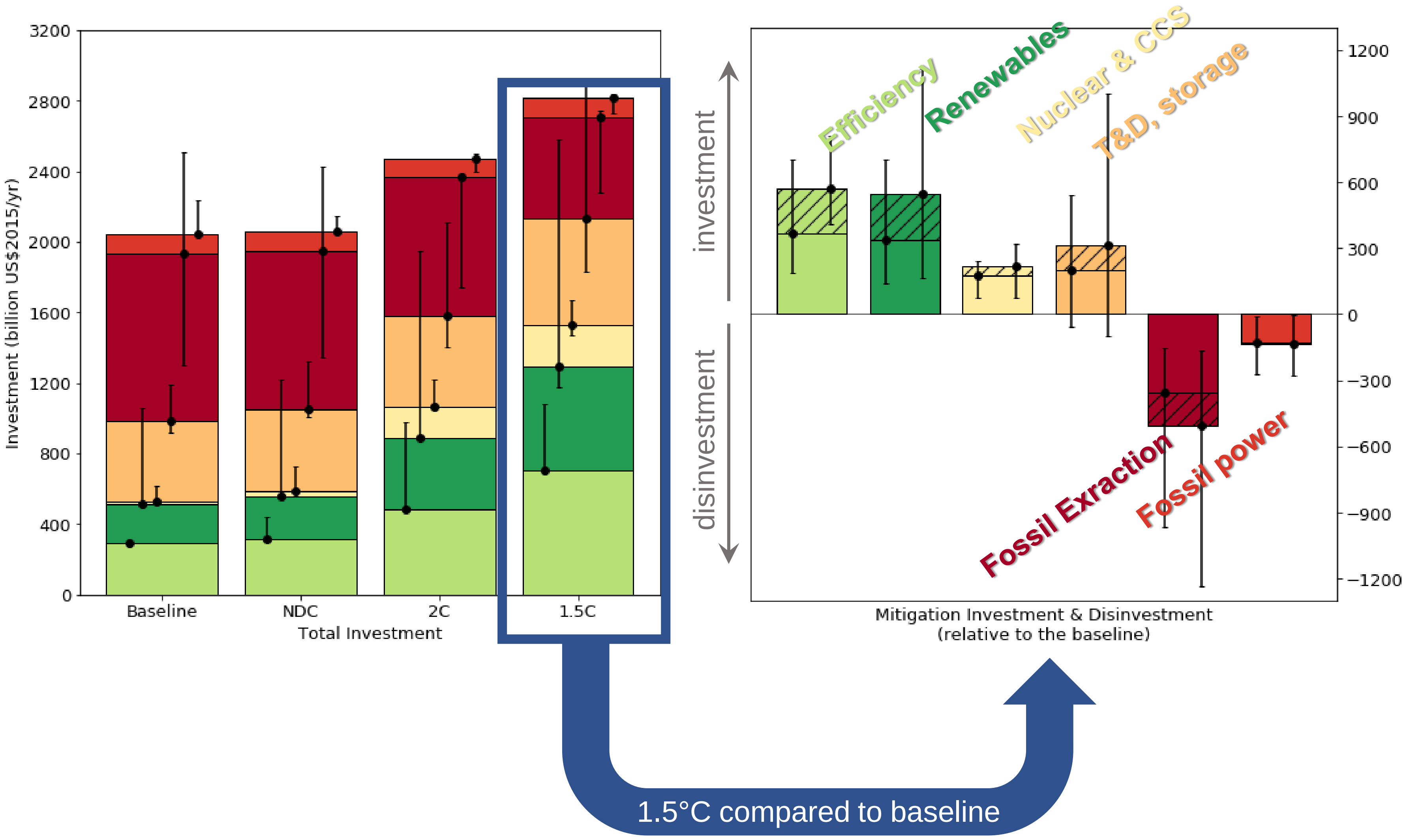
Average annual investments 2010 to 2050



McCollum et al, 2018, Nature Energy

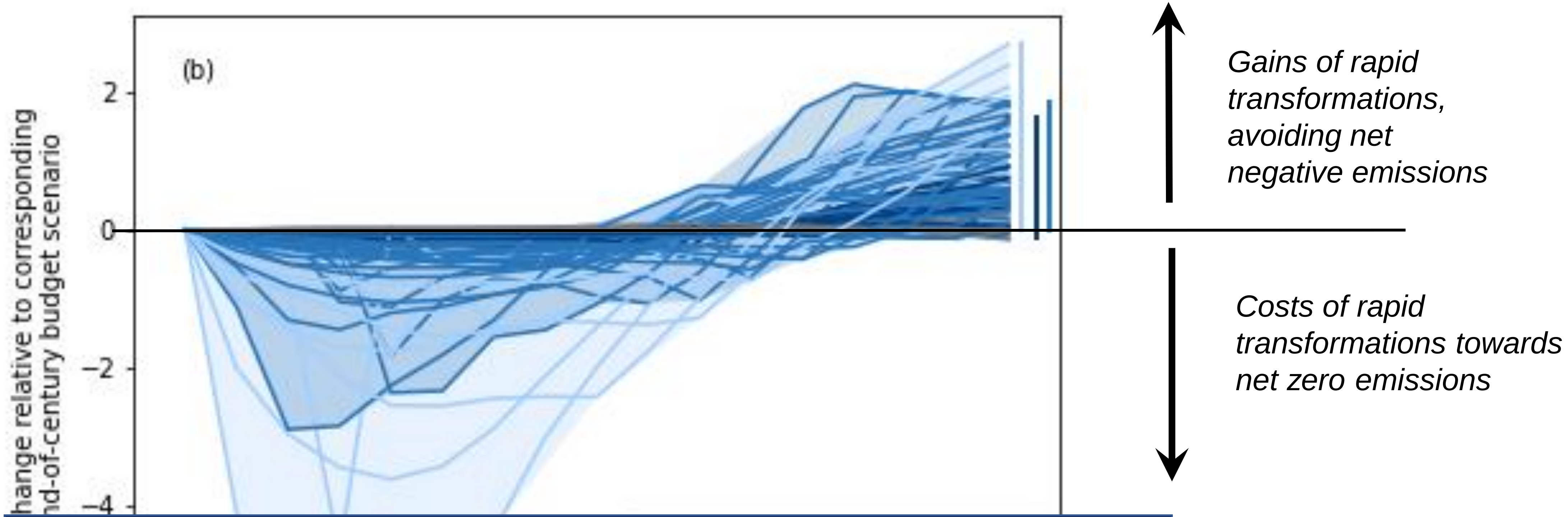
Global Investment Portfolios for 1.5 and 2C

Average annual investments 2010 to 2050



McCollum et al, 2018, Nature Energy

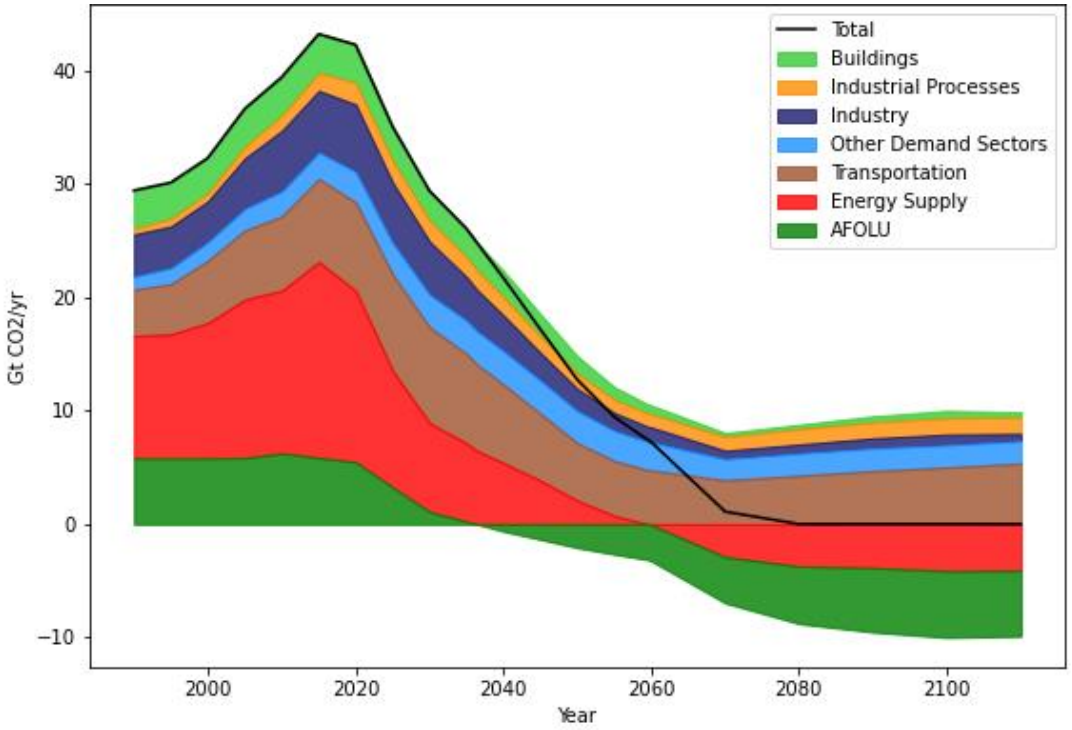
Economic losses and gains



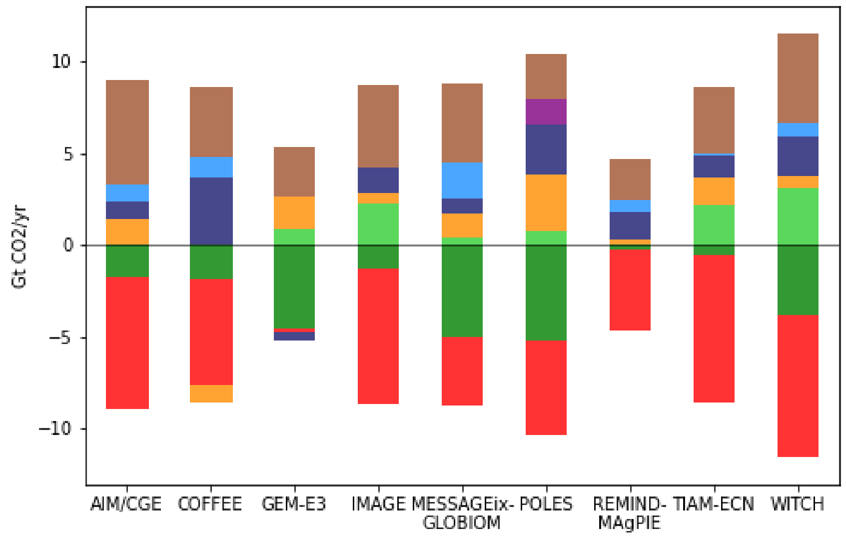
Long-term GDP is higher without reliance on net negative emissions and without overshoot

What does carbon neutrality mean?
SECTORAL emissions sources and sinks

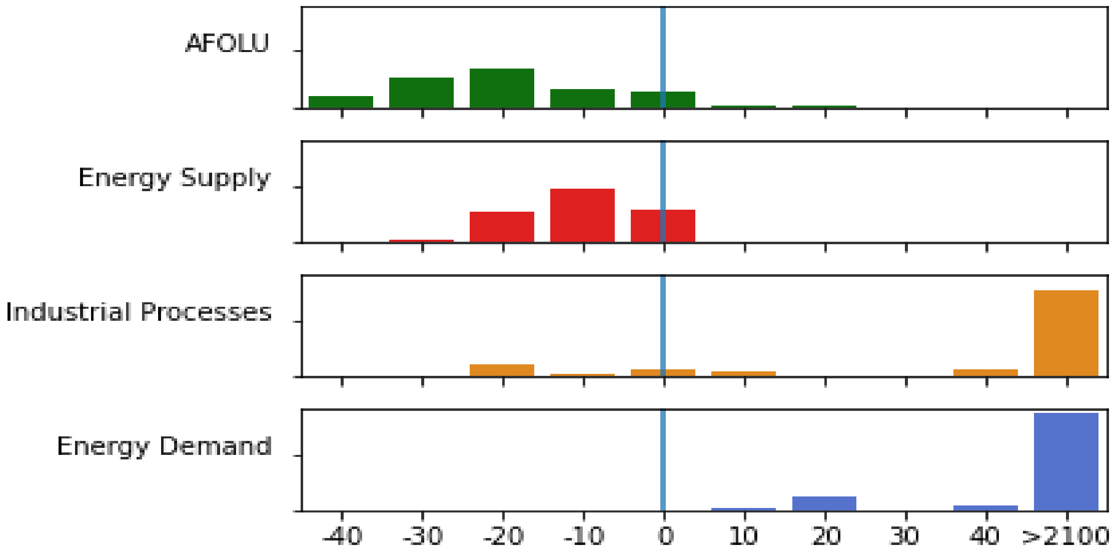
Illustrative zero emissions pathway



Different strategies across models



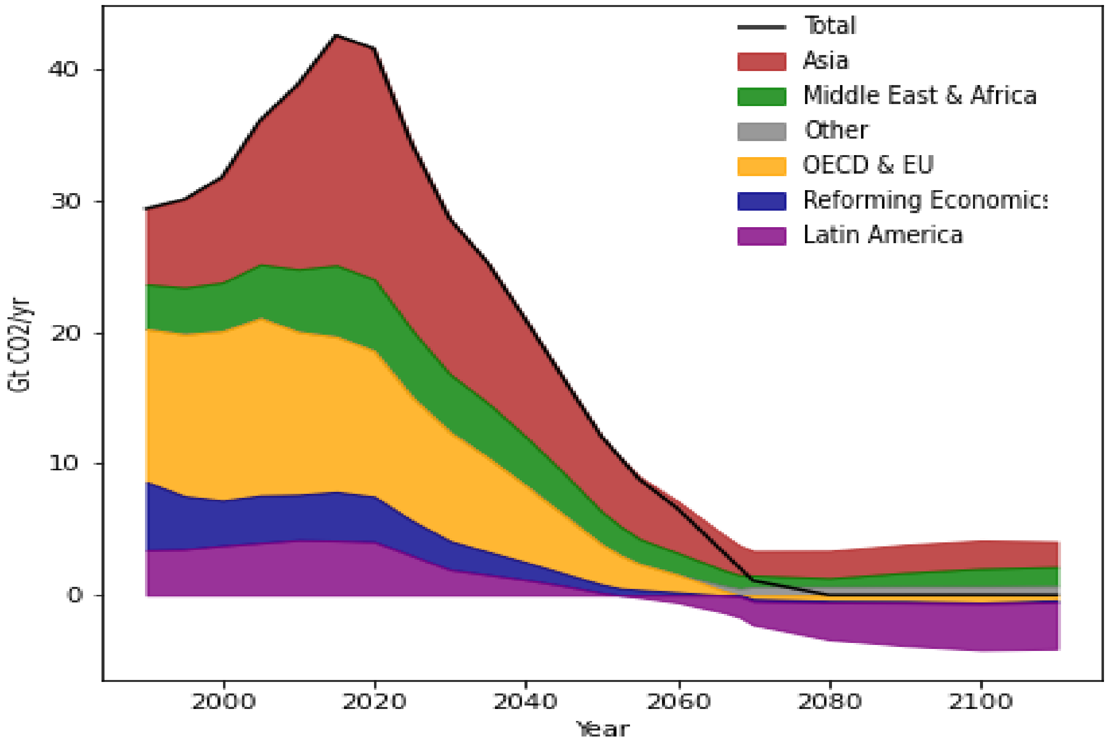
Timing of sectors for zero emissions
(compared to the timing of the overall system)



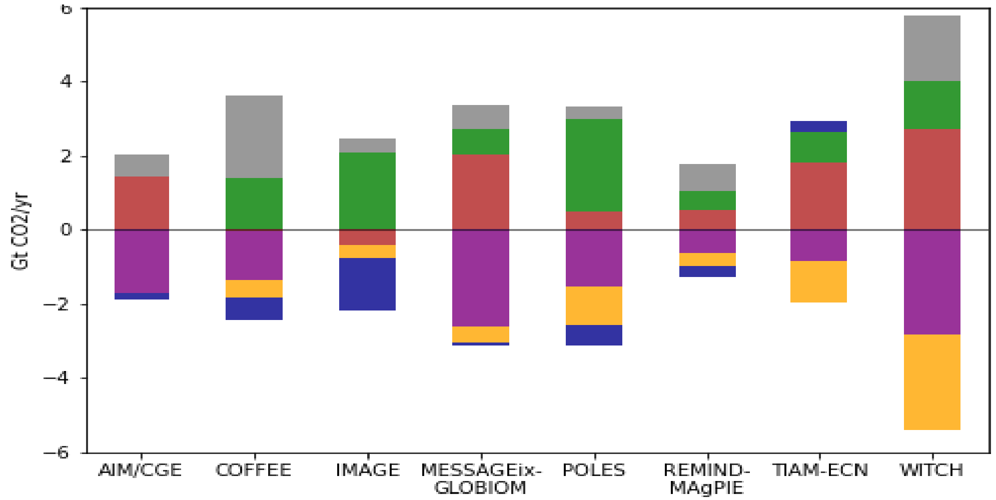
What does carbon neutrality mean?

REGIONAL emissions sources and sinks

Illustrative zero emissions pathway

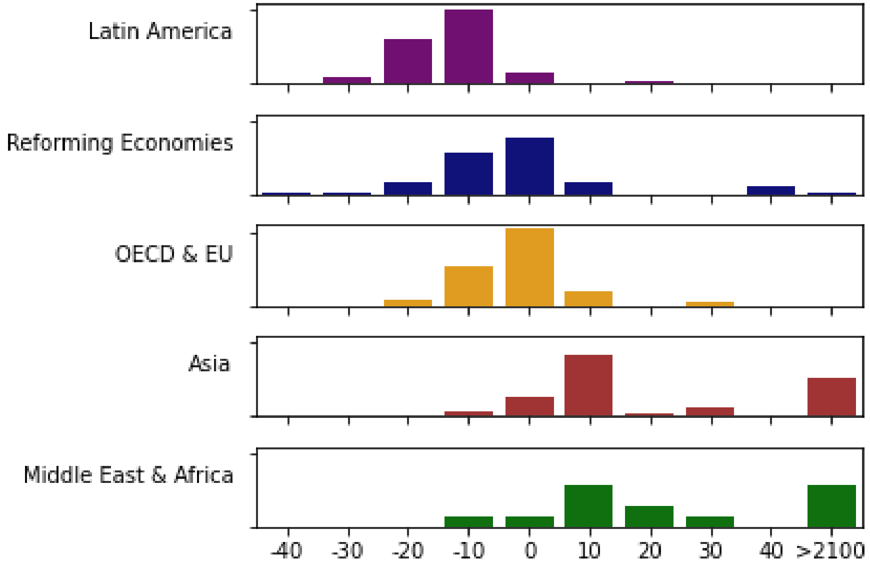


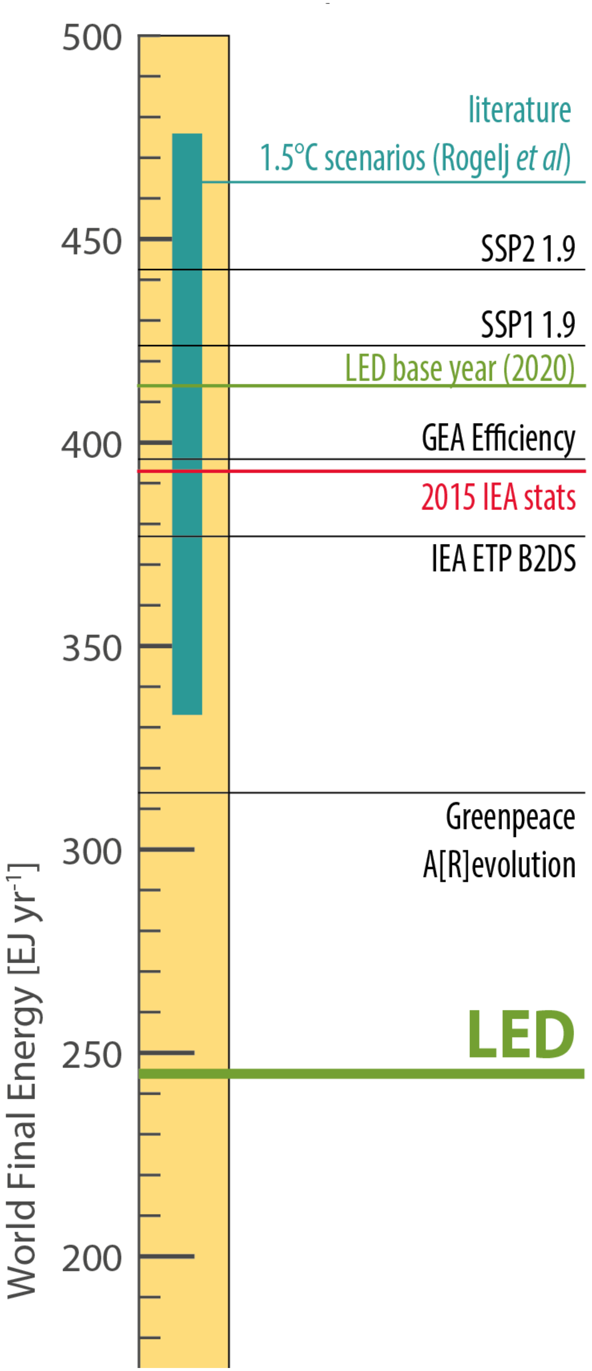
Different strategies across models



Timing of regions for zero emissions

(compared to the timing of the overall system)





nature energy

ANALYSIS

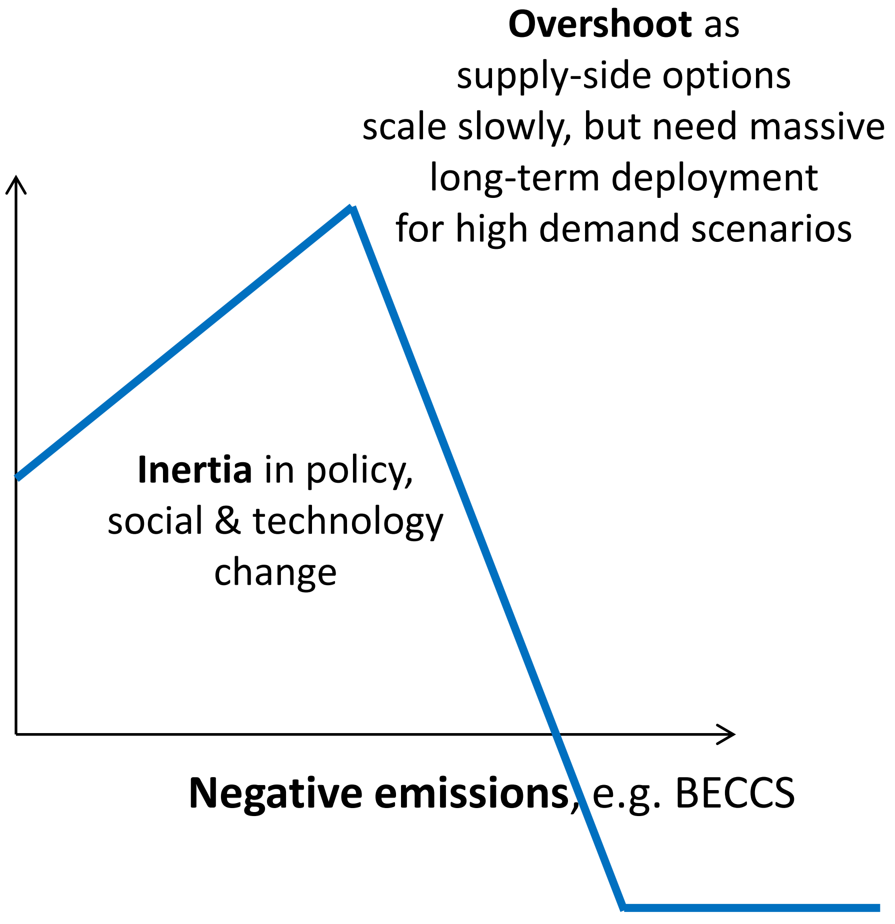
https://doi.org/10.1038/s41560-018-0172-6

A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies

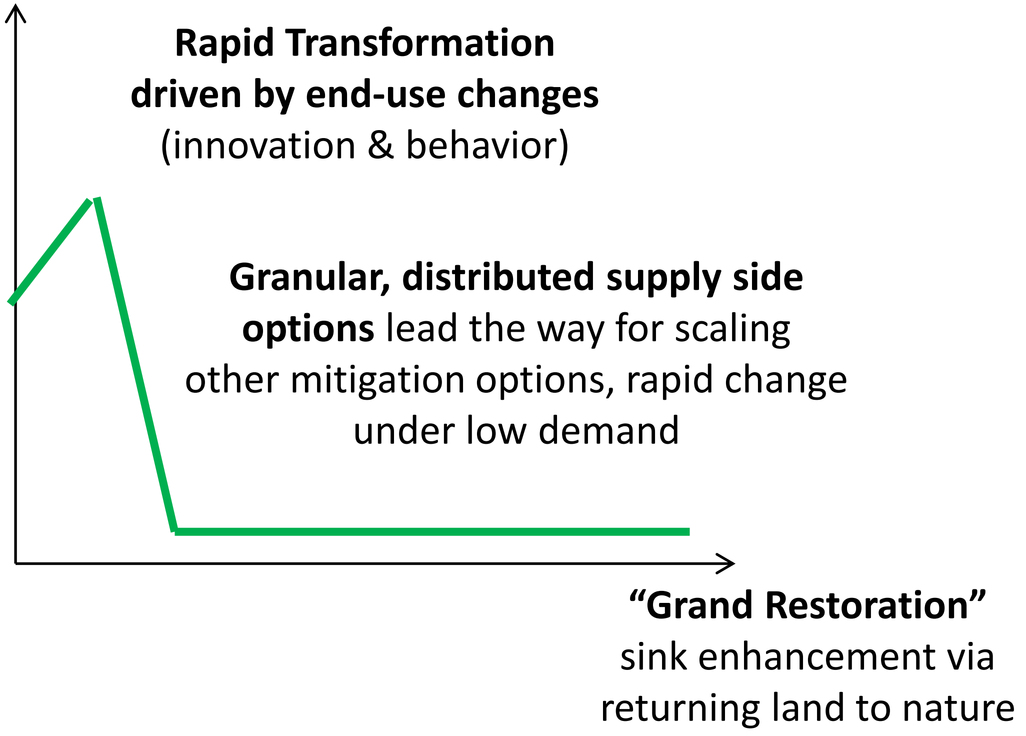
Arnulf Grubler[1*], Charlie Wilson[1,2], Nuno Bento[1,3], Benigna Boza-Kiss[1], Volker Krey[1], David L. McCollum[1], Narasimha D. Rao[1], Keywan Riahi[1,4,5], Joeri Rogelj[1,6], Simon De Stercke[1,7], Jonathan Cullen[8], Stefan Frank[1], Oliver Fricko[1], Fei Guo[1], Matt Gidden[1], Petr Havlík[1], Daniel Huppmann[1], Gregor Kiesewetter[1], Peter Rafaj[1], Wolfgang Schoepp[1] and Hugo Valin[1]

Scenarios that limit global warming to 1.5 °C describe major transformations in energy supply and ever-rising energy demand. Here, we provide a contrasting perspective by developing a narrative of future change based on observable trends that results in low energy demand. We describe and quantify changes in activity levels and energy intensity in the global North and global South for all major energy services. We project that global final energy demand by 2050 reduces to 245 EJ, around 40% lower than today, despite rises in population, income and activity. Using an integrated assessment modelling framework, we show how changes in the quantity and type of energy services drive structural change in intermediate and upstream supply sectors (energy and land use). Down-sizing the global energy system dramatically improves the feasibility of a low-carbon supply-side transformation. Our scenario meets the 1.5 °C climate target as well as many sustainable development goals, without relying on negative emission technologies.

2 Perspectives on Meeting 1.5°C
GHG Emissions Profiles



“Conventional” 1.5 C Scenario



LED Scenario narrative

New Trends in Social and Technological Change

- Changing consumer preferences (e.g. diets)
- Value change enabling new lifestyles and behaviors (service rather than ownership)
- New business models (sharing & circular economy)
- Pervasive digitalization and ICT convergence
- Rapid innovation in granular technologies and integrated digital services

Social Change: Change in Car Driving Licenses held by Young

Trends: near-term: <50%, long-term: ~0?

Location	year a	year b	age group	% of age group with drivers license		change
				year a	year b	%-points
Austria 2	2010	2015	17-18	39	28	-11
Germany	2008	2017	18-24	71	66	-5
Great Britain	1995	2008	17-20	43	36	-7
Great Britain	1995	2008	21-29	74	63	-11
Israel 2	2005	2015	17-18	34	30	-4
Israel 2	2009	2016	19-24	65	64	-1
Japan	2001	2009	16-19	19	17	-2
Japan	2001	2009	20-24	79	75	-4
Norway	1991	2009	19	74	55	-19
Norway	1991	2009	20-24	85	67	-18
Sweden	1983	2008	19	70	49	-21
Sweden	1983	2008	20-24	78	63	-15
Switzerland	1994	2015	18-24	71	61	-10
USA	1983	2014	18	80	60	-20
USA	1983	2014	19	86	69	-17
USA	1983	2014	20-24	91	77	-14

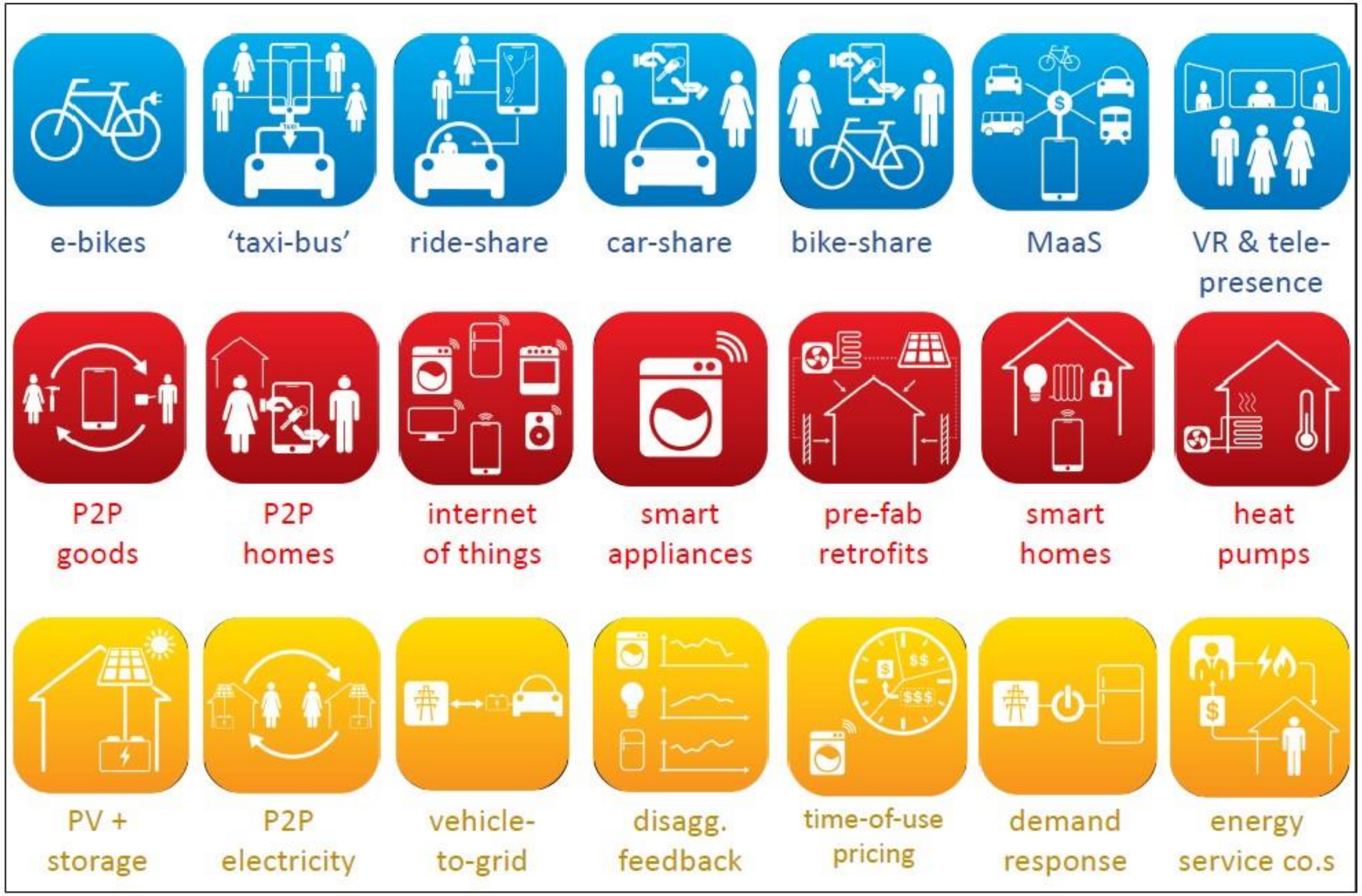
Location	year a	year b	age group	% of age group with drivers license		change
				year a	year b	%-points
Austria 1	2006	2010	17-18	32	39	7
Finland	1983	2008	18-19	37	68	31
Finland	1983	2008	20-29	51	82	31
Israel 1	1983	2008	19-24	42	64	22
Israel 1	1983	2008	25-34	62	78	16
Netherlands	1985	2008	18-19	25	45	20
Netherlands	1985	2008	20-24	64	64	0
Spain	1999	2009	15-24	37	50	13

Note in particular much larger prevalence of declining driving license ownership and shift from growth to decline trends in Austria and Israel around 2008/2010 (for Finland, Netherlands, Spain no more recent data available to uncover similar trend breaks)

Data sources: Sivak & Schottle, 2011; Delbosc & Currie, 2013; National Statistics, 2017 for Austria, Germany, Israel, Switzerland

Mobility: *'usership'* vs. *ownership*

Disruptive End-user Innovations



(1) From ownership to usership – (2) Sharing Economy – (3) From atomized to connected

Source: Charlie Wilson

lumpy

large unit size

high unit cost

indivisible

high risk

Technology Unit Size

granular

small unit size

low unit cost

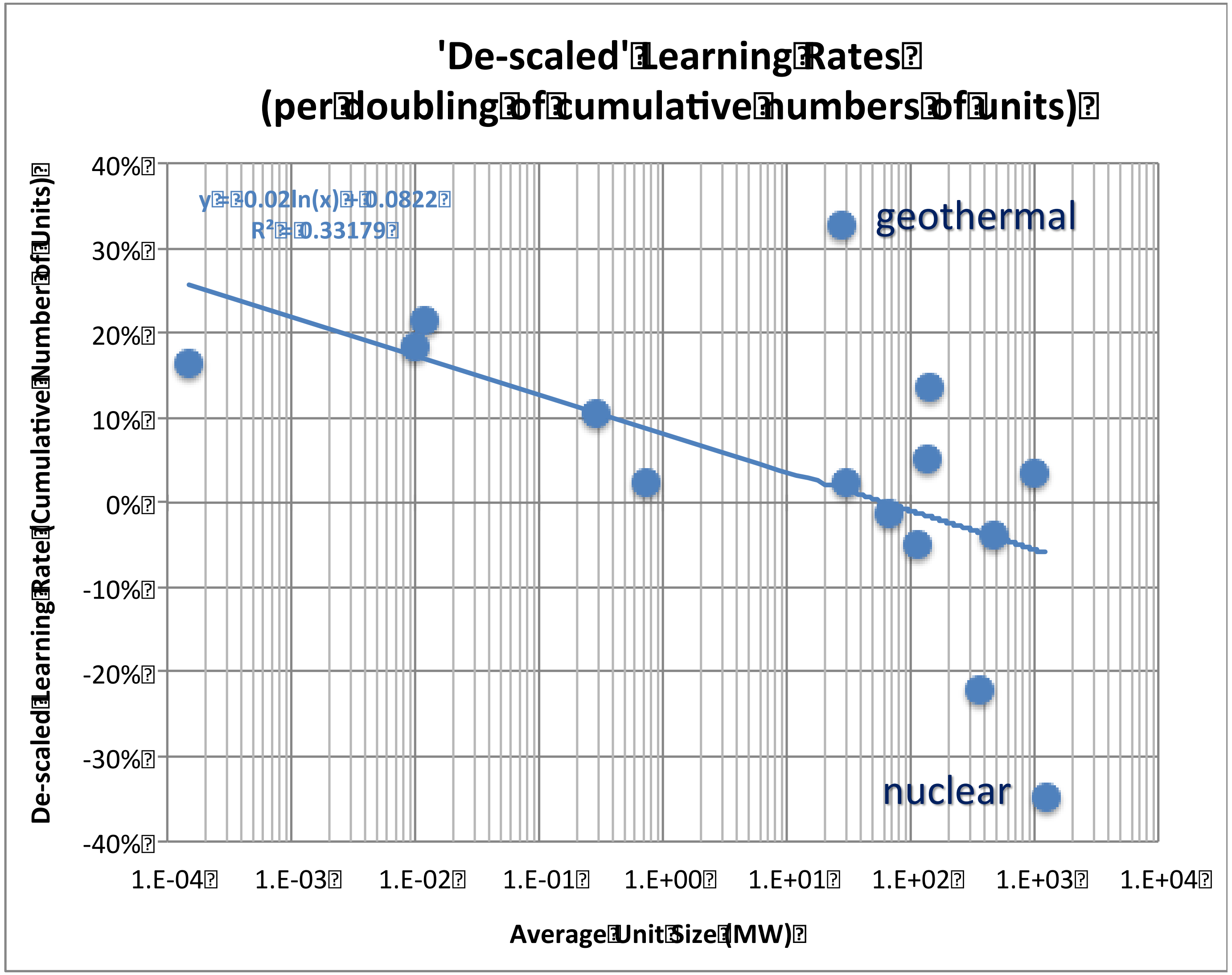
modular

low risk

Source: Grubler, ESA class material

Granularity Benefits: faster learning

Higher Learning with Smaller Unit Scale after Accounting for Economies of Scale



smaller units

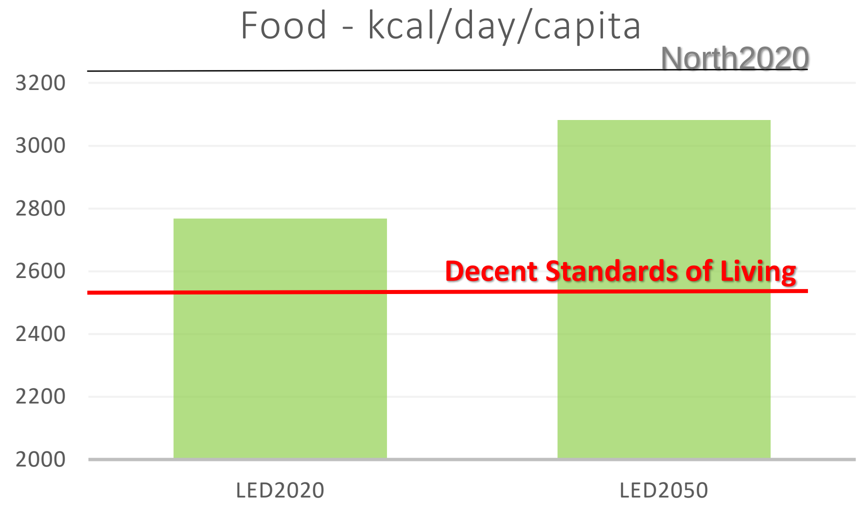
-> more units

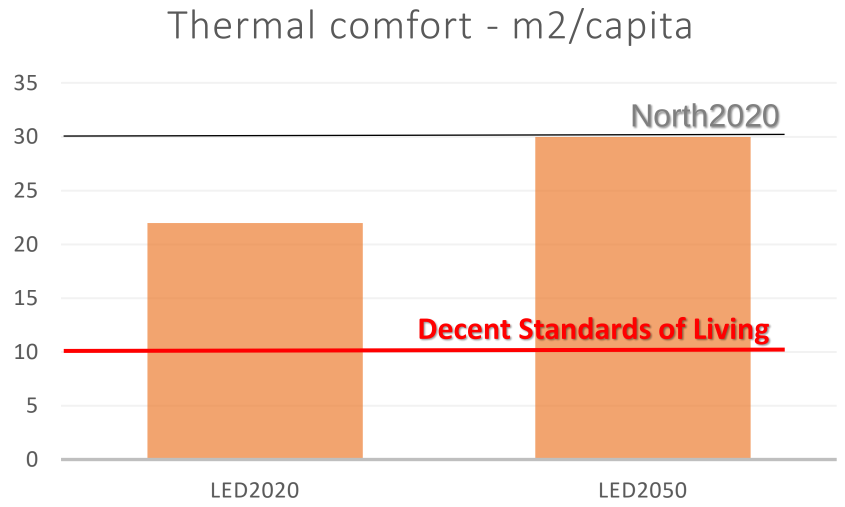
-> more opportunities to experiment

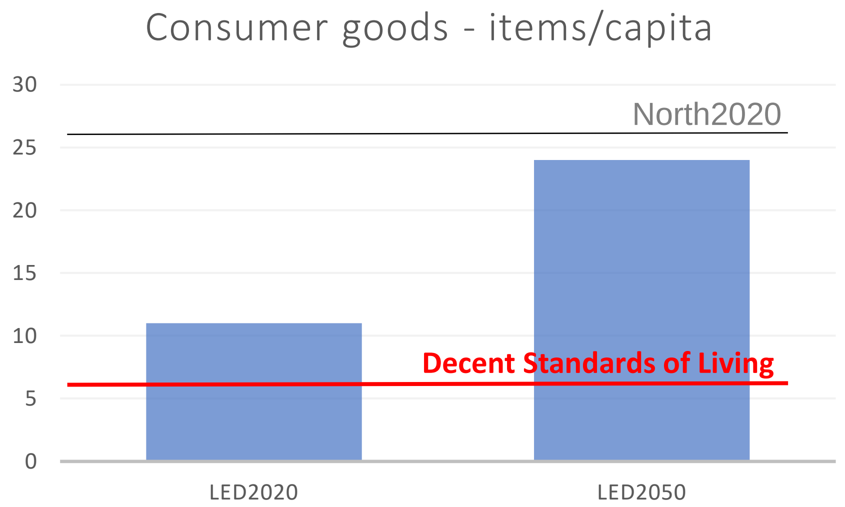
-> more learning

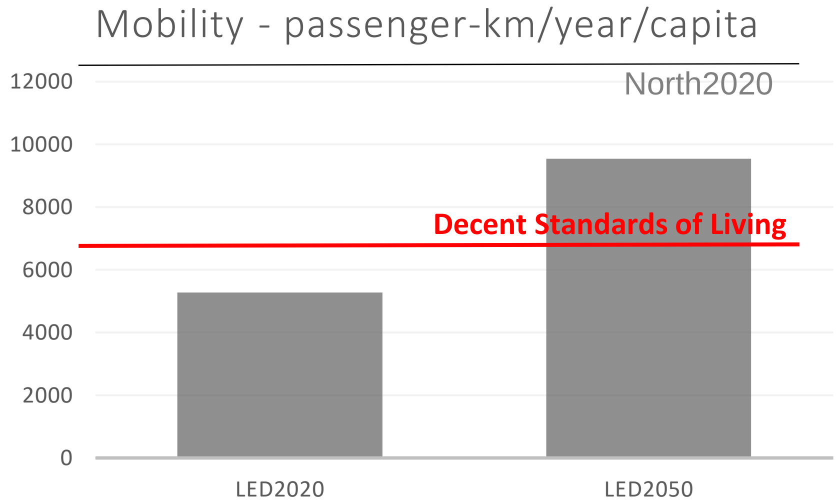
Healey, S. (2015). Separating Economies of Scale and Learning Effects in Technology Cost Improvements. IR-15-009. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Granularity Benefits: equal distribution
per capita energy services in the global South

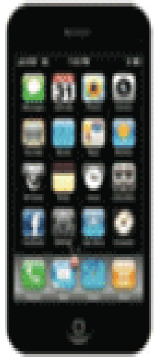




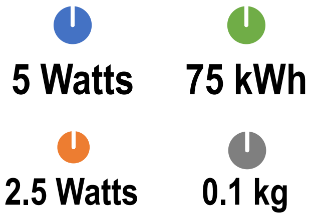


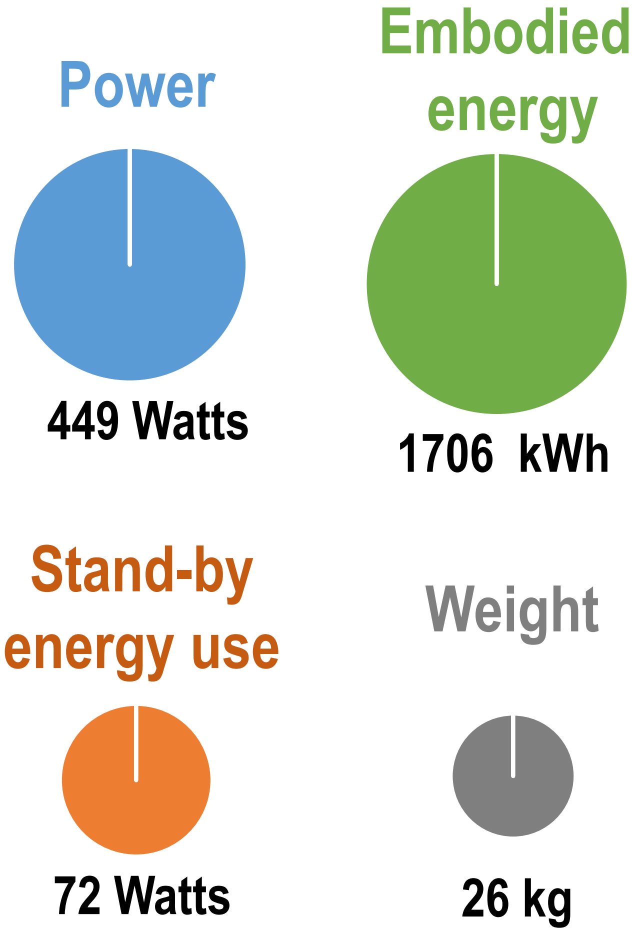


Resource Impacts of Digital Convergence



=





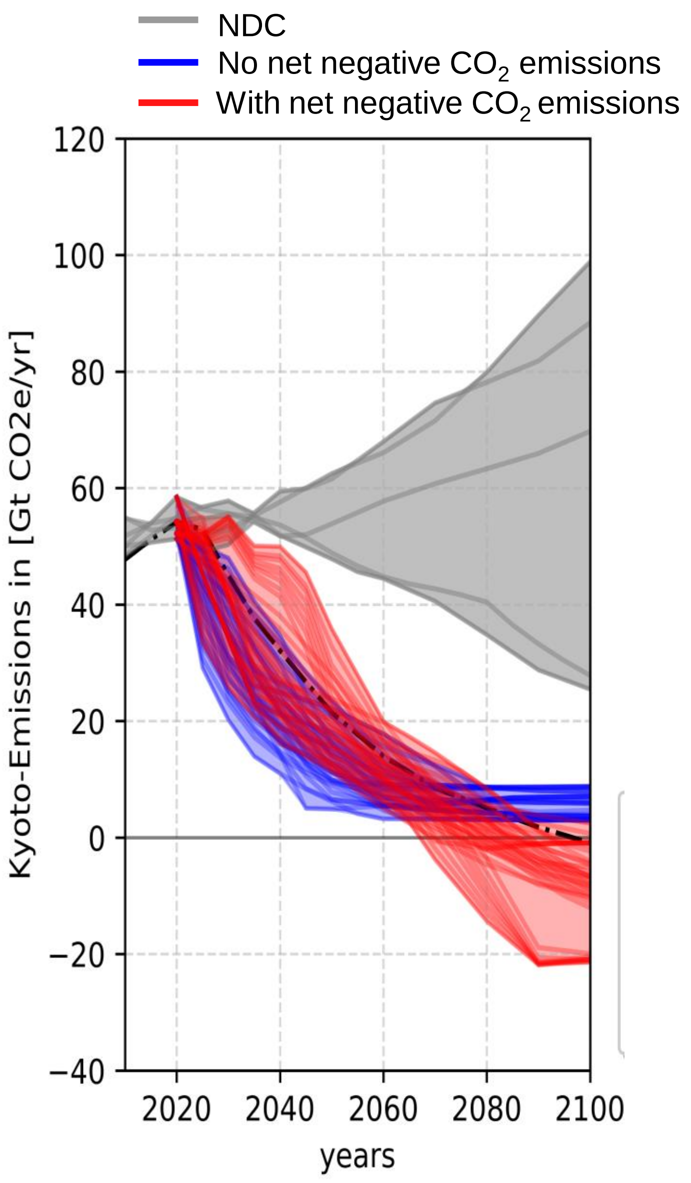
Updated (Malmodin & Lundén, 2018; Bento, 2016)
from Grubler et al, 2018. Pictorial representation based on Tupy, 2012.

Thank you.

Keywan Riahi
riahi@iiasa.ac.at

Note PRELIMINARY results of ENGAGE – UNDER EMBARGO, please do not circulate outside the meeting

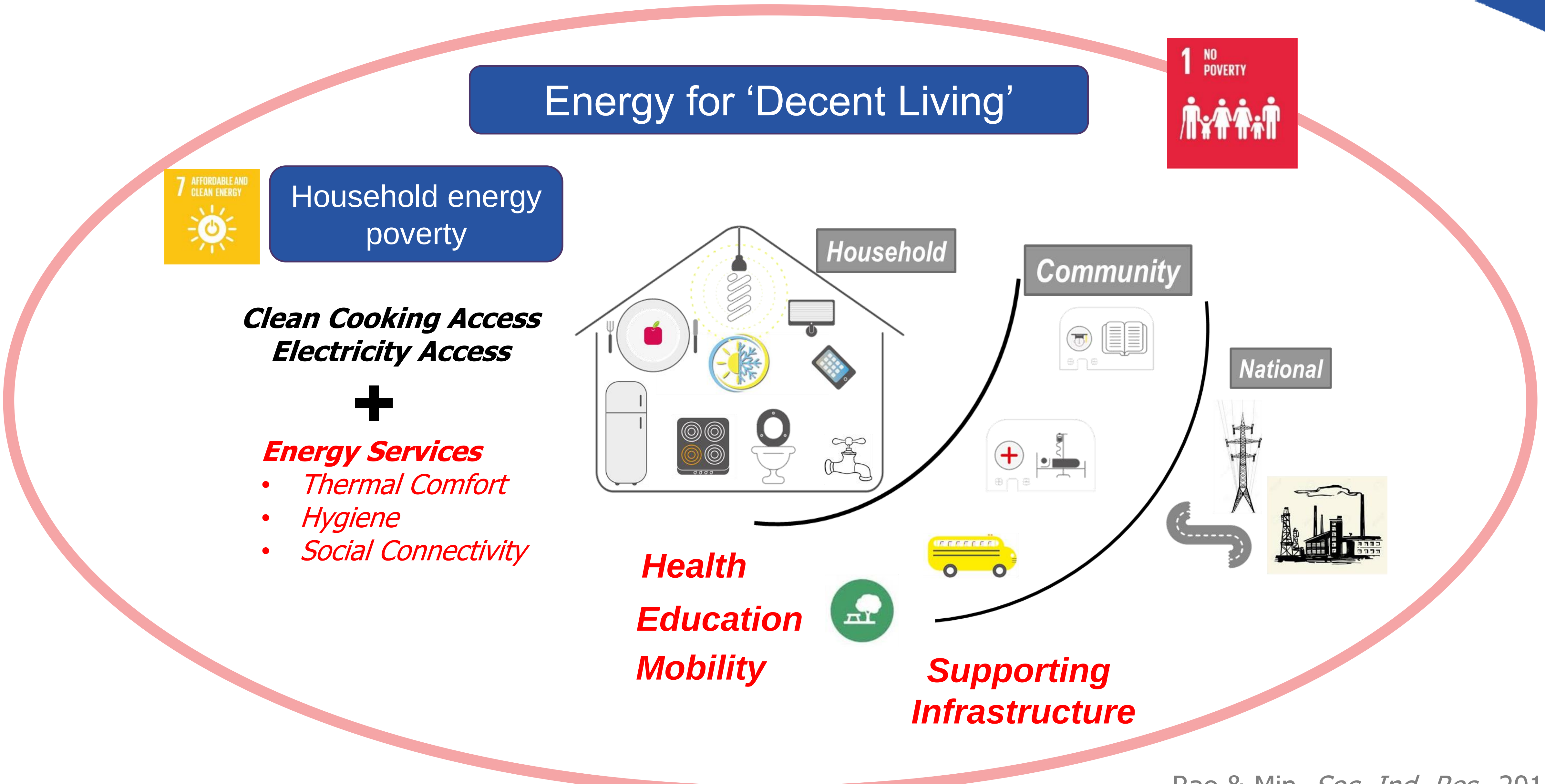
World GHG Emissions



Nine global IAMs

AIM
COFFEE
GM-E3
IMAGE
MESSAGEix-GLOBIOM
POLES
REMIND-MagPie
TIAM-ECN
WITCH

Energy for Poverty Eradication



Rao & Min, *Soc. Ind. Res.*, 2018

Decent Living Standards – Material basis for Well-being

DLS Indicators

Dimension	Unit
Food	kCal, Micronutrition
Shelter Comfort	m^2, Durable (ºC, RH)
Basic appliances	Stove, TV, Fridge
Health/Educ	$$
Clothing	Kg
Water/Sanit	Access, m^3
Mobility	P-km

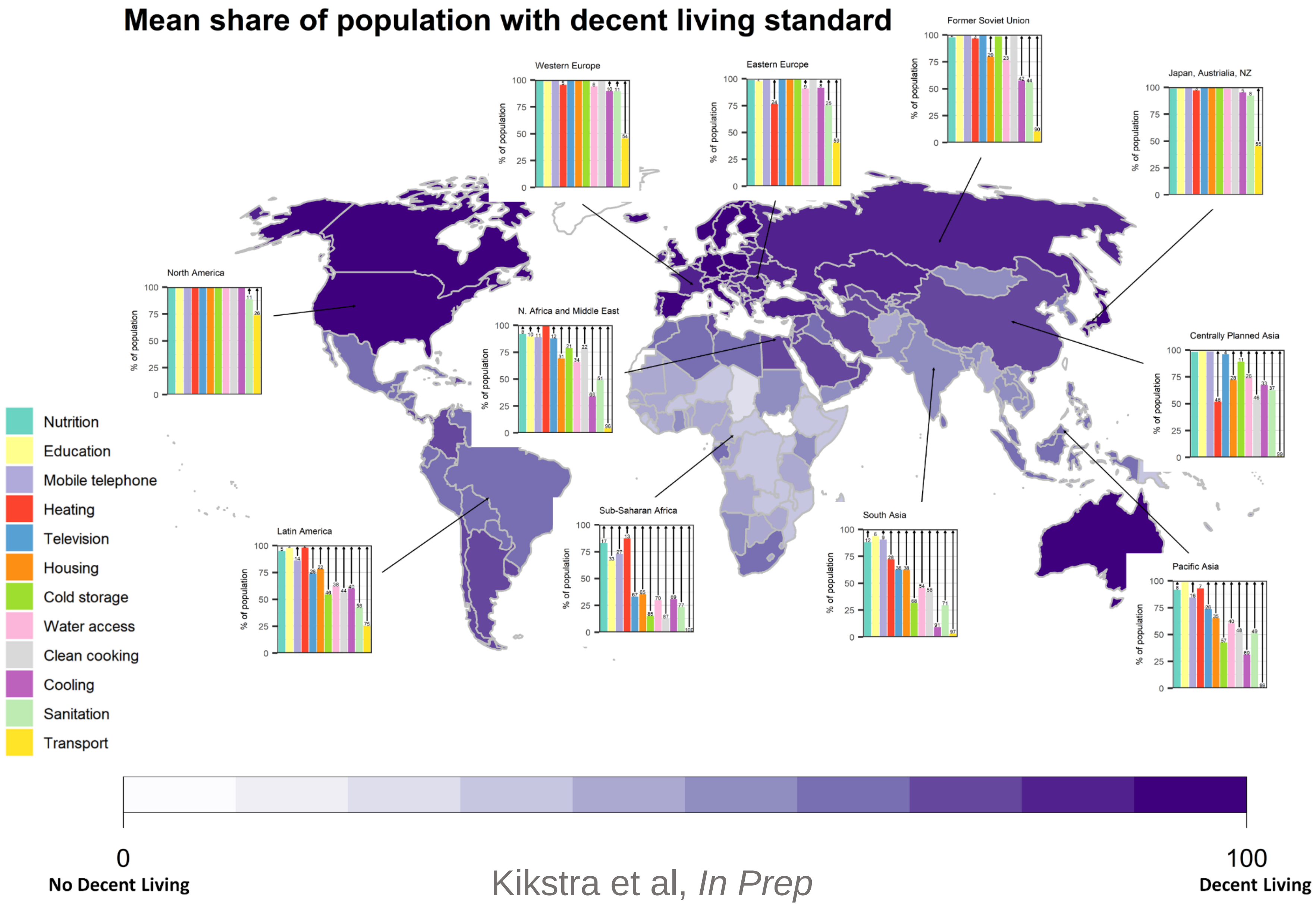
Physical Wellbeing

Social Wellbeing

Dimension	Description/ (Minimum) Thresholds
Housing	Safe, durable (permanent), min space (10 m^2/cap)
Thermal comfort	AC Use (26°C, 60% Humidity), 1 bedroom, nights only. Heating to 18°C
Nutrition	Macro- and micronutrients (protein, zinc, iron, calories)
Clean ckg	LPG or electricity cook stoves
Water	65 l/cap/day, indoor access
Sanitation	Sewage distribution (urban only)
Appliances	Fridge: <200 l; TV; cell phone per adult
Health care	$665 per capita (national)
Education	$1000 -$1500 per student (national)
Mobility Infrastructure	10K p-km motorized; paved roads; public transit

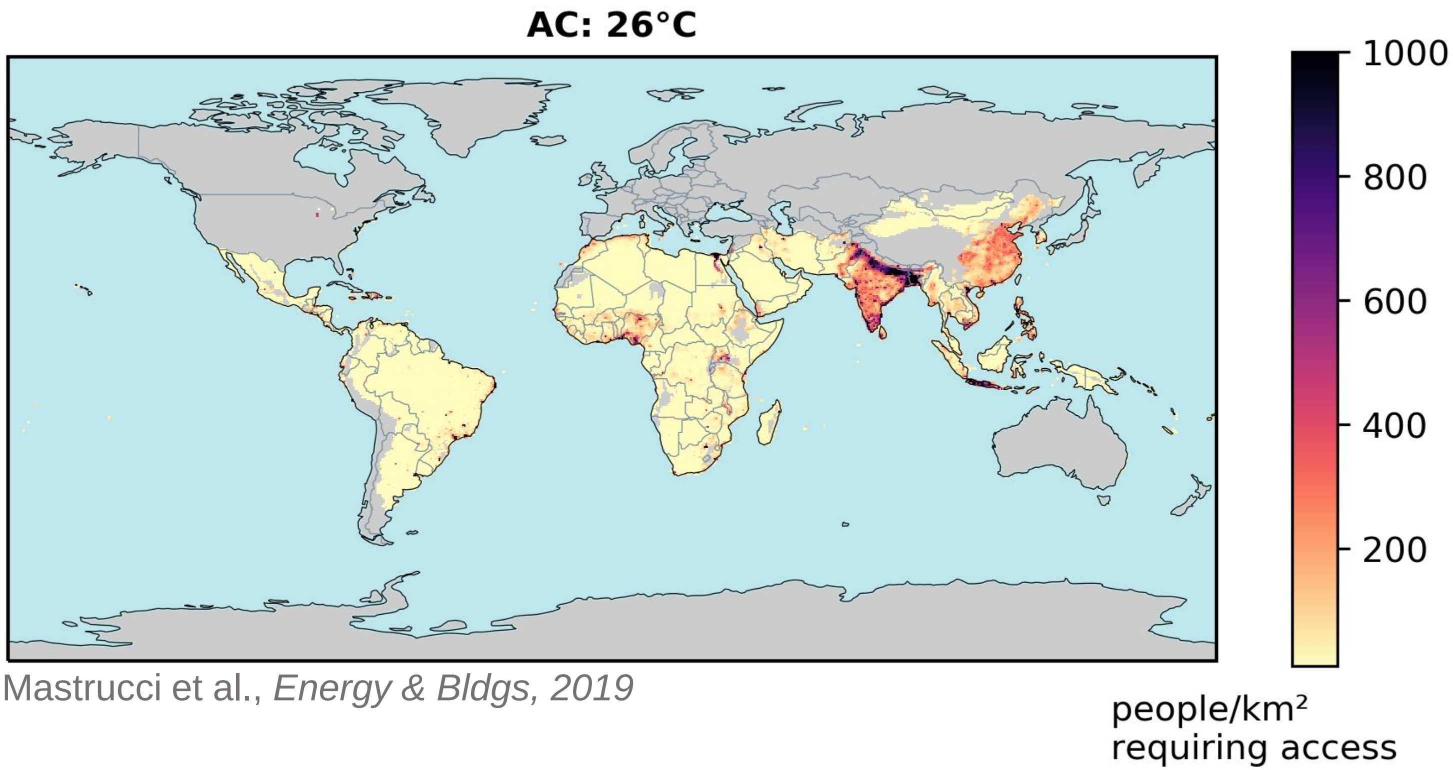
Rao & Min, *Soc. Ind. Res.*, 2018

Decent Living Standards – Current Conditions

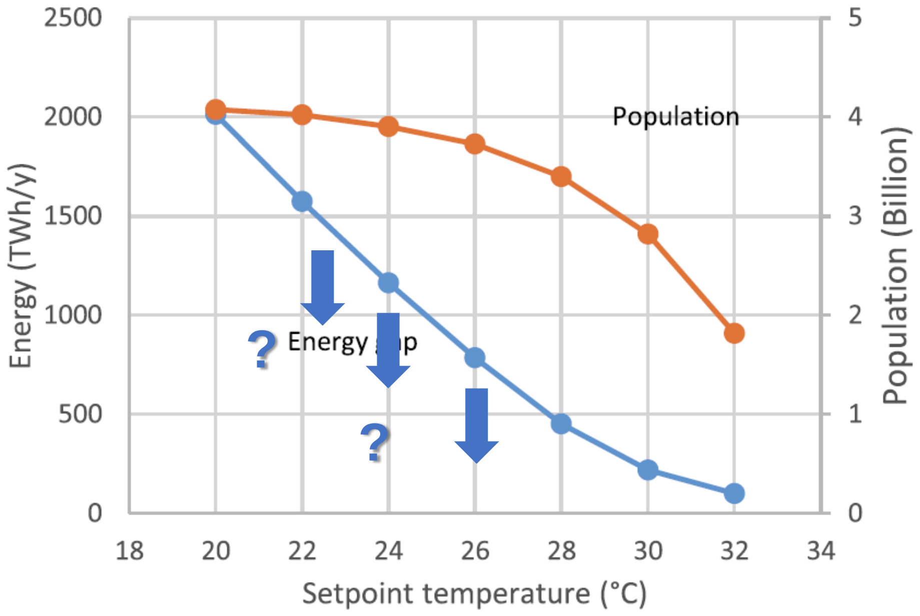


Kikstra et al, *In Prep*

Cooling ‘Poverty’



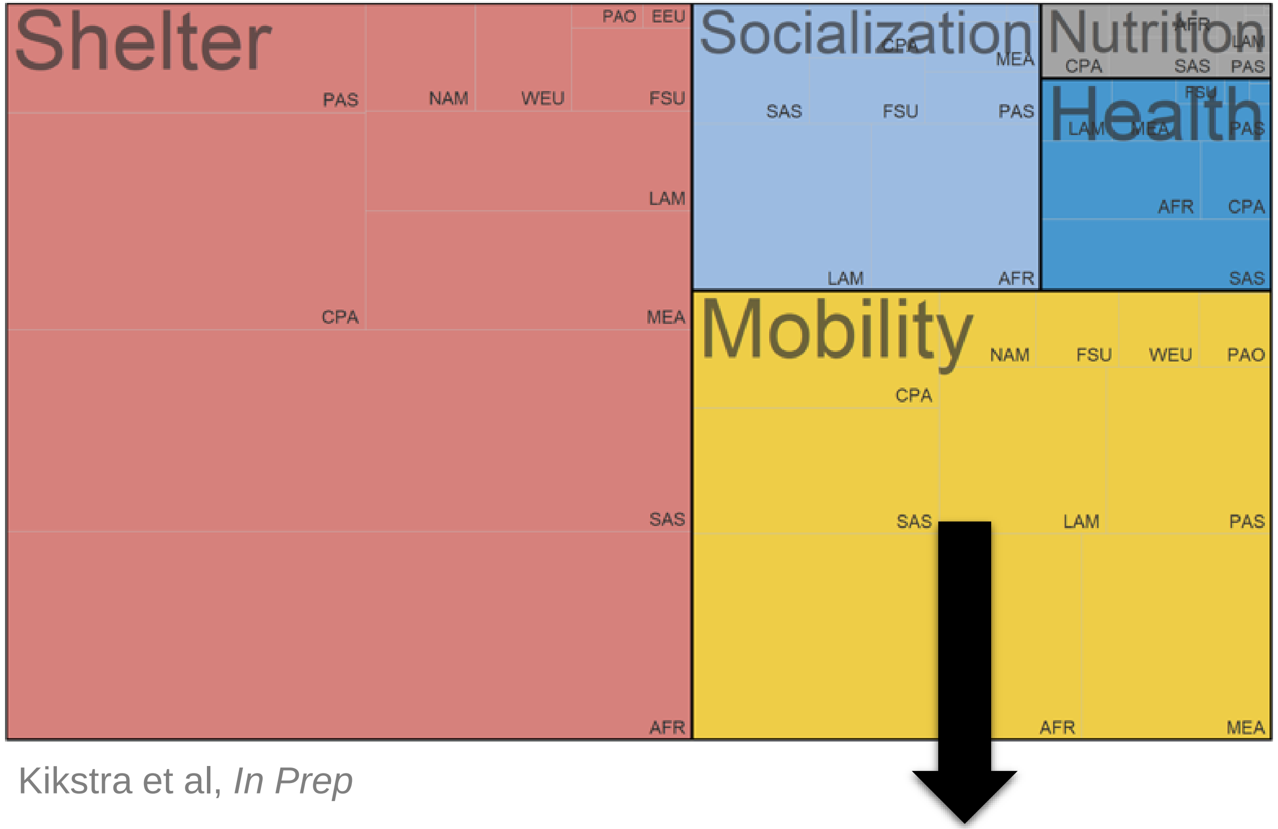
Mastrucci et al., *Energy & Bldgs, 2019*



What is the scope for reducing cooling demand with passive and advanced cooling technologies?

Global Mobility Gaps – Leapfrog Opportunity?

Total construction energy need from 2015 until 2040 to provide Decent Living
Based on SSP2



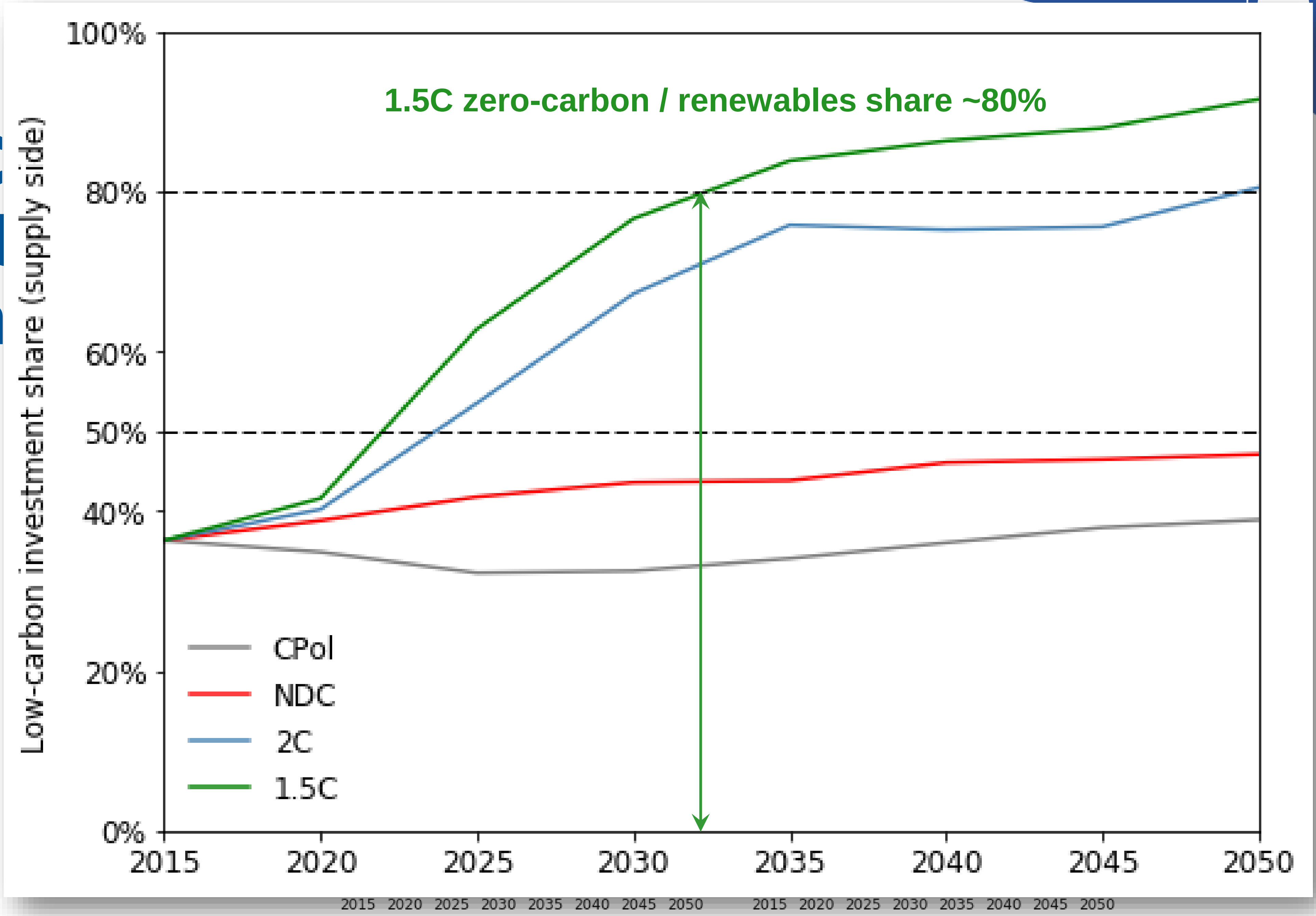
Kikstra et al, *In Prep*

> 70 Exajoules

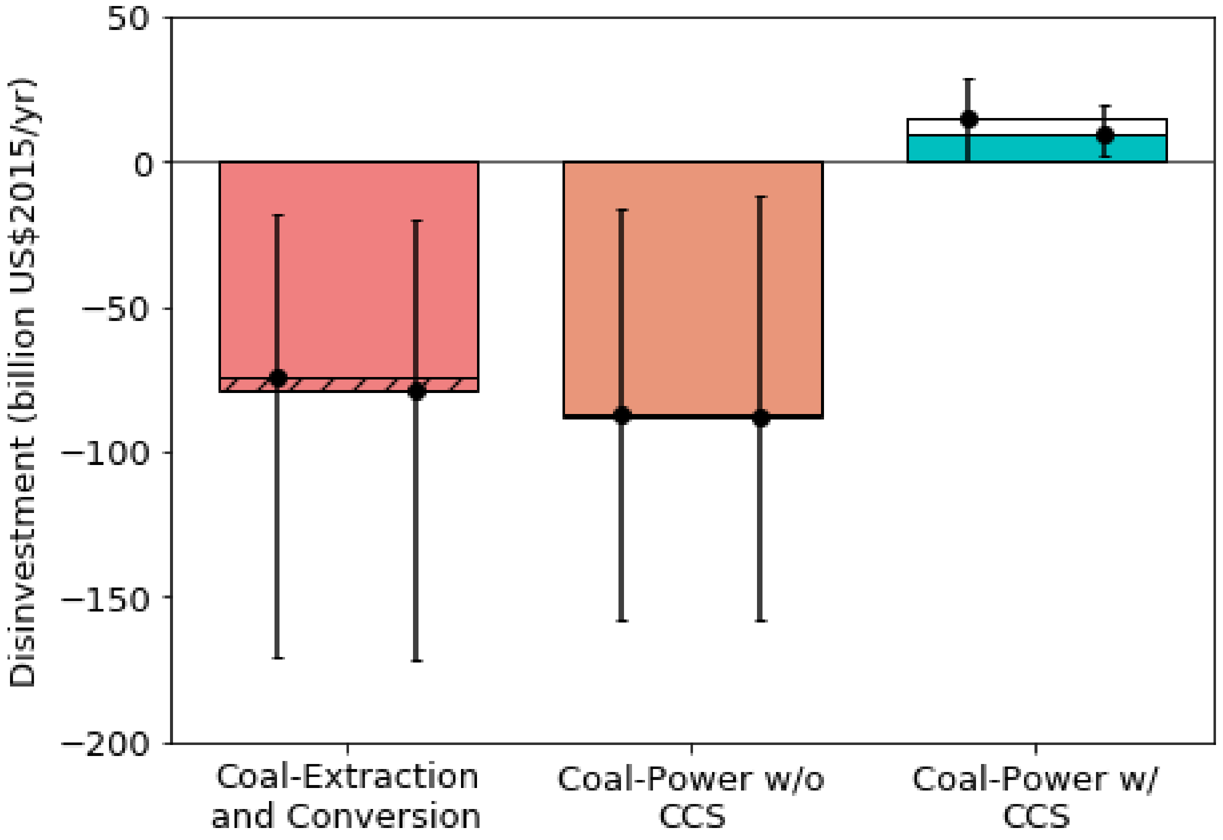
(based on current mode shares)

Scope for Shared Mobility?

Low-C
Invest
Sha



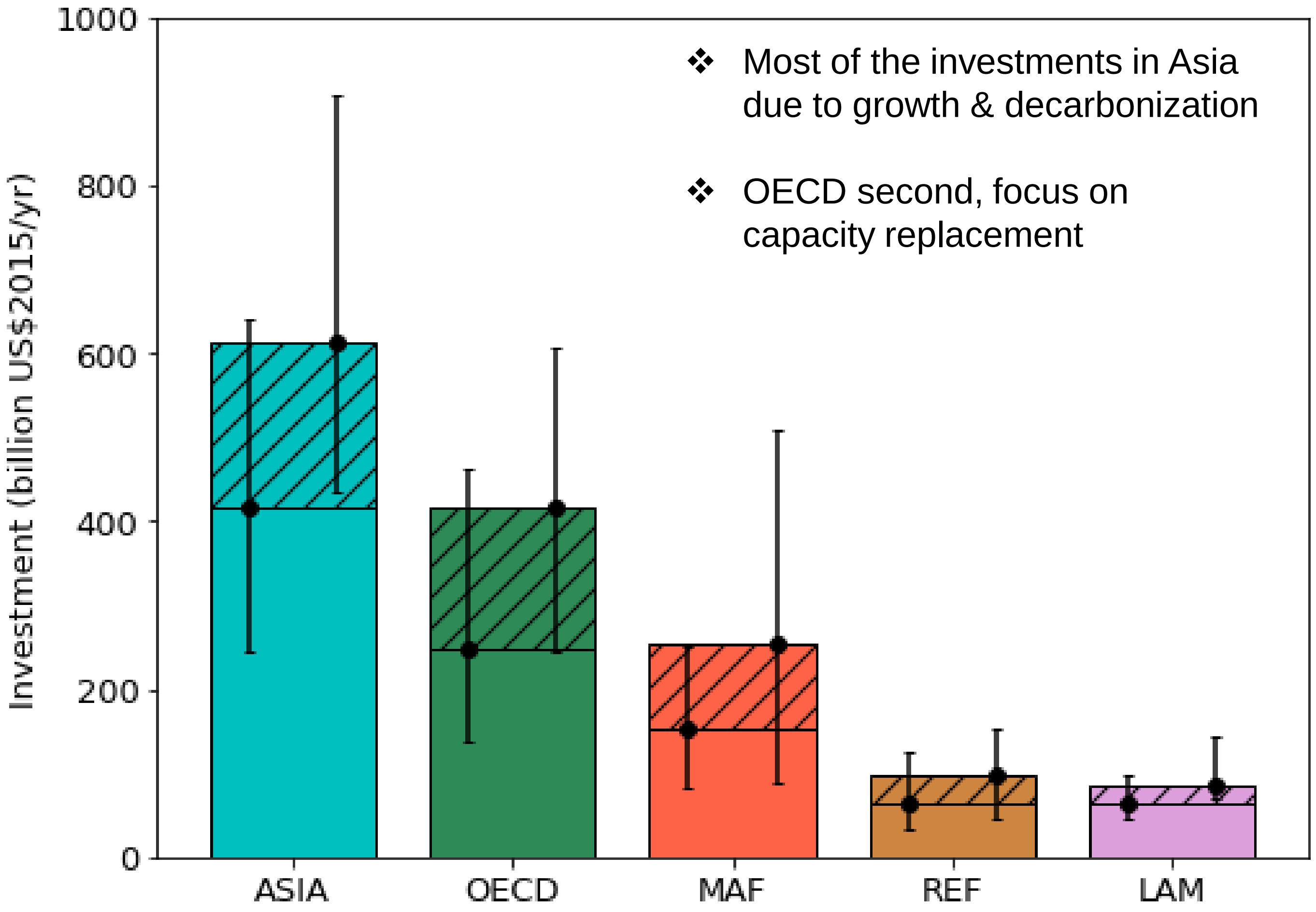
Coal is phased out with only small investment into CCS



McCollum et al, (under embargo – do not cite or quote)

Regional Investments (1.5 vs 2C)

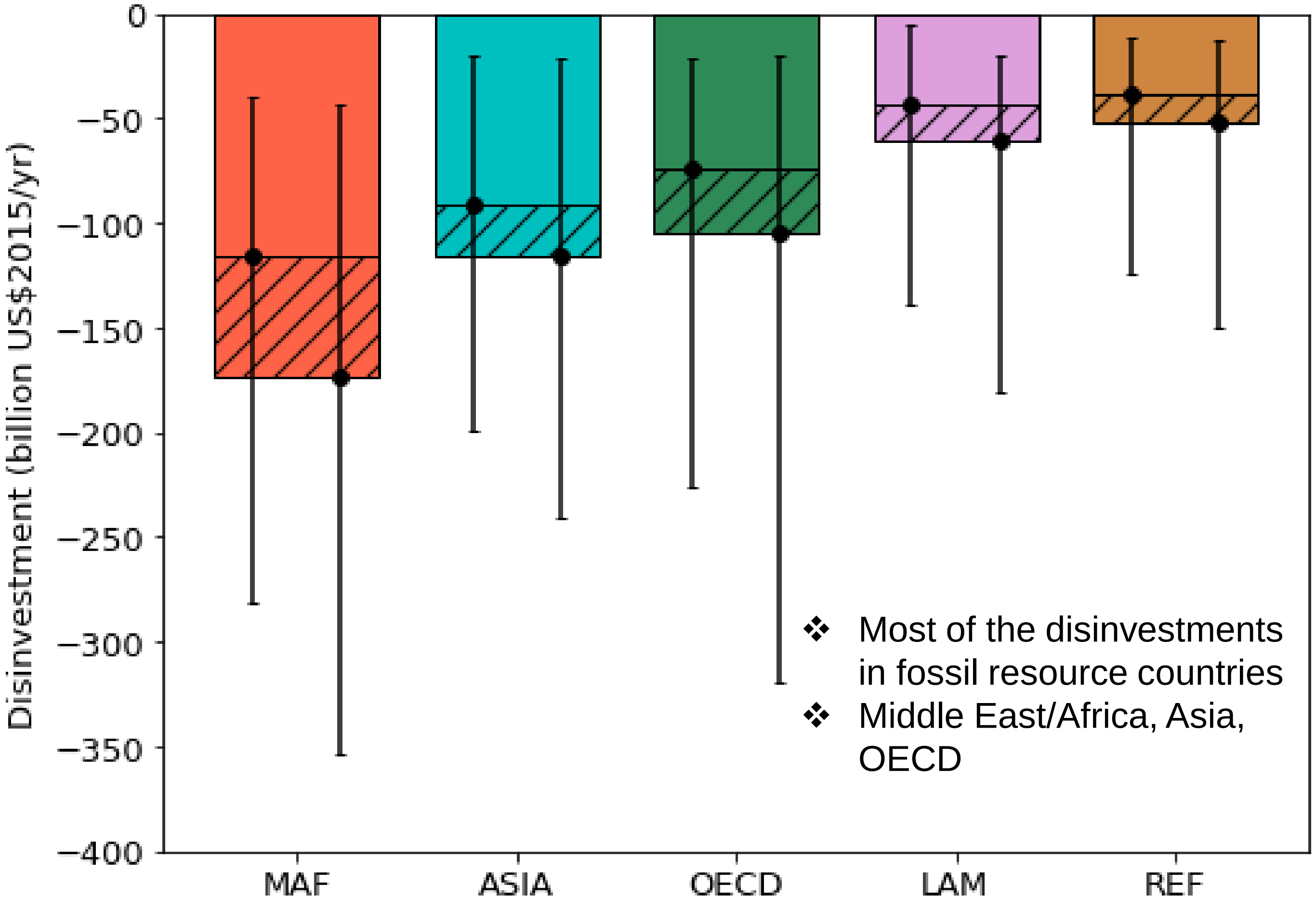
2015-2050, compared to baseline



McCollum et al, 2018, Nature Energy

Regional Disinvestments (1.5C vs 2C)

2015-2050, compared to baseline



- ❖ Most of the disinvestments in fossil resource countries
- ❖ Middle East/Africa, Asia, OECD

McCollum et al, 2018, Nature Energy