UNIVERSITY OF MARYLAND

Climate Mitigation and Other SDGs

PLCY-798K
Integrated Human-Earth System Modeling and Policy Assessment

April 12, 2023

Agenda

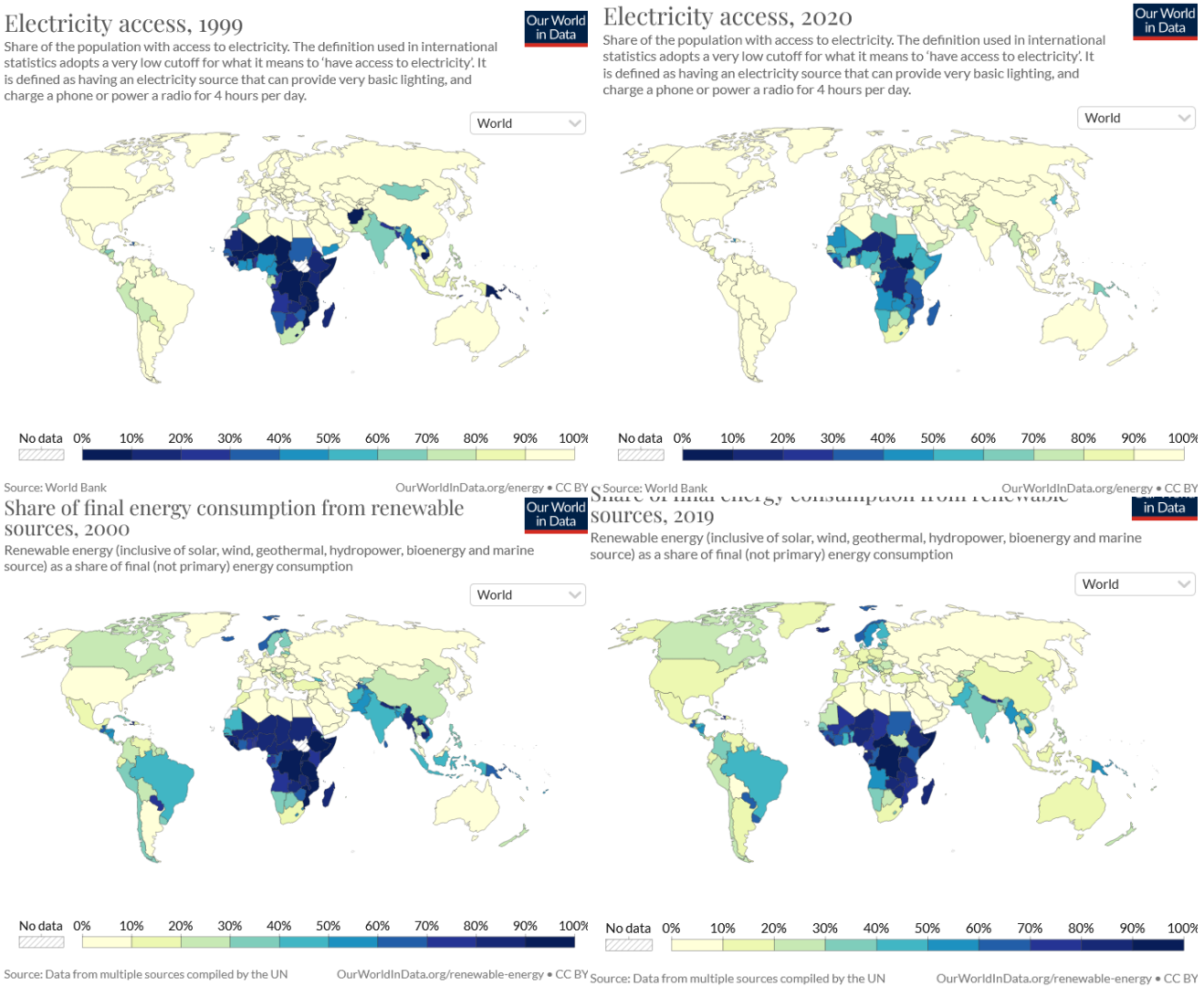
- **1:40 – 2:45: Section I**
  1. **What are SDGs and how do they relate to mitigation research and IAMs?**
  2. **Which are key synergies and trade-offs between different SDGs?**
     - **Empirical literature**
     - **IAM literature →**
  3. **What policies and measures can help exploit synergies and minimize trade-offs?**
- 2:45 Break
- 2:45 – 4:00 Section II
  - GCAM tutorial – creating input files using headers

1. What are the SDGs?

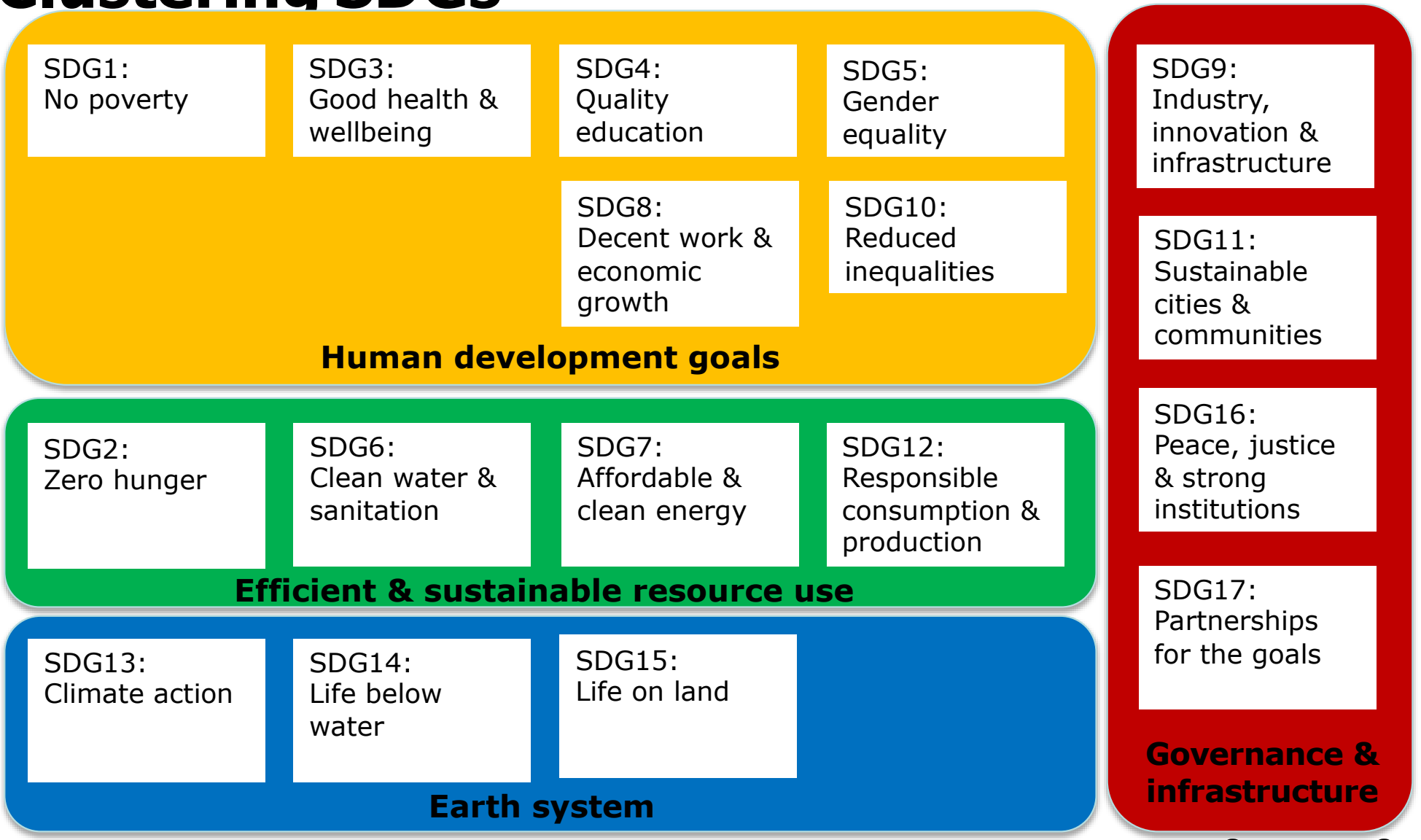
17 Sustainable Development Goals – each with specific targets, mostly for 2030 (169 targets, 232 indicators)

SDG target tracker https://sdg-tracker.org

- **Target 7.1: Universal access to modern energy**
- **Target 7.2: Increase global percentage of renewable energy**
- Target 7.3: Double the improvement in energy efficiency
- Target 7.A: Promote access, technology and investments in clean energy
- Target 7.B: Expand and upgrade energy services for developing countries



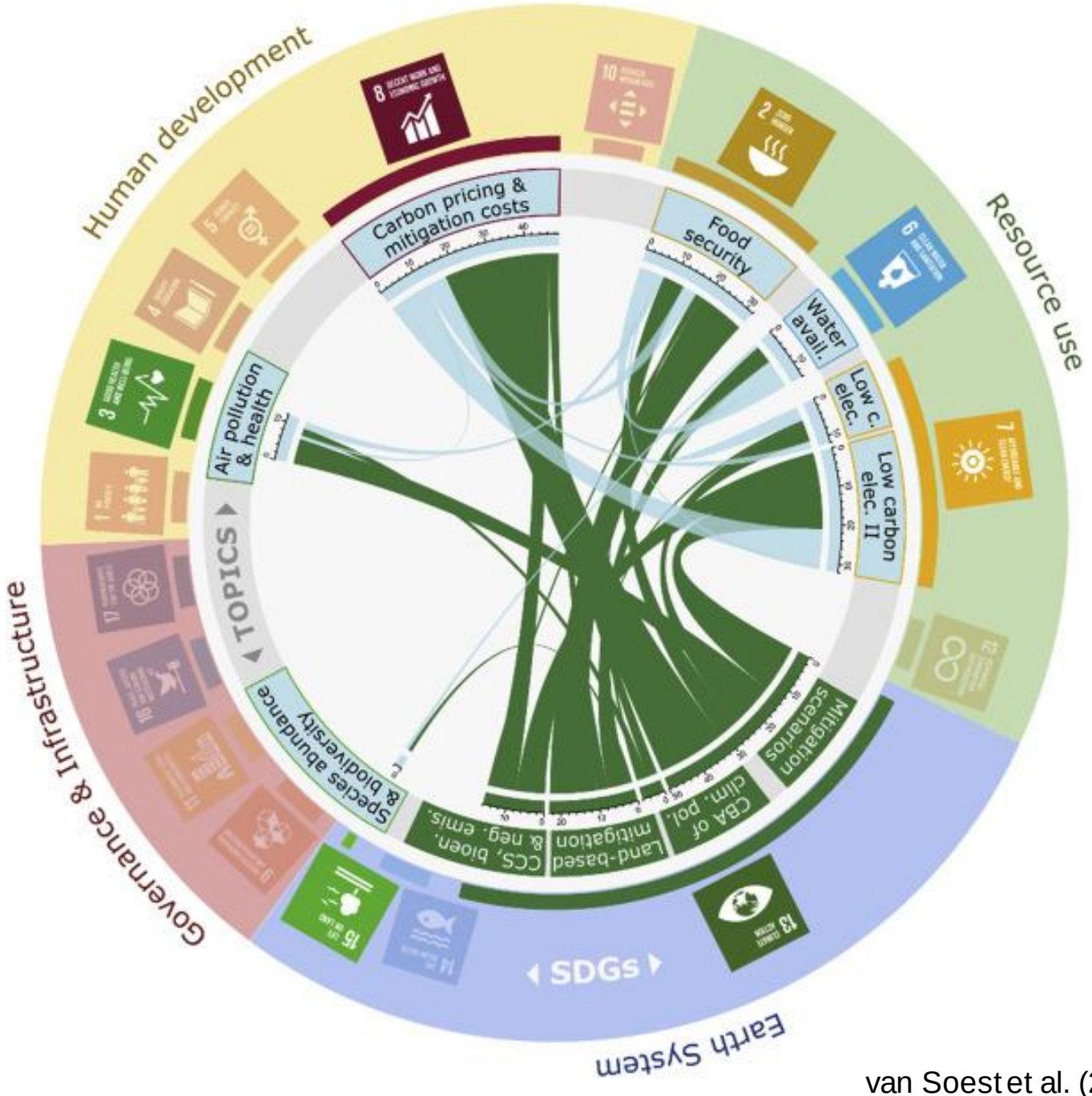
How do they relate to IAMs?
→ Clustering SDGs



Source: van Soest et al. (2019)

SDG representation in IAM literature

- Many SDGs can (partly) be quantified by IAMs especially in '**Efficient & sustainable resource use**' + '**Prevent environmental degradation**' clusters
- More challenging in '**Human development goals**' + '**Good governance and infrastructure**'



van Soest et al. (2019)

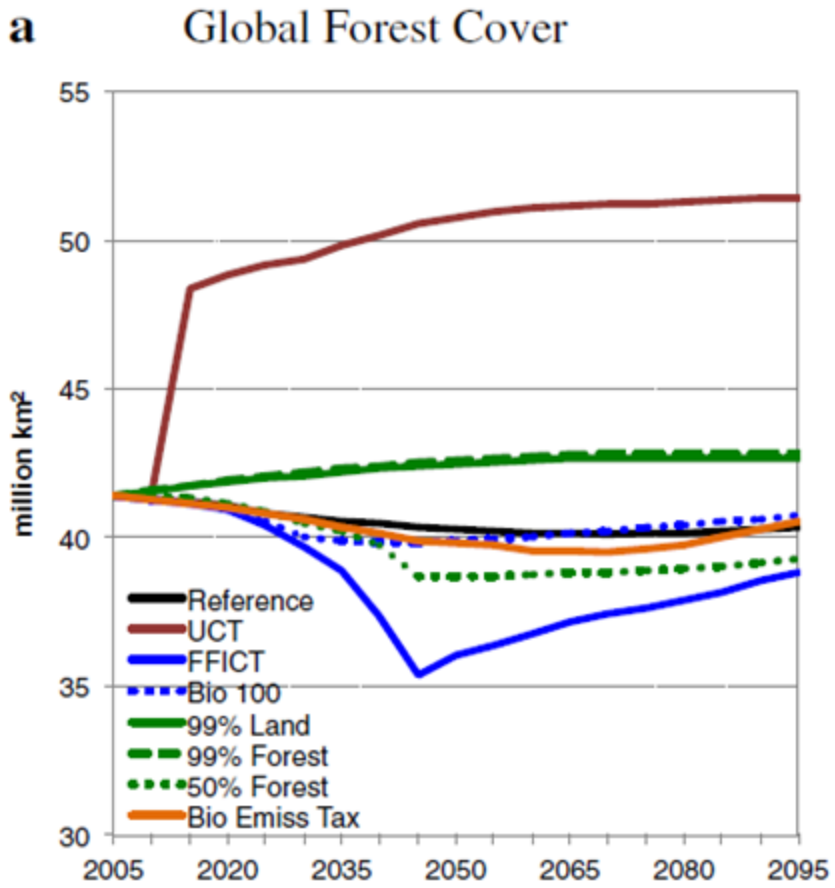
IAM study examples

- IAM community has been evaluating societally relevant metrics (similar to SDGs) for a long time
- Examples from
  - (1) energy and food security under climate mitigation;
  - (2) air quality and human health under climate mitigation;
  - (3) national mid-century climate change strategies that include multiple societally relevant metrics.

Trade-offs of different land and bioenergy policies on the path to achieving climate targets

Table 1 Bioenergy and land policy scenarios

Name	Climate policy	Bioenergy	Terrestrial carbon price	Protected areas
Reference	None	No constraints	None	None
UCT	≤3.7 W/m^2	No constraints	Equal to Energy System Carbon Price	None
99 % Land	≤3.7 W/m^2	No constraints	None	99 % of natural ecosystems in each region
99 % Forest	≤3.7 W/m^2	No constraints	None	99 % of non-commercial forests in each region
50 % Forest	≤3.7 W/m^2	No constraints	None	50 % of non-commercial forests in each region
FFICT	≤3.7 W/m^2	No constraints	None	None
Bio 100	≤3.7 W/m^2	≤100 EJ/yr	None	None
Bio Emiss Tax	≤3.7 W/m^2	Penalized for potential LUC emissions	None	None



Calvin et al. (2014), *Climatic Change*

Trade-offs of different land and bioenergy policies on the path to achieving climate targets

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99 % Forest	≤3.7 W/m^2	No constra
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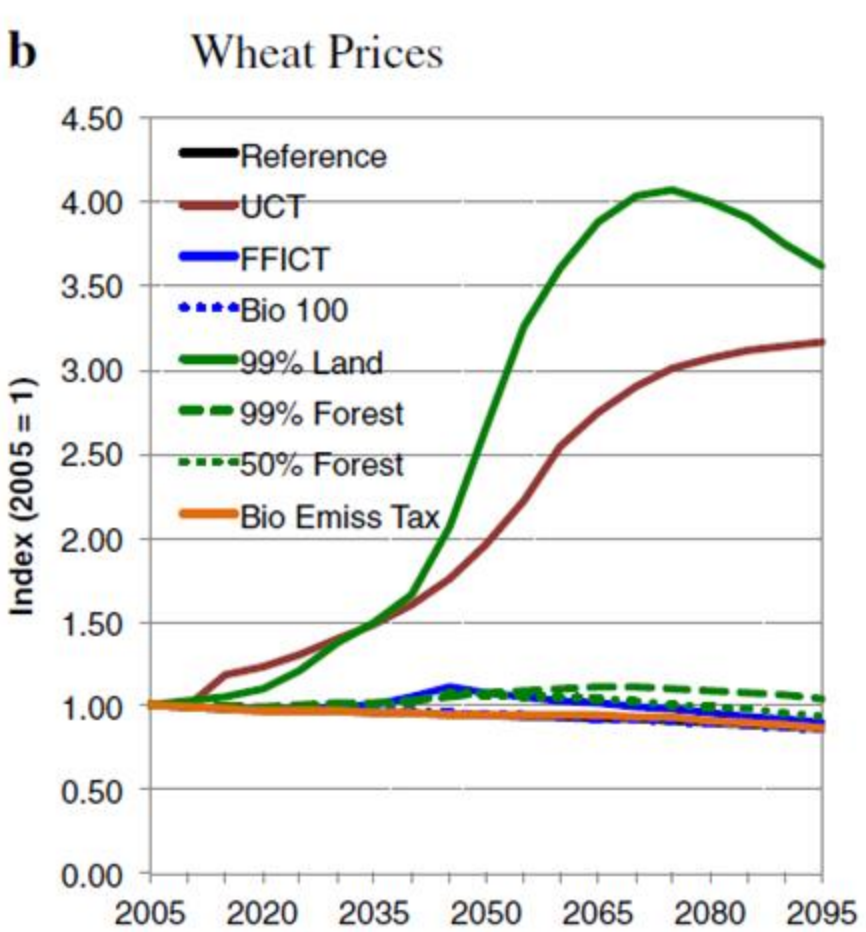
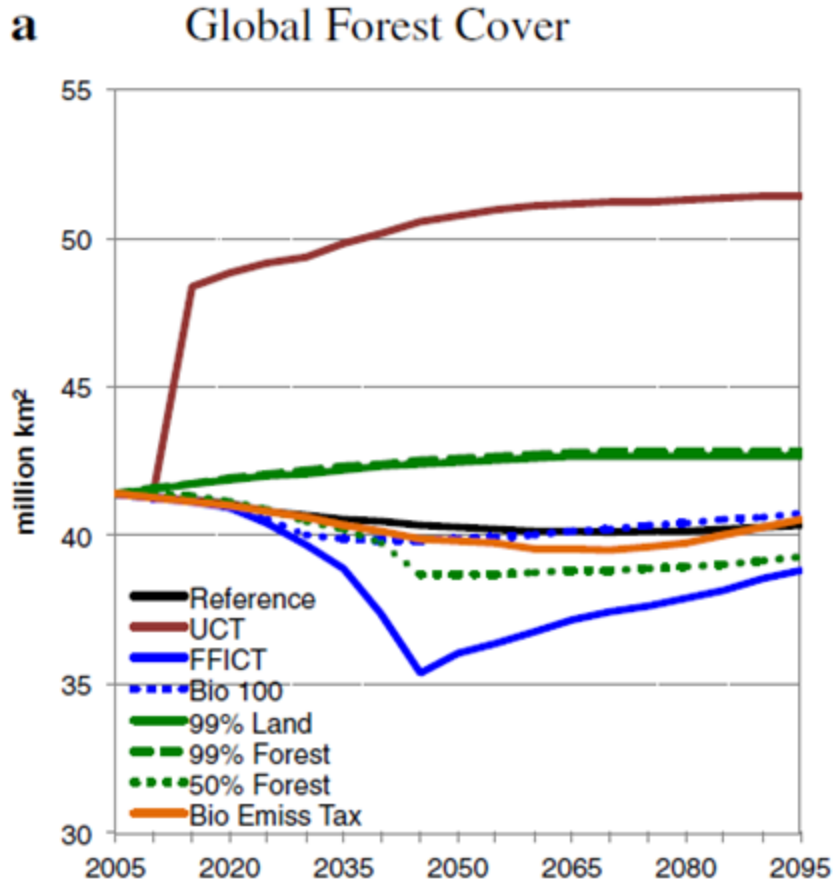
FFICT	≤3.7 W/m^2	No constra
Bio 100	≤3.7 W/m^2	≤100 EJ/yr
Bio Emiss Tax	≤3.7 W/m^2	Penalized t potential emissior





Calvin et al. (2014), *Climatic Change*

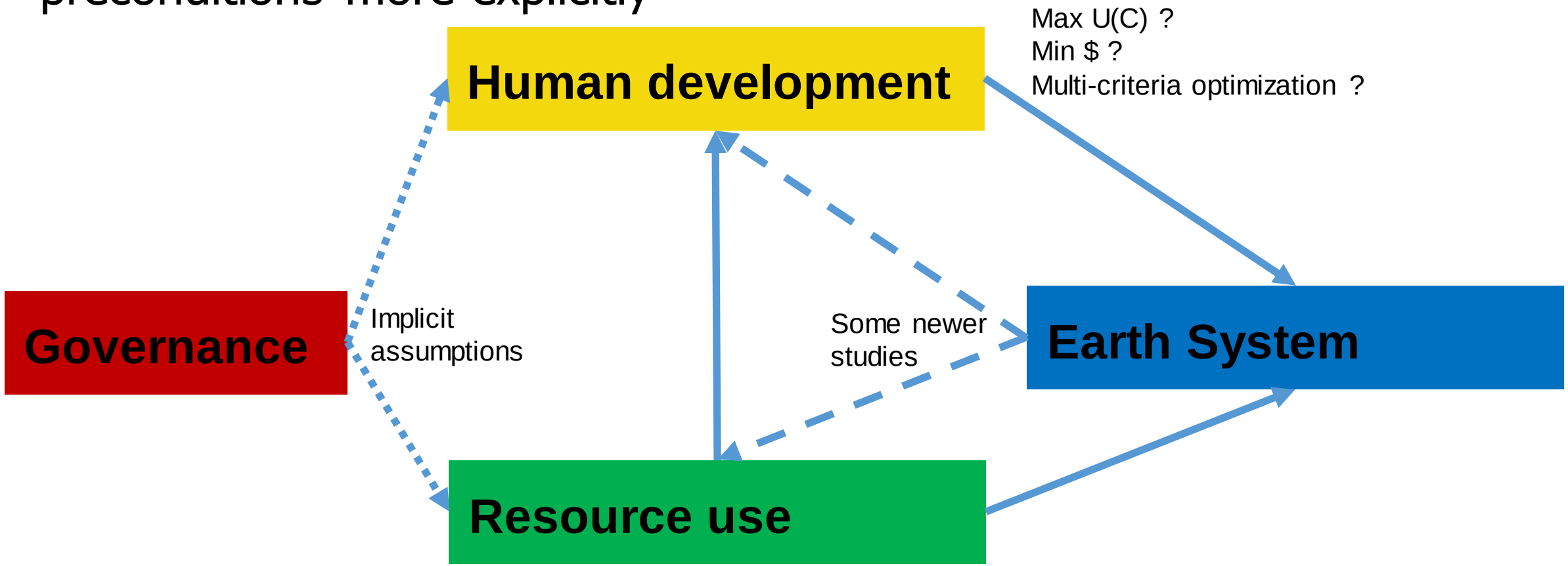
SDG Indicators and Modeling Tools

SDG		Target	Indicator (sectoral limitation) [units]	Evidence Base	
#				# of IAMs	Method
	Zero Hunger	2.1	Population at risk of hunger [million]	5	ex-post (FAO)
			Food (non-energy crop & livestock) price index [-]	4	endogenous
	Good Health and Well-being	3.9	Mortality due to outdoor air pollution (energy system) [million/yr]	3	ex-post (GAINS)
		3.9	PM2.5 emissions [kt PM2.5/yr]	3	ex-post (GAINS)
		3.9	Human toxicity (electricity generation) [kg 1,4-DCB-eq]	5	ex-post (LCA)
	Clean Water and Sanitation	6.4	Water consumption (electricity generation) [km^3/yr]	5	endogenous
		6.4	Water withdrawal for irrigation (agriculture) [km^3/yr]	4	endogenous
		6.3	Nitrogen fertilizer use (agriculture) [TgN/yr]	4	endogenous
	Affordable and Clean Energy	7.1	Population relying on solid cooking fuels [million]	5	ex-post (M-Access)
		7.2	Primary renewable energy share (excl. traditional biomass) [%]	6	endogenous
		7.3	Final energy intensity [MJ/$\$_{2010}$]	7	endogenous
	Decent Work and Economic Growth	8.1	GDP per capita [1000 $\$_{2010}$/cap]	5	endogenous
		8.5	Unemployment [million]	1	endogenous
	Responsible Consumption and Production	12.2	Mineral resource use (electricity generation) [Mt Fe-eq/yr]	5	ex-post (LCA)
		12.2	Fossil energy resource use [EJ/yr]	8	endogenous
	Life Below Water	14.1	Marine eutrophication (electricity generation) [kg N-eq/yr]	5	ex-post (LCA)
			Marine ecotoxicity (electricity generation) [kg 1,4-DCB-eq]	5	ex-post (LCA)
	Life on Land	15.1	Forest area [Mha]	6	endogenous
		15.1	Freshwater toxicity (electricity generation) [kg 1,4-DCB-eq]	5	ex-post (LCA)
			Land occupation (electricity generation) [Mha]	5	ex-post (LCA)
		15.5	Animal species with habitat loss >50% (agriculture/forestry) [%]	1	ex-post (AIM/Diversity)

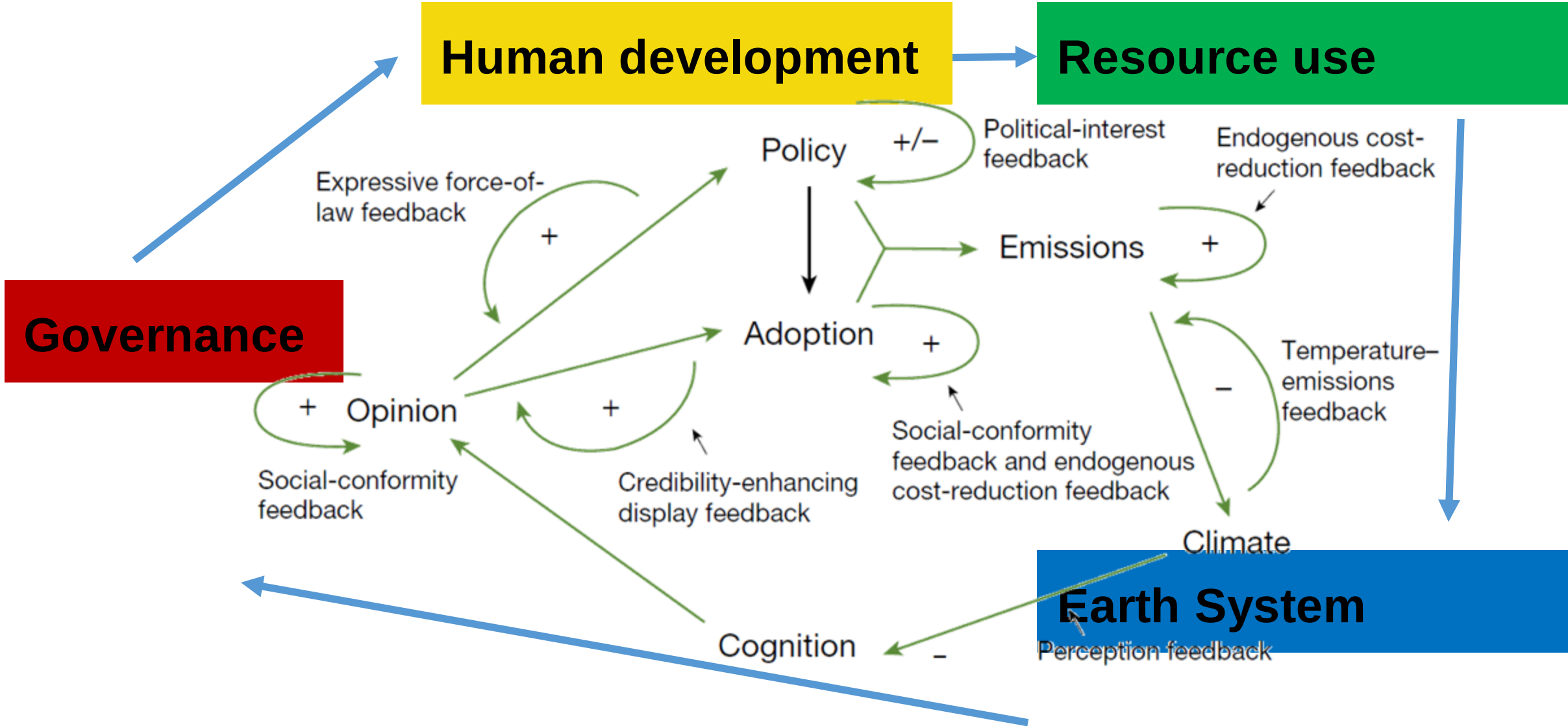
CD-Links Project
http://www.cd-links.org

Many IAMs try to optimize (explicitly or implicitly) social welfare (human well-being)

SDGs try to operationalize both human well-being, and its different preconditions more explicitly



Full coupling – first (very stylized) attempt



Source: Moore et al. (2022)

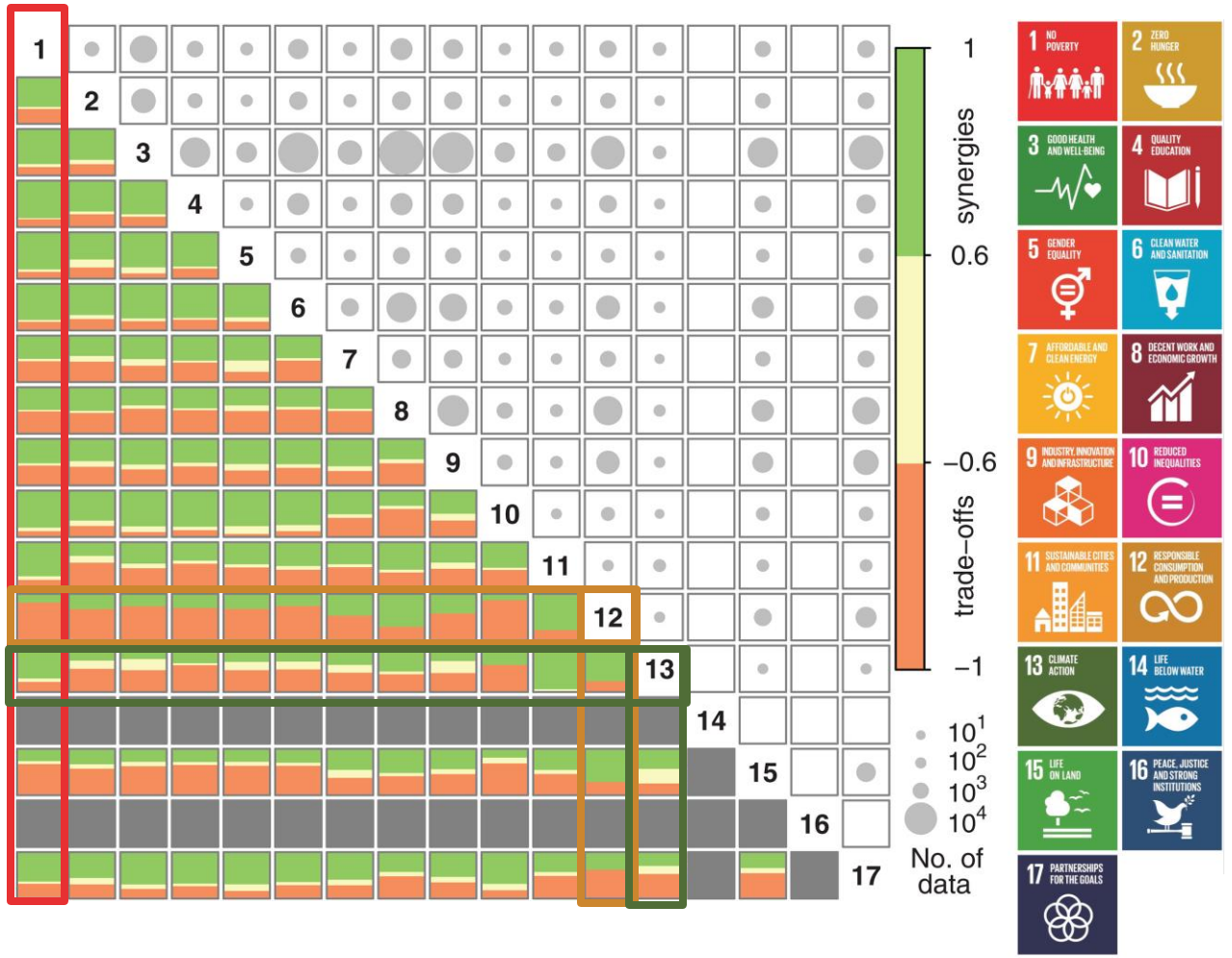
Summary section 1.:

- SDGs are goals of global human development that the UN GA has agreed on in 2015
- Intent to comprehensively cover all relevant aspects of human development, resource use, governance, and earth system
- IAMs have traditionally tracked subset of interactions among those systems well
- Comprehensive coverage of interactions in one modeling framework still illusionary

SDG interactions

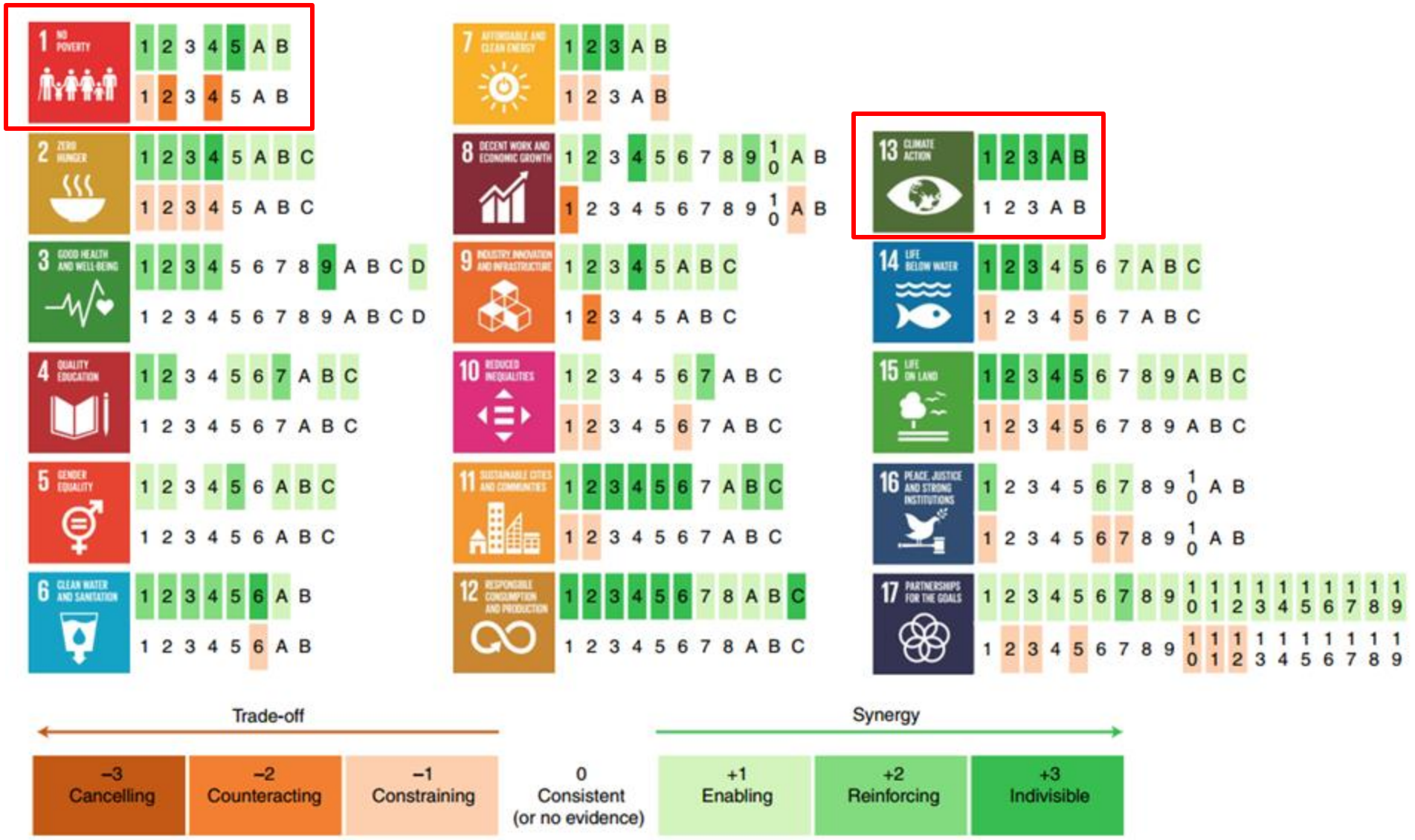
SDG interactions - empirical

- Analysing correlation between official SDG indicators across more than 200 countries:
  - Overall positive correlation dominates, especially for **SDG 1 (no poverty); SDG 12 (Responsible consumption and production)** is most commonly associated with trade-offs with other SDGs



Pradhan et al. (2017)

Climate action and SDGs are interconnected

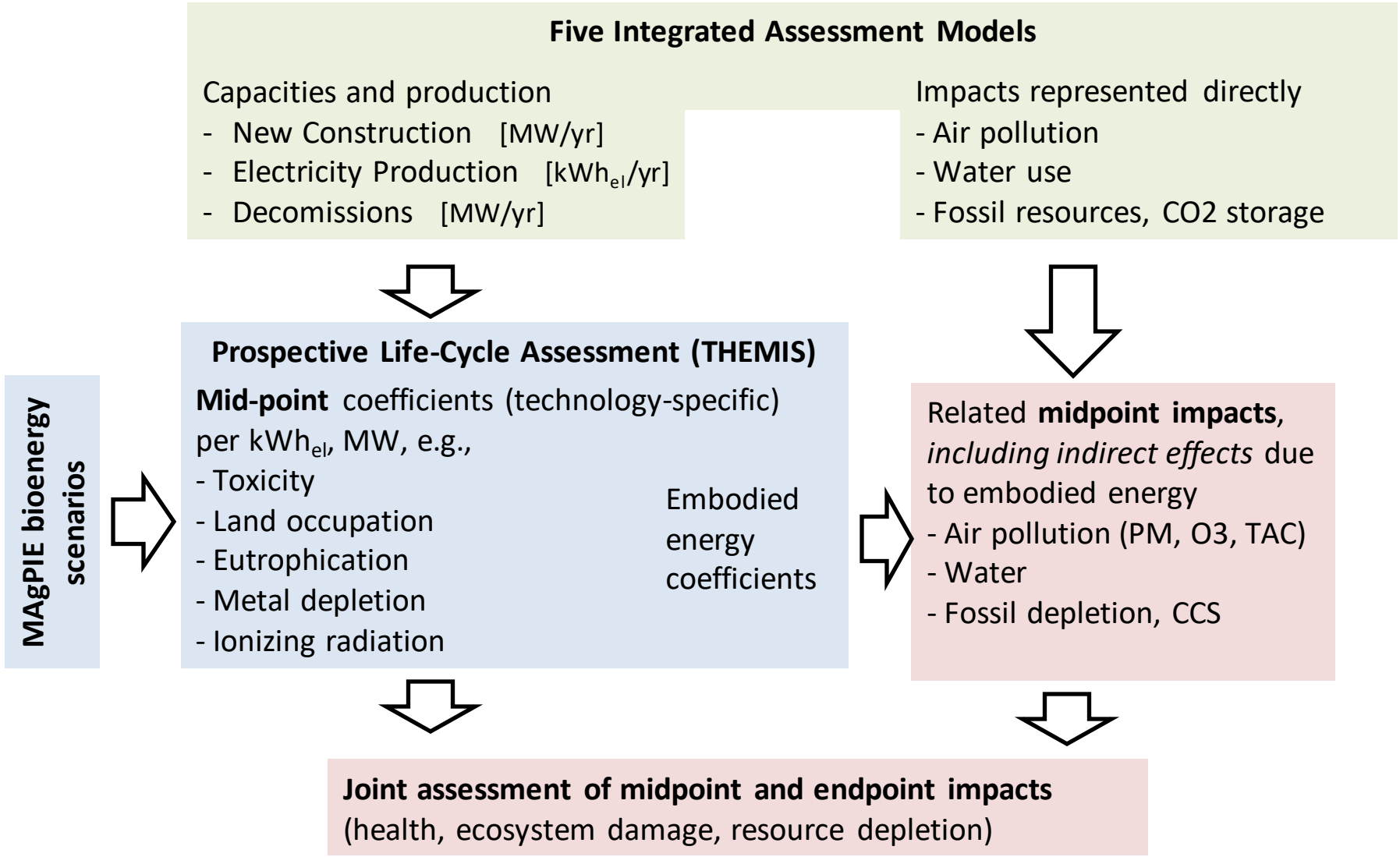


Fuso Nerini et al. (2019)

Energy and SDGs are interconnected

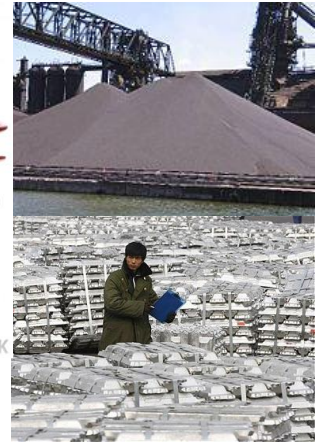
McCollum et al. (2018)

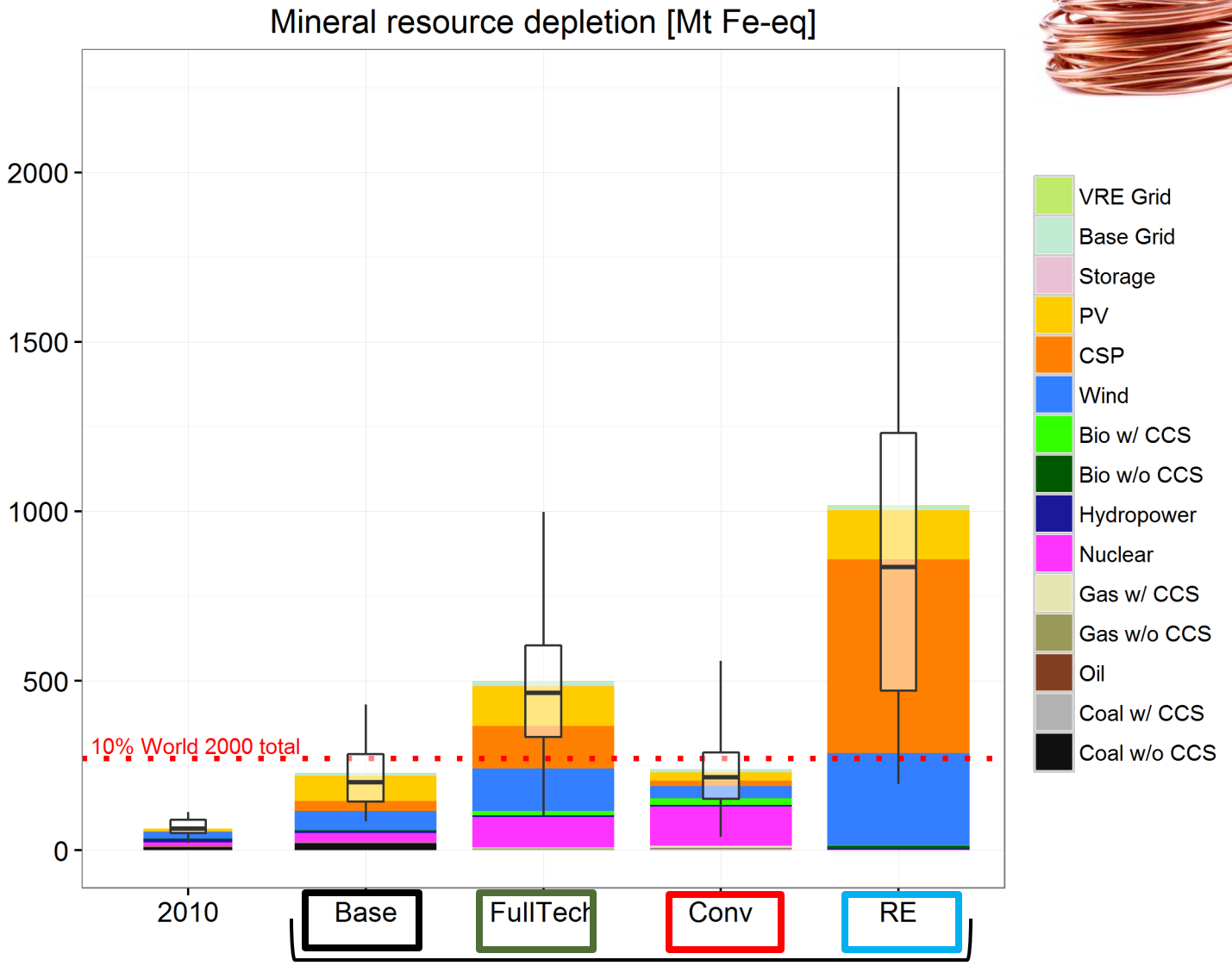
Integrated IAM – SDG research: Example Workflow



Luderer et al. (2019)

Mineral resource depletion





Luderer et al. (2019)

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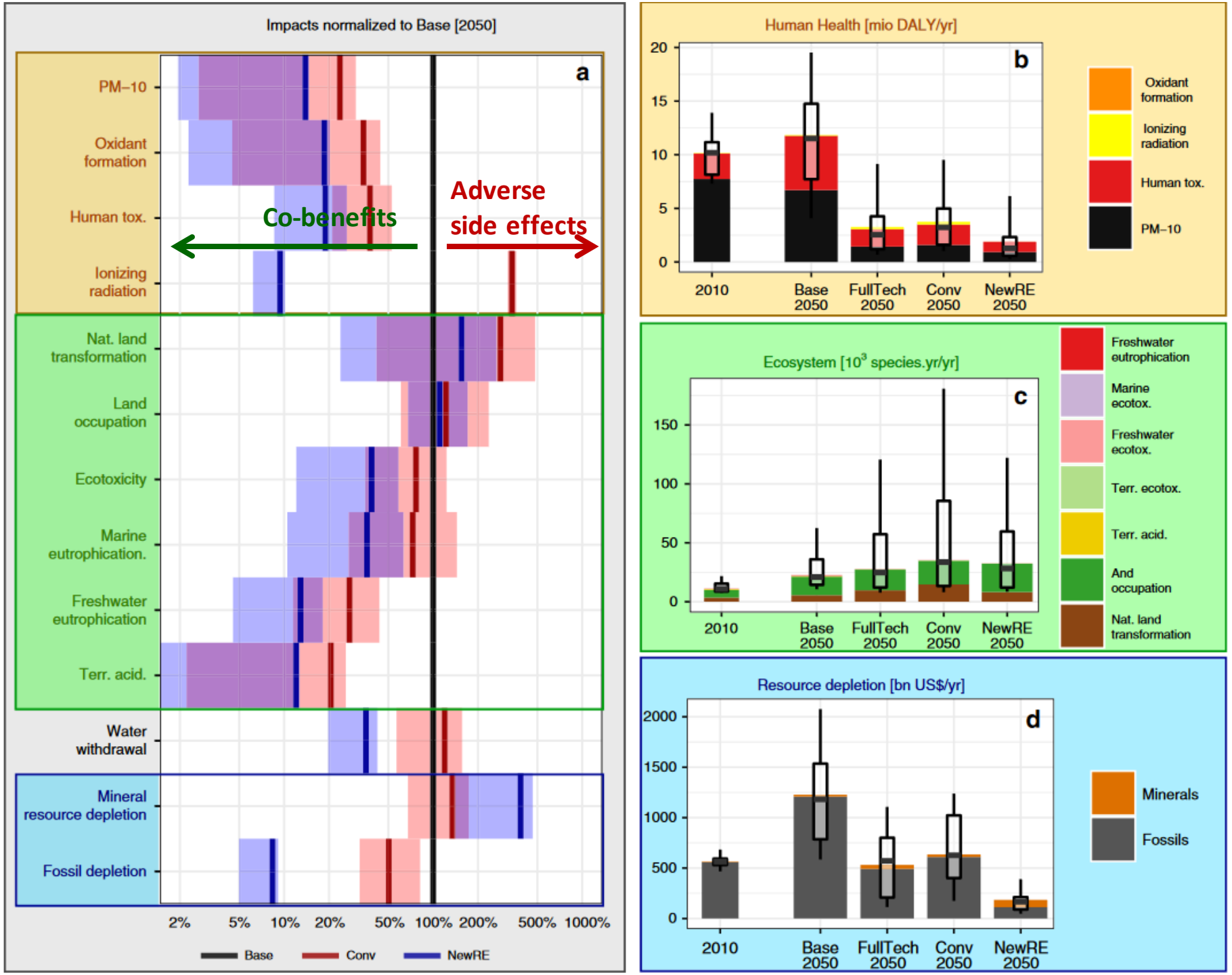


Luderer et al. (2019)

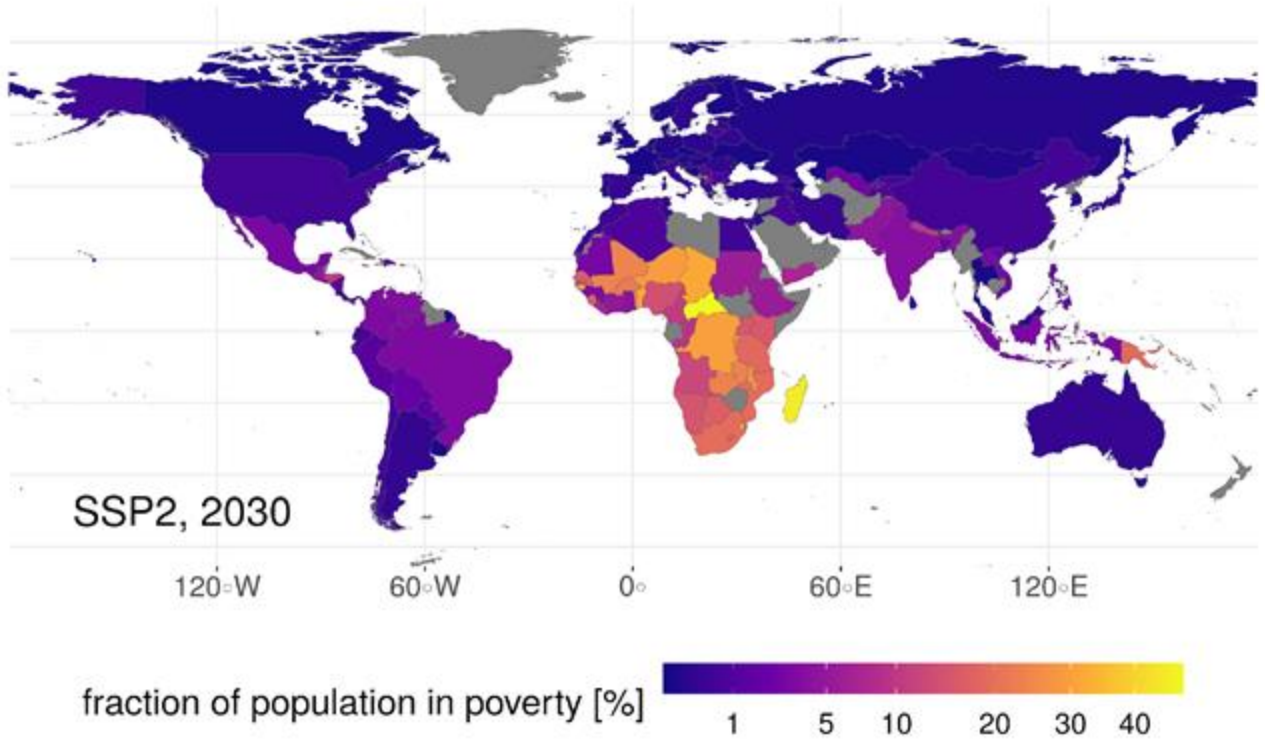
Summary section 2.:

- Empirical research shows strong synergies as well as some trade-offs across SDGs and targets
- Various methodologies used lead to differences in results
- IAM scenarios allow for scenario anlaysis of trade-offs
- coupling to detailed models (like life-cycle assessment LCA tools) expands scope of covered aspects (and SDGs)
- Renewable-focused mitigation strategies lower health and ecosystem impacts, as well as fossil resource depletion, but require larger mineral resource depletion

Policy options to maximize synergies and reduce trade-offs

The world is not on track towards the targets

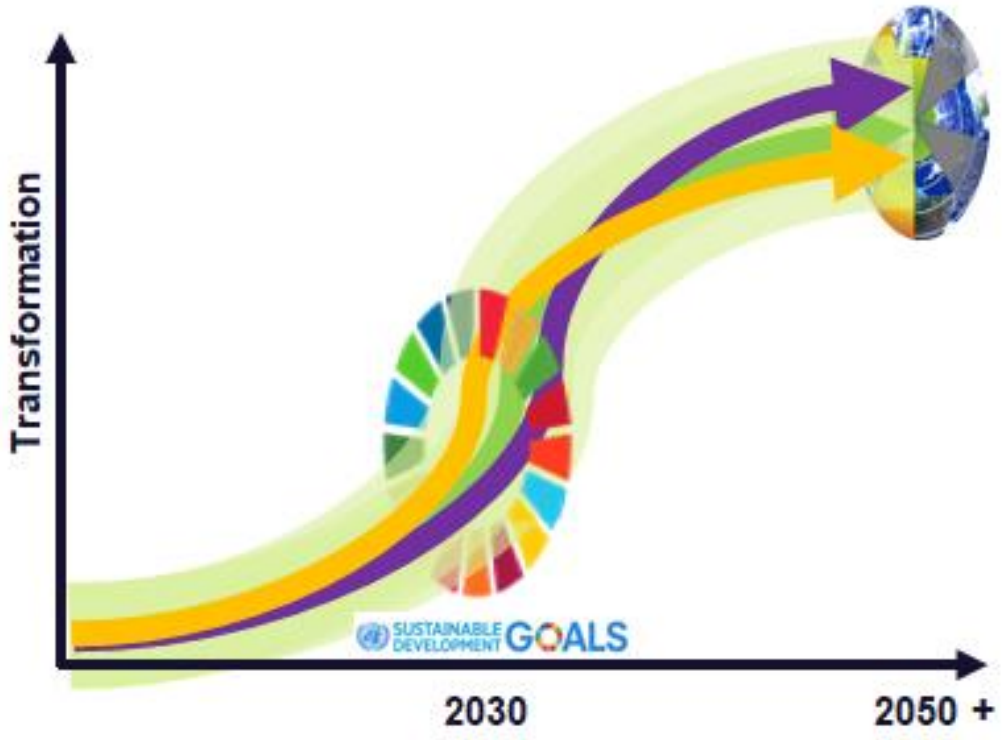
Projection for 2030 poverty rates (pre-COVID)



-> 350 million people left in extreme poverty by 2030

Soergel et al. (2021), Nature Communications

A sustainable development pathway (SDP)



Source: TWI2050 Report 2018
http://pure.iiasa.ac.at/id/eprint/15347/

SDP as “target-seeking” scenario:

- as much progress towards SDGs as possible by 2030
- continue sustainable development towards 2050 and beyond
- meet climate targets of the Paris Agreement
- respect Planetary Boundaries for other environmental indicators

A sustainable development pathway (SDP)

Current trends and policy actions extrapolated (SSP2-NDC)

Soergel et al. (2021), Nature Climate Change

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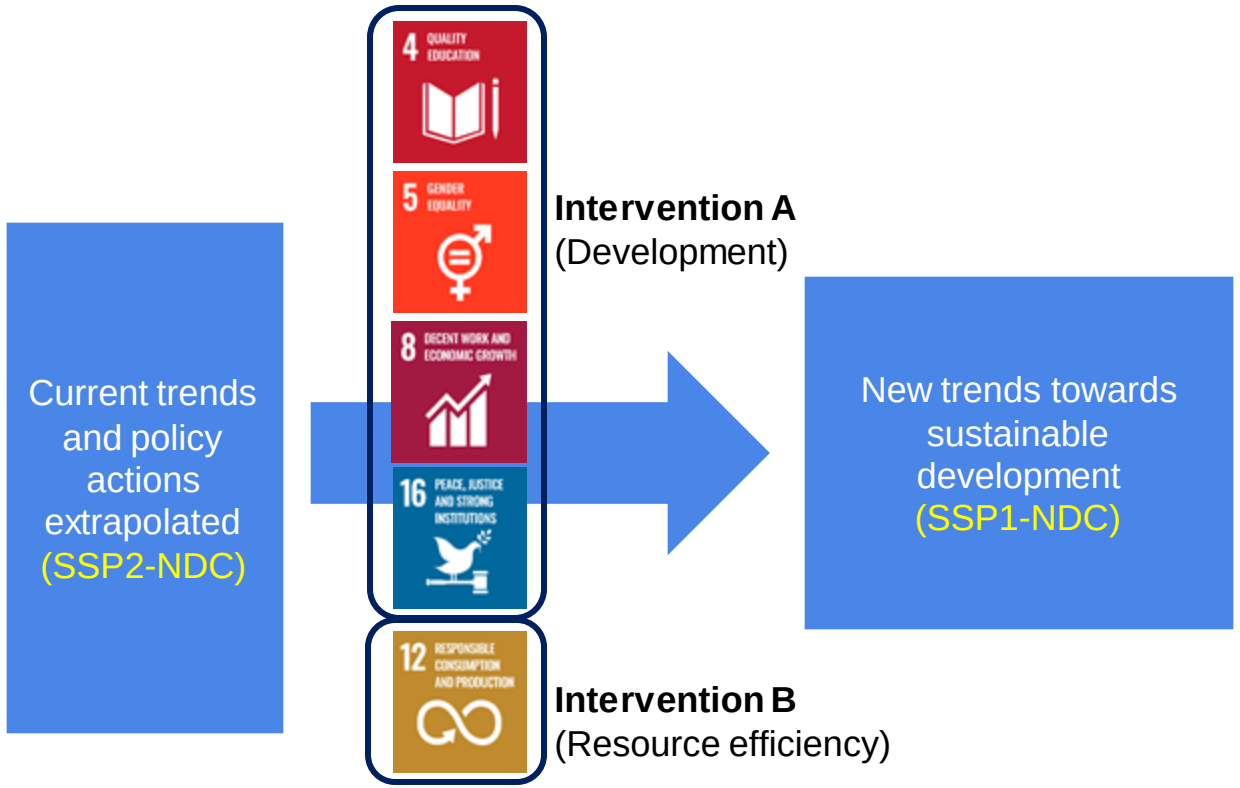

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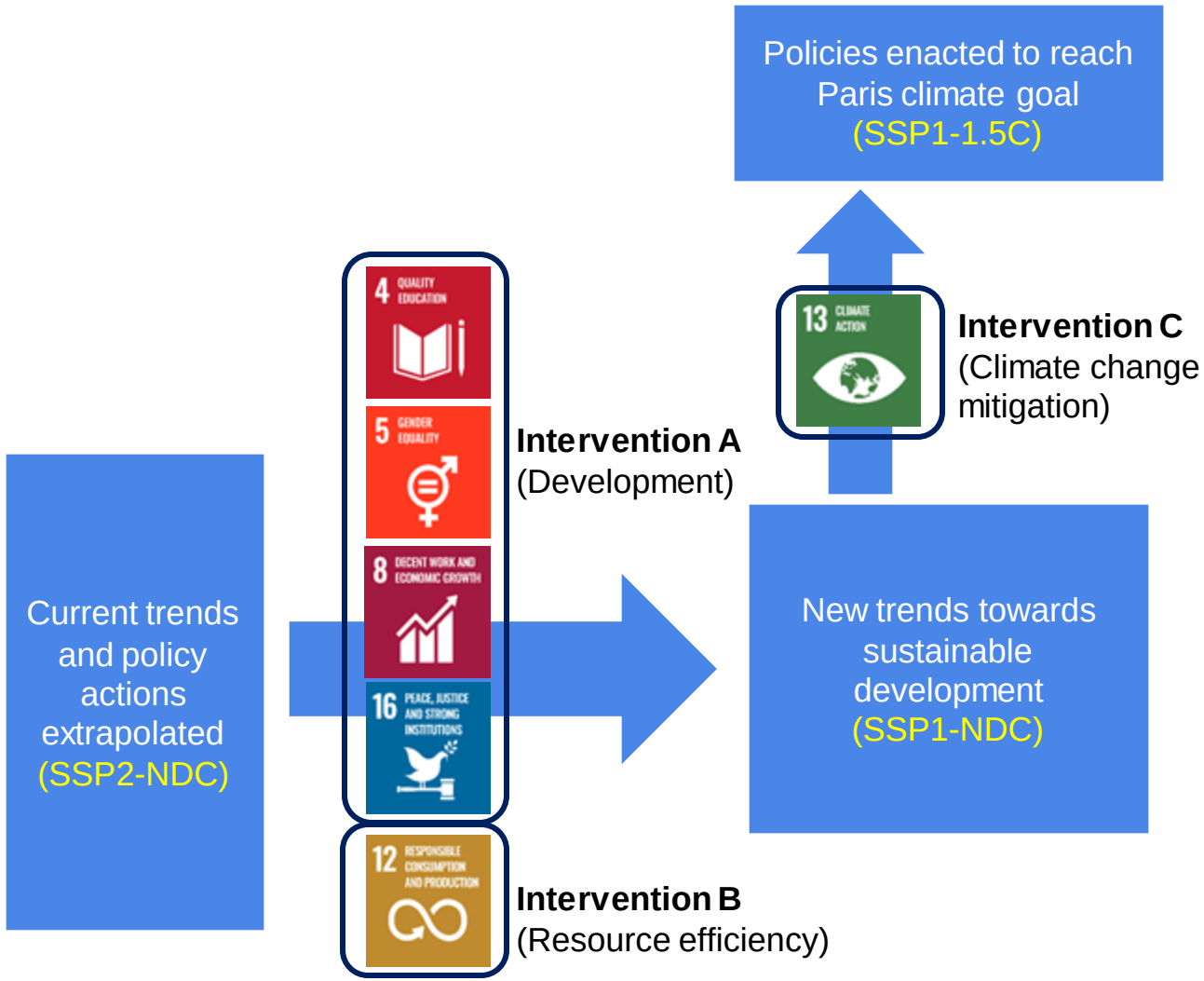

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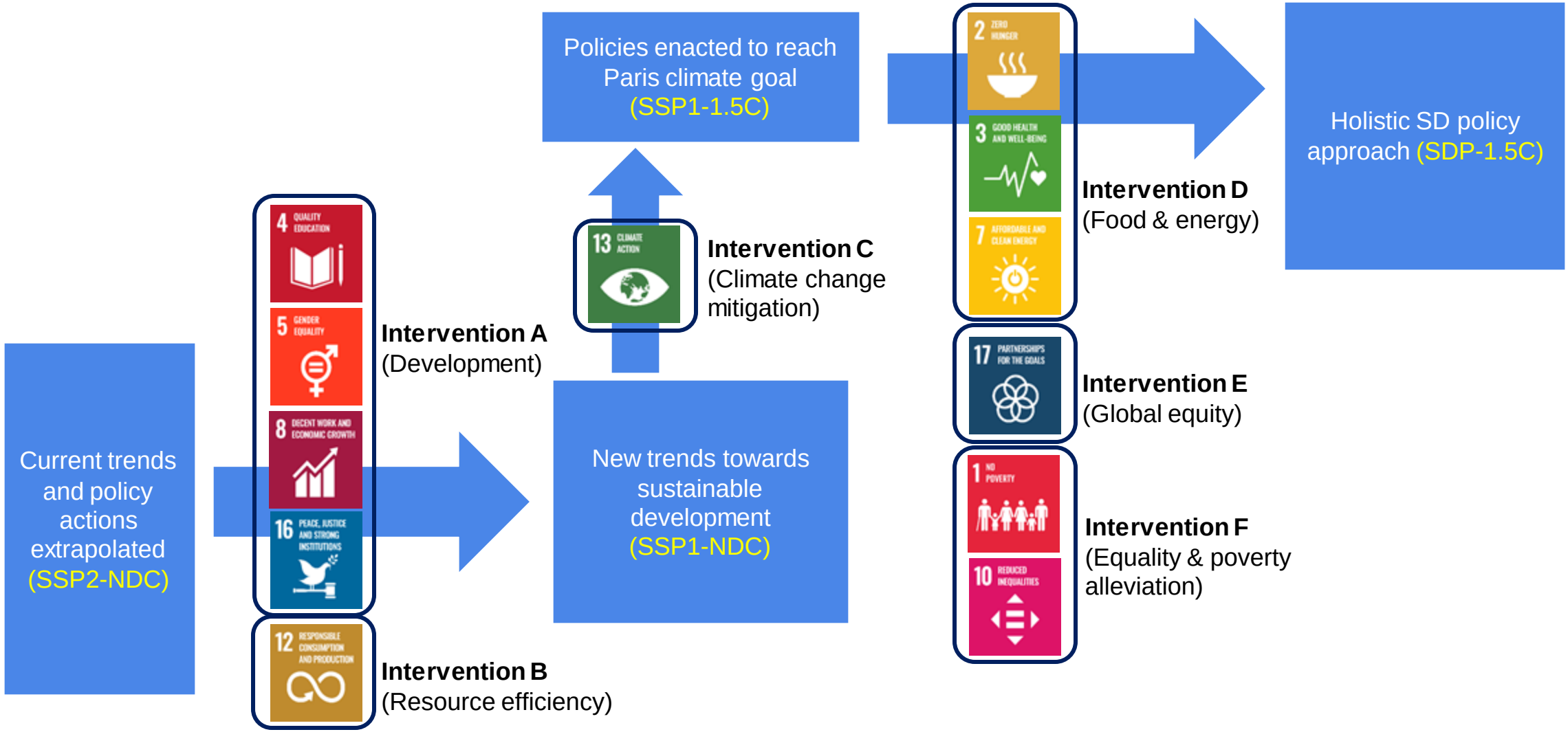
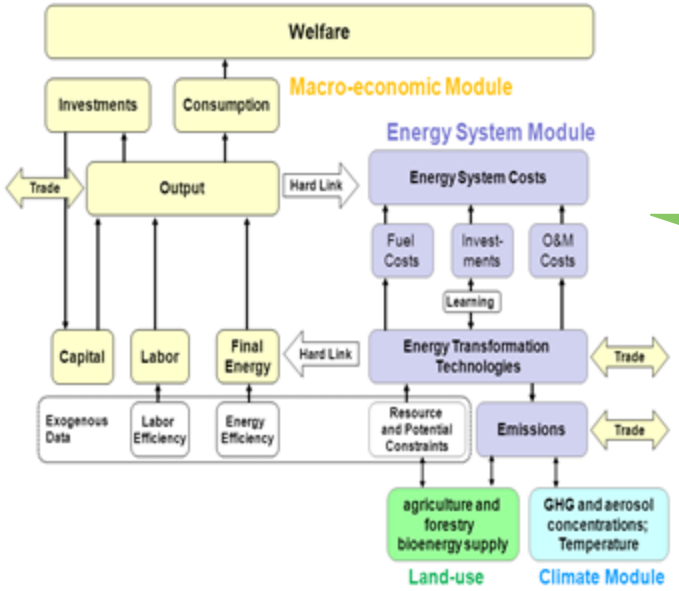


Soergel et al. (2021), Nature Climate Change

REMIND-MAgPIE framework

REMIND

(e.g. Luderer et al. 2015)

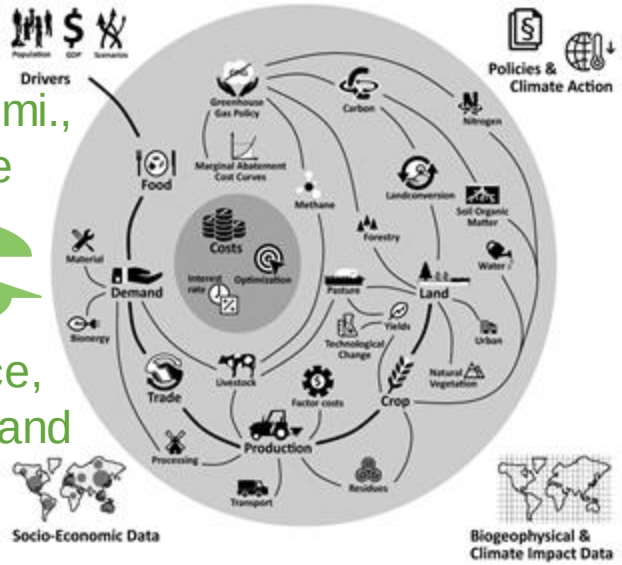


Land-use emi.,
Bioen. price

Carbon price,
Bioen. demand

MAgPIE

(Dietrich et al. 2018)



Energy and land-use system are interlinked.

Resolution:

- Flexible, default: 12 regions
- Large countries as regions
- Small countries grouped

Climate policy setting:

- Policy starts after 2020
- Staged accession: convergence to global carbon price in 2050

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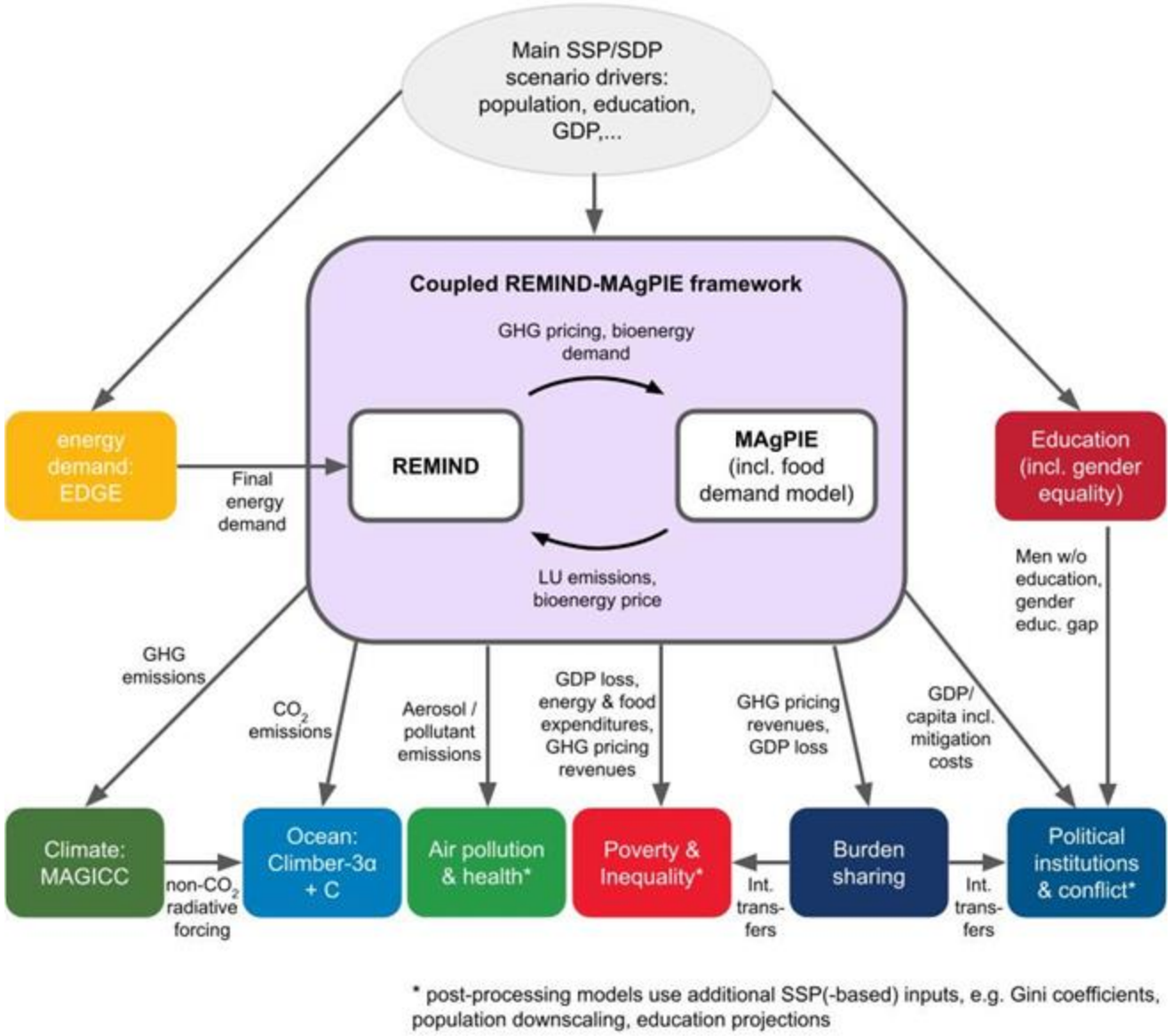
Modelling toolbox + indicators



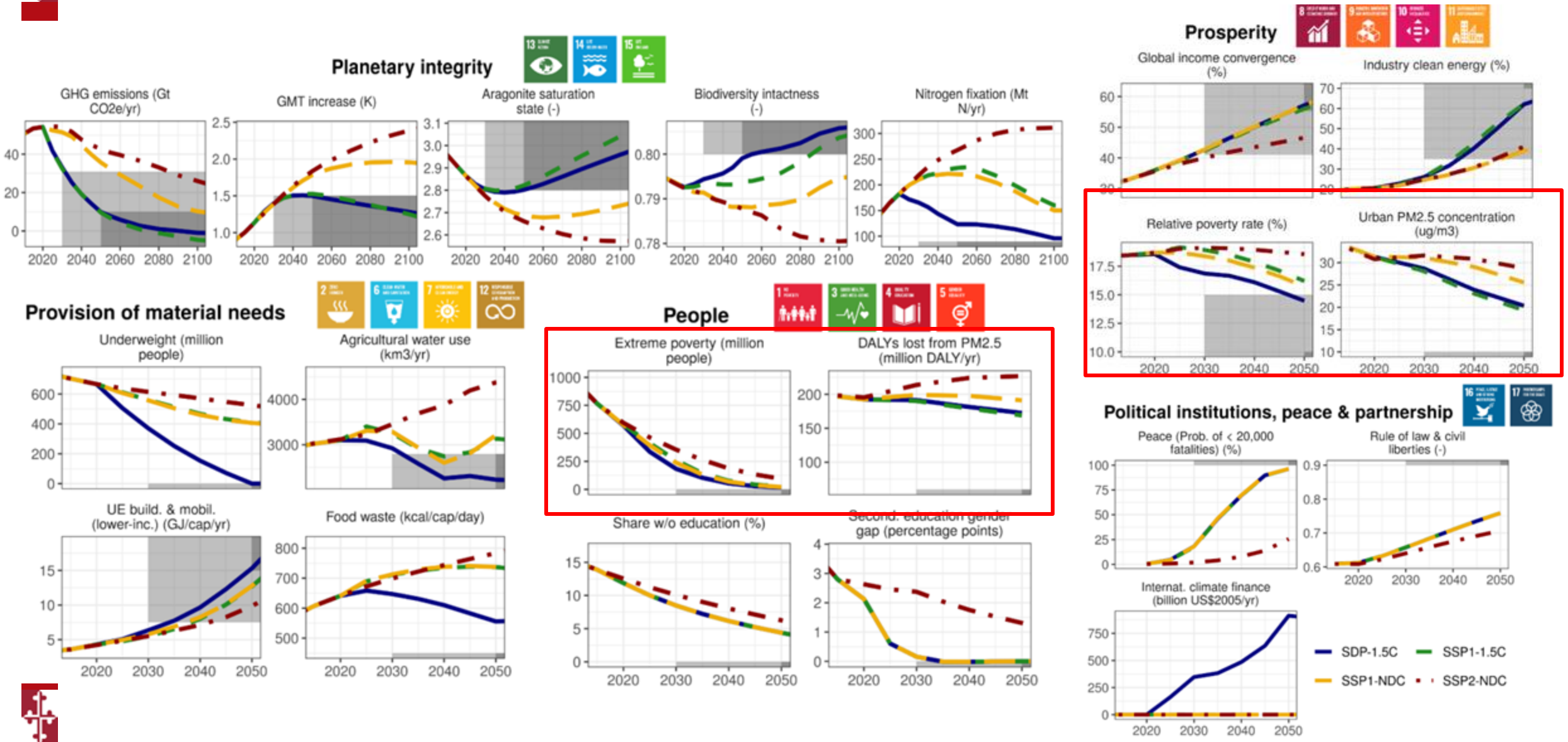
- SSP scenarios as basis
- energy-economy-land-climate modelling framework REMIND-MAgPIE as workhorse
- additional downstream models for SDG indicators
  - Ocean (SDG 14)
  - Air pollution & health (SDG 3,11)
  - Inequality & Poverty (SDG 1,10)
  - Political institutions & violent conflict (SDG 16)

Goal: quantify indicators or meaningful proxies for all 17 SDGs

Comprehensive coverage of the SDG space

Soergel et al. (2021), Nature Climate Change

Comprehensive coverage of the SDG space



Soergel et al. (2021), Nature Climate Change

Interventions: Global equity & poverty alleviation

Intervention E
(Global equity)

- international redistribution of part of the carbon pricing revenues
  -> 'climate & development finance'
  (ImPo: post-proc)

Intervention F
(Equality & poverty alleviation)

- national redistribution of carbon pricing revenues (+ int'l transfers) as equal-per-capita 'climate dividend'
  (ImPo: post-proc)

Legend*: **Sc**enario **As**sumption; **Im**plemented **Po**licy; **Mo**del **Dy**namics

Burden sharing & climate & development finance

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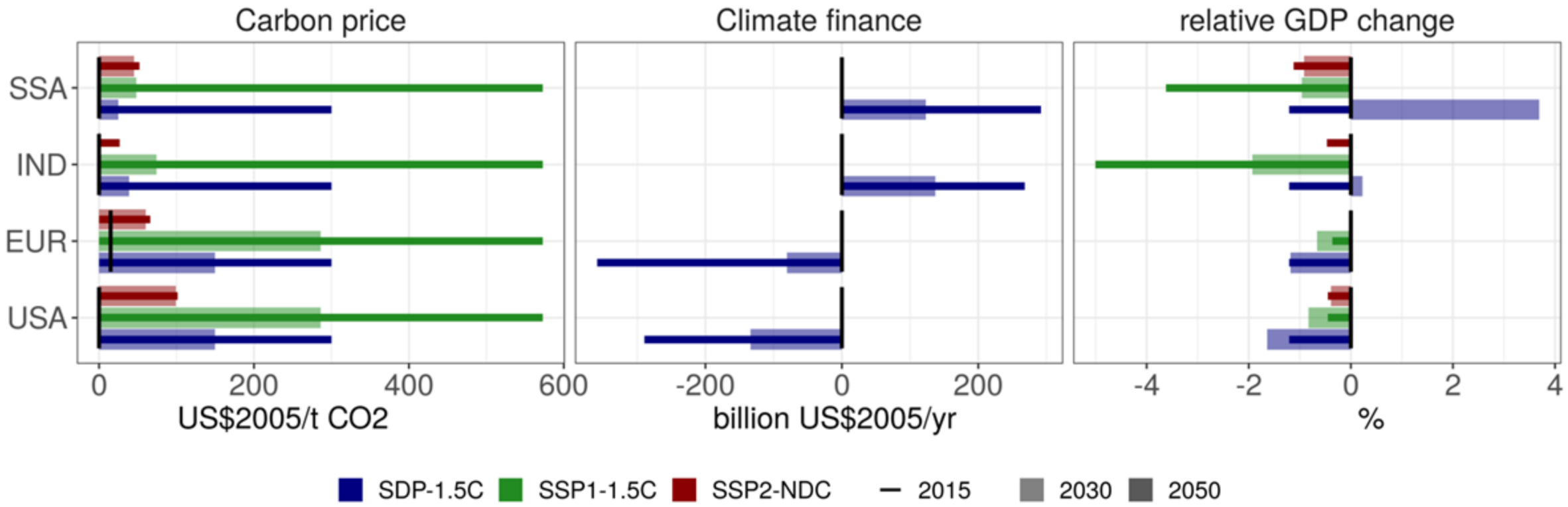
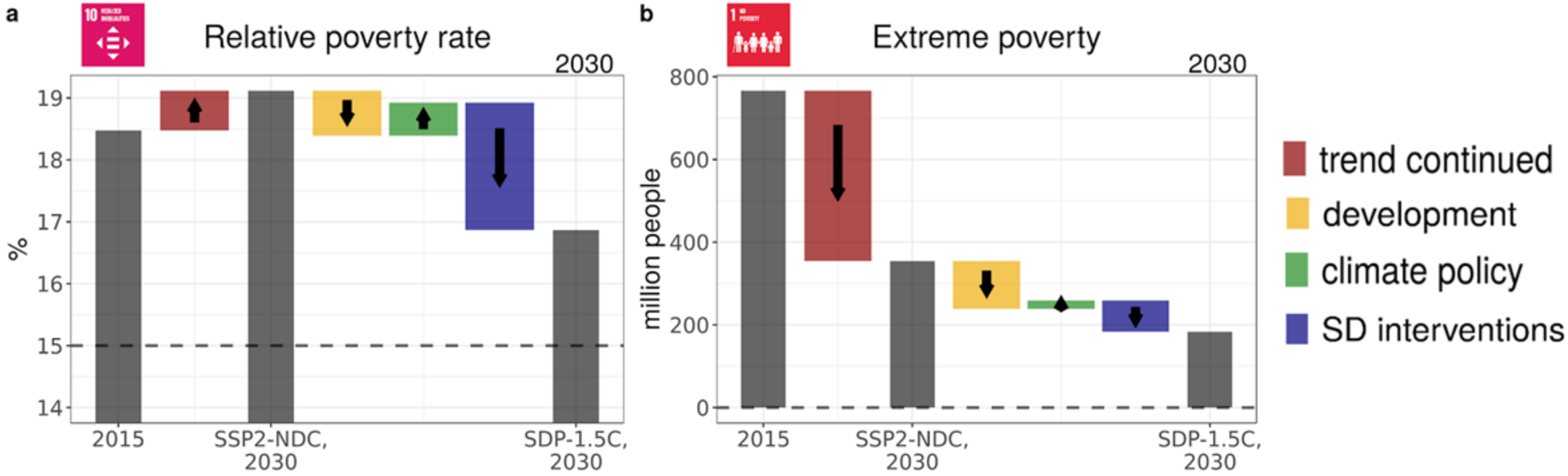


- SDP: Carbon prices roughly halved compared to SSP1-1.5C
- differentiated carbon prices & international climate finance: low policy costs for developing regions
- redistribution of carbon pricing revenues reduces inequality and poverty

Soergel et al. (2021), Nature Climate Change

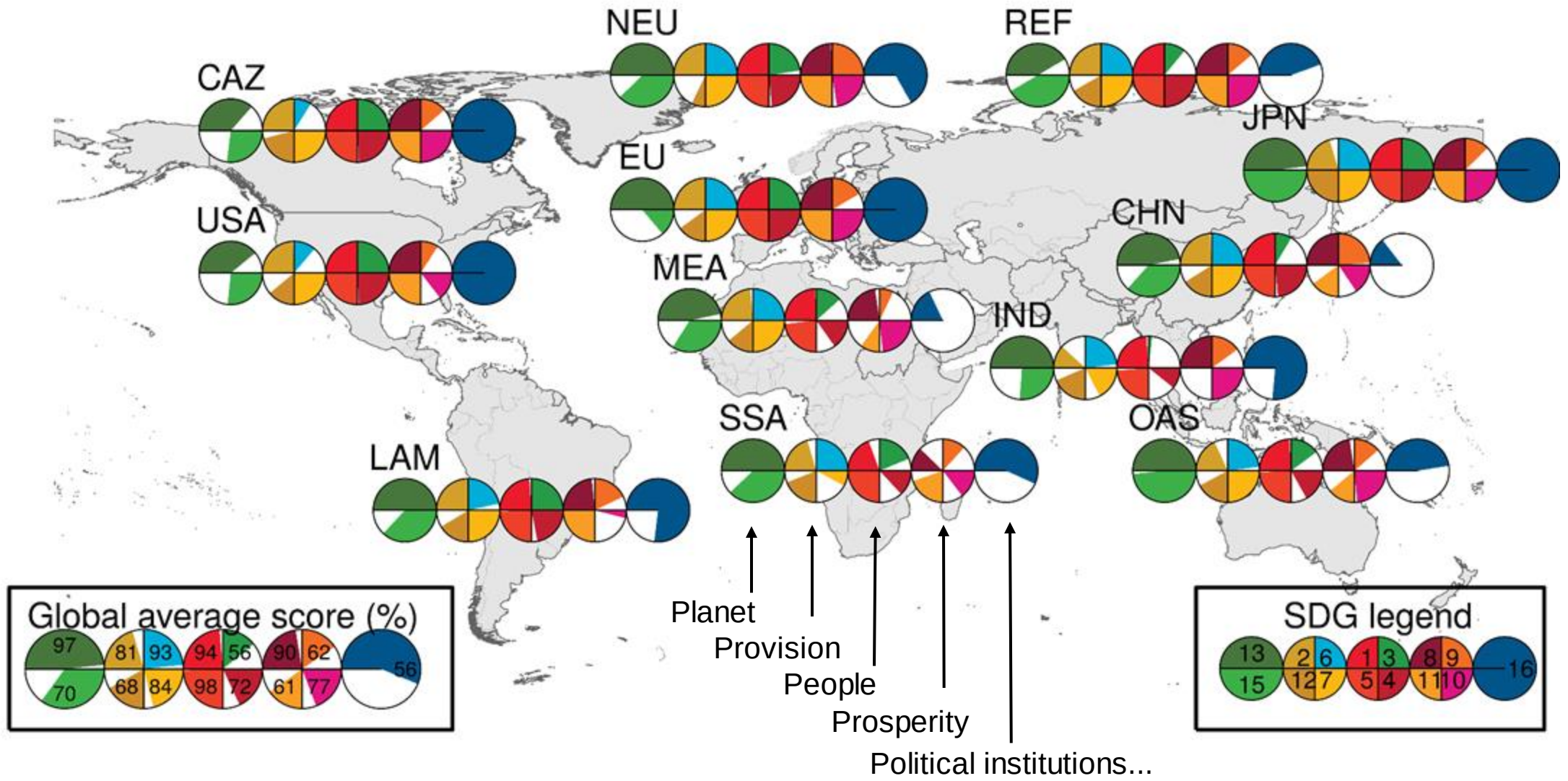
Effects of the interventions: inequality & poverty



- **Redistribution policies funded from carbon pricing revenues reduce inequality and poverty.**
- **Climate policy trade-off is more than compensated.**

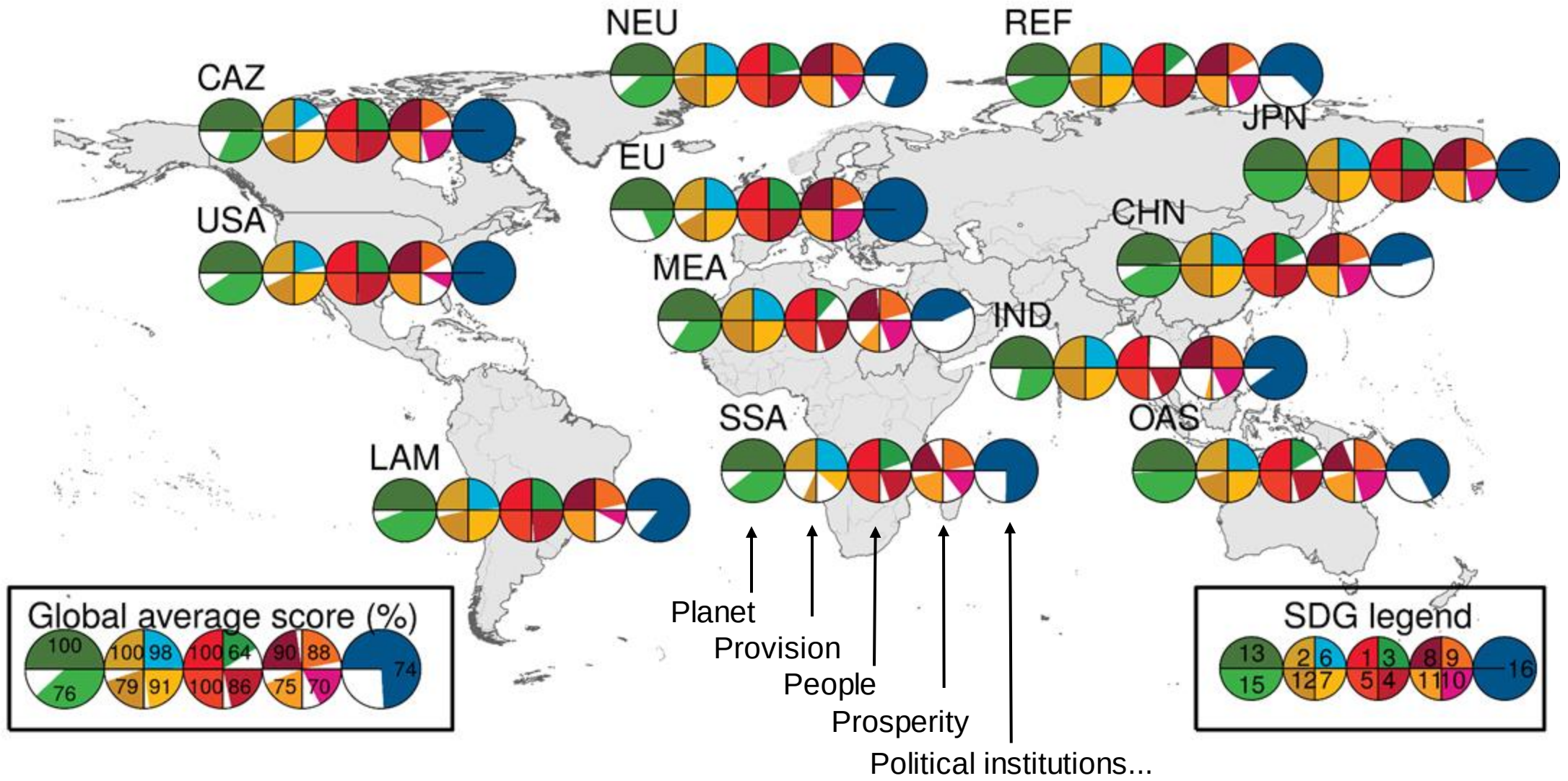
Soergel et al. (2021), Nature Climate Change

Regional SDG achievement and gaps (SDP 2030)



Soergel et al., Nature Climate Change

Regional SDG achievement and gaps (SDP 2050)



Soergel et al., Nature Climate Change

Summary section 3.

- **development**, **resource efficiency** and **moderate lifestyle change** + **climate policies** are **insufficient to meet SDGs**

- additional **SD interventions** required:
  - **global cooperation**: “climate & development” scheme
  - **national redistributive policies** funded from carbon pricing revenues (“policy linking”)
  - **food & energy** -> co-benefits of healthy diets for climate, land, water, nitrogen cycle, biodiversity

  => Substantial improvements towards nearly all SDGs

- comprehensive coverage of SDG space

- SDG achievement **gaps remain in 2030**, but can largely be **closed by 2050**

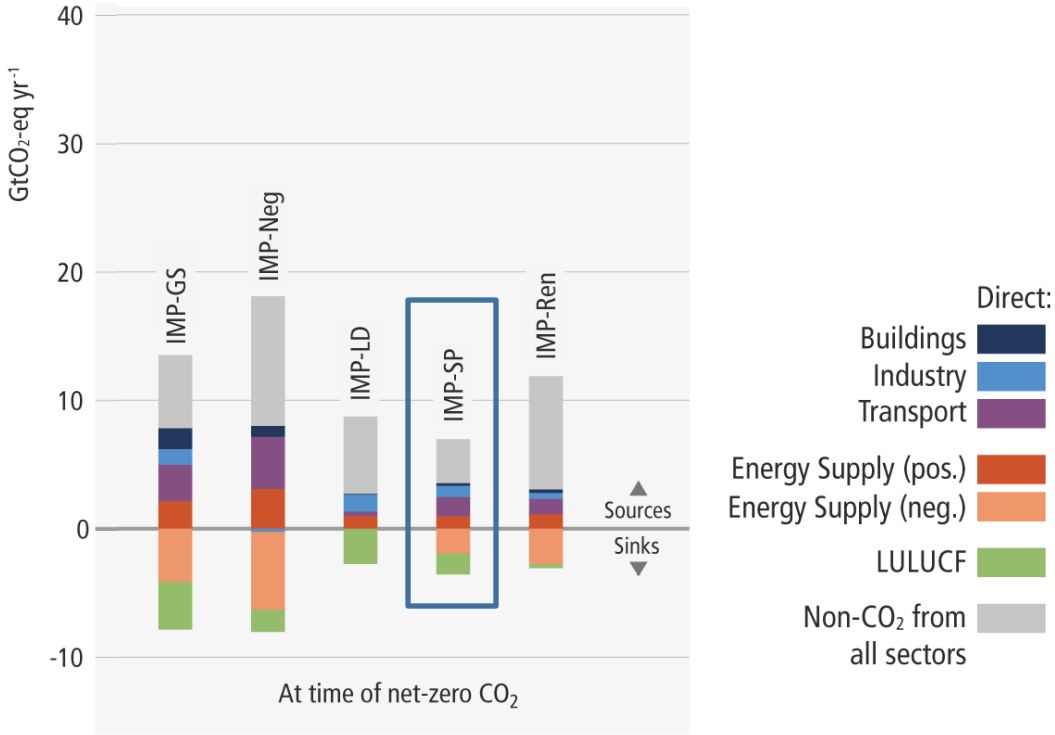


Figure SPM.5e (IPCC 2022)

Future directions for IAM-related SDG research

- More multi-dimensional, more granular analysis
- More explicit representation of both end-point goals (aspects of well-being, like health, affluence, participation, safety and security), as well as preconditions (environmental integrity, resource availability)
- Centrality of governance (which so far is blind spot of IAMs)
  - Endogeneity? (Moore et al. 2022)
  - Scenario approach with more detailed representation of political reality (IRA, EU Fit-for-55, behavioral changes, subnational scale…)

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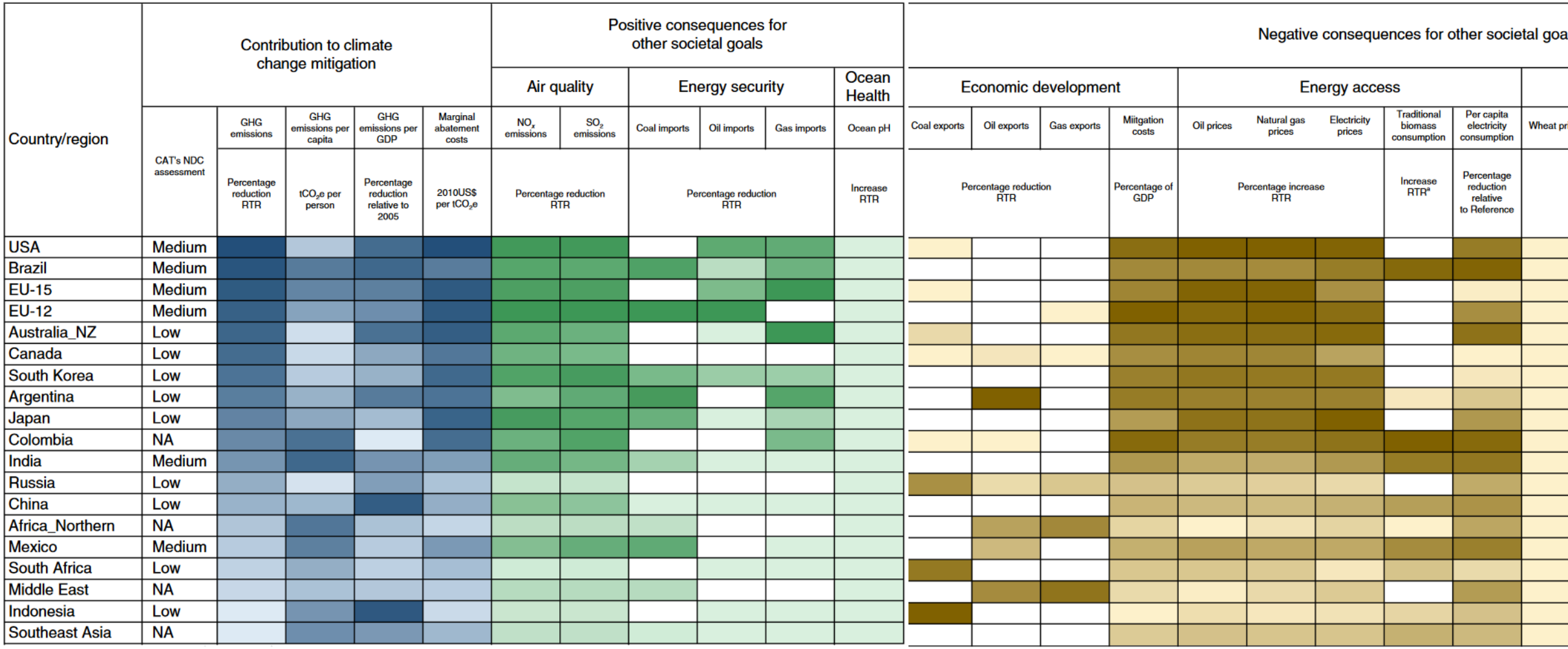
Discussion

Back-up

Implications of SDG considerations for comparability across NDCs



Iyer et al. (2018)

Interventions: Food and energy

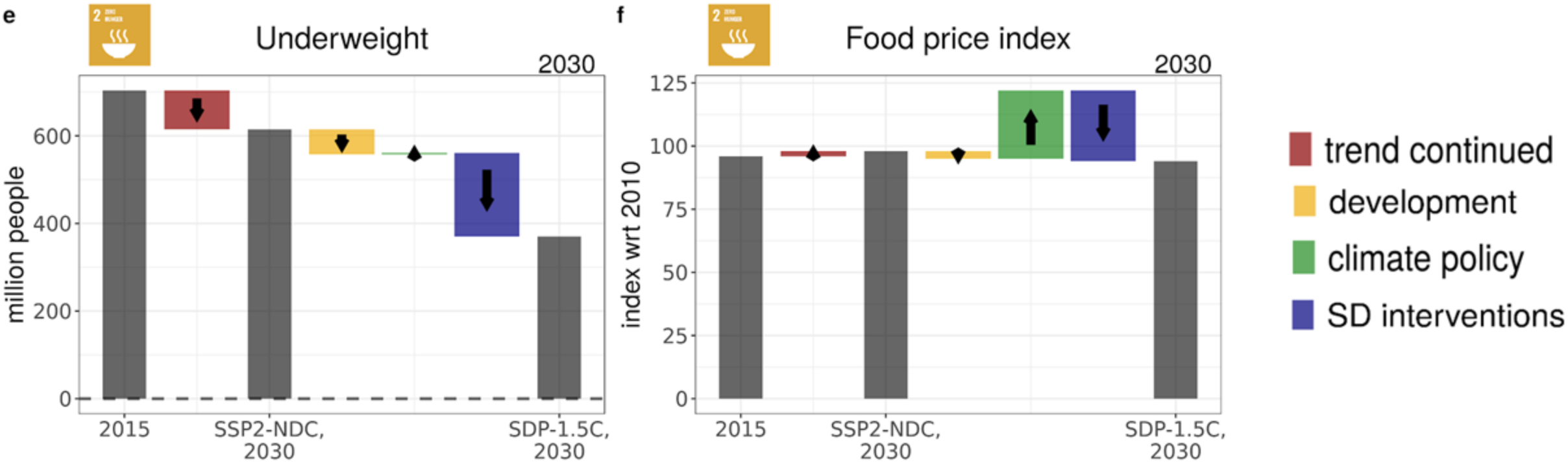
Intervention D
(Food & energy)

- transition to zero hunger and healthy and sustainable diets (EAT-Lancet) by 2050 **(ScAs)**
- meet energy demand for decent living standards in developing regions **(ScAs / MoDy)**
- reduce energy consumption in high-income regions **(ScAs / MoDy)**
- additional energy and land system sustainability policies, e.g. coal phase out, BECCS limit, biodiversity hotspot protection **(ImPo: constraint)**

Legend*: **Sc**enario **As**sumption; **Im**plemented **Po**licy; **Mo**del **Dy**namics

* see Supplementary Tables of paper for detailed description

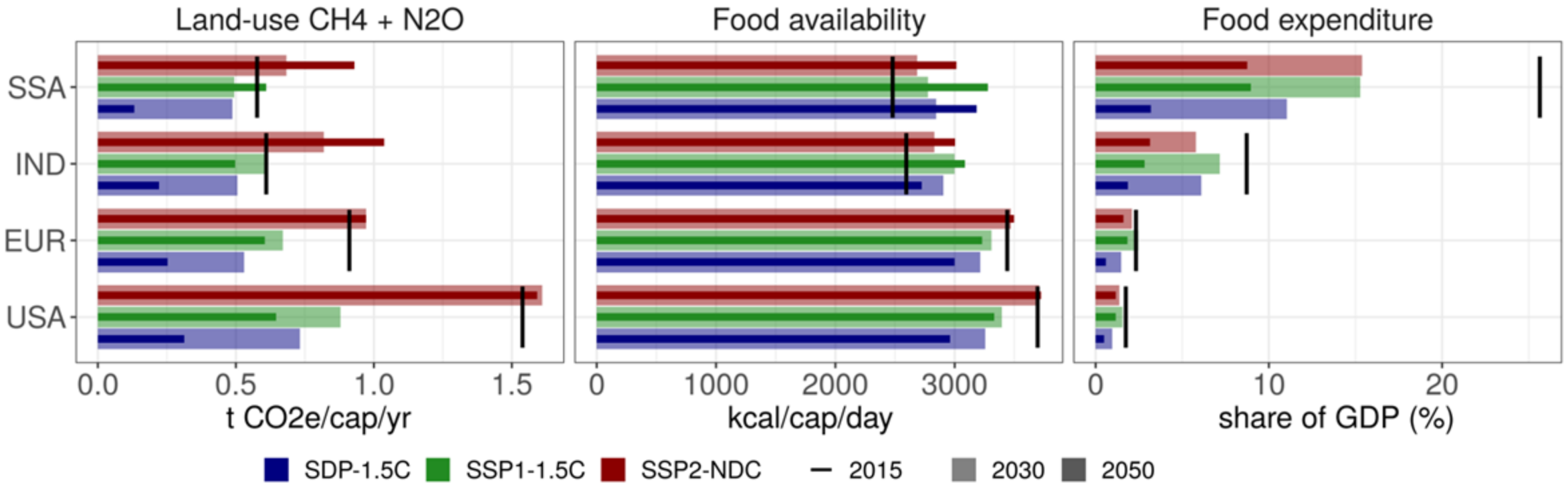
Effects of the interventions: food



- **Transition to healthy and sustainable nutrition (EAT-Lancet)**
- **Prevalence of underweight is substantially reduced (zero by 2050)**
- **Effect of climate policy on food prices is fully compensated.**

Soergel et al. (2021), Nature Climate Change

Food and land-use system



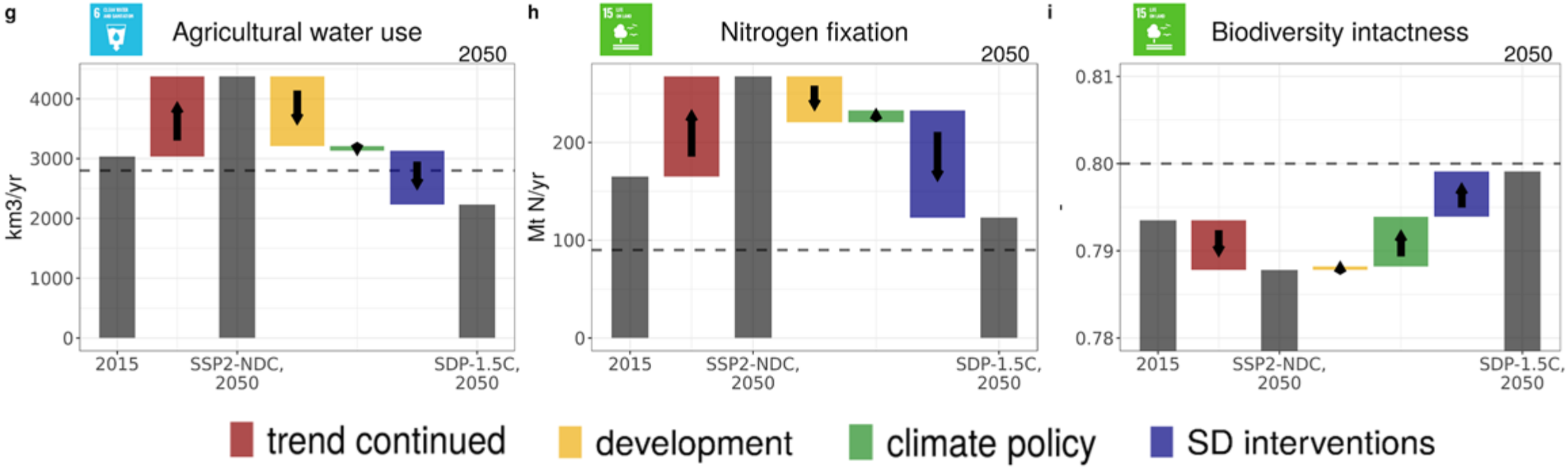
SDP: Transition to sustainable diets:

- rapid reduction of agricultural emissions
- slightly (100 Gt) higher 1.5°C-compatible CO_2 budget

Soergel et al. (2021), Nature Climate Change

Effects of the interventions: land & water

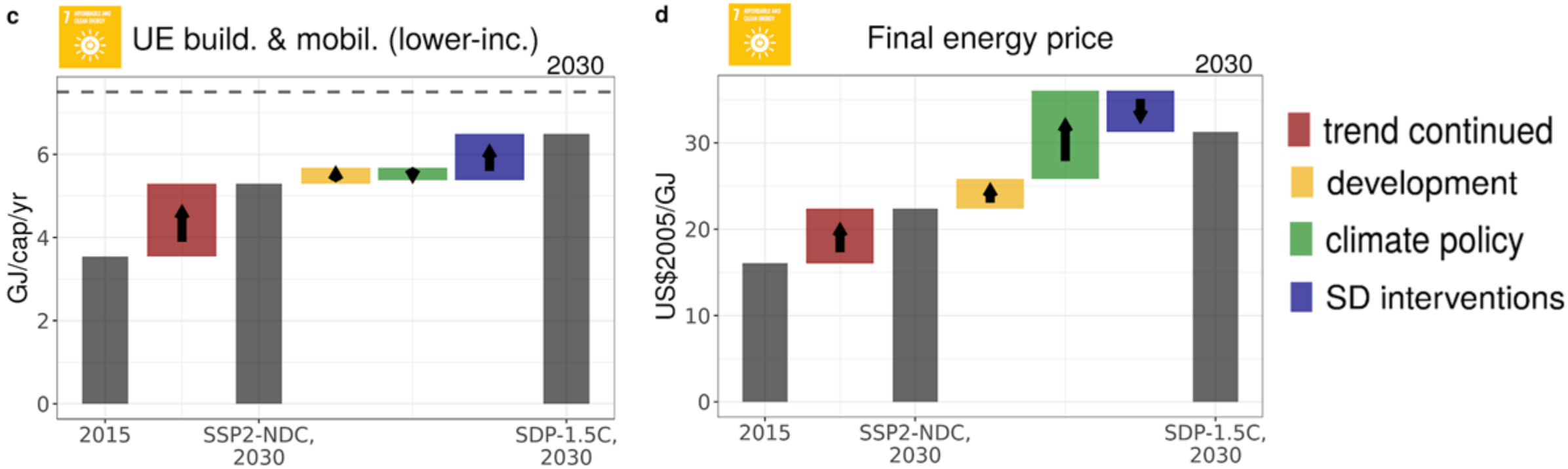
Planetary boundaries in 2050



Large co-benefits of healthy and sustainable nutrition for multiple planetary boundaries.

Soergel et al. (2021), Nature Climate Change

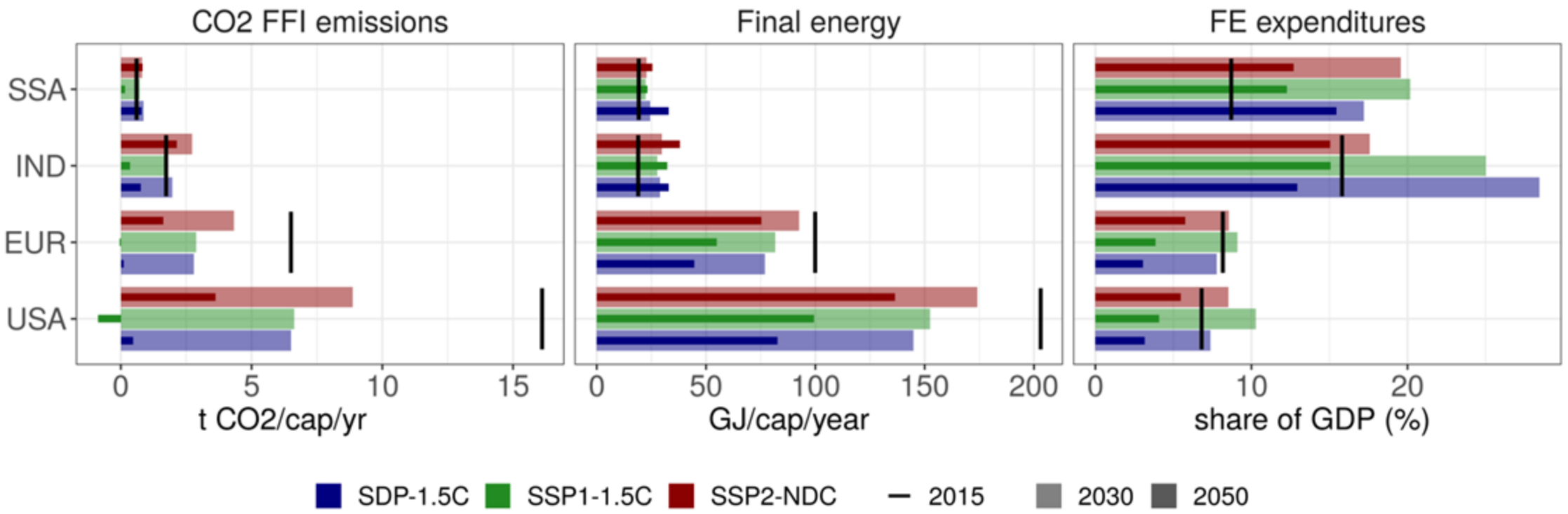
Effects of the interventions: energy



- **improved availability of modern energy services in lower-income regions**
- **ambitious shift to sustainable lifestyles in high-income regions**
- **price increase caused by climate policy is dampened**

Soergel et al. (2021), Nature Climate Change

Energy system

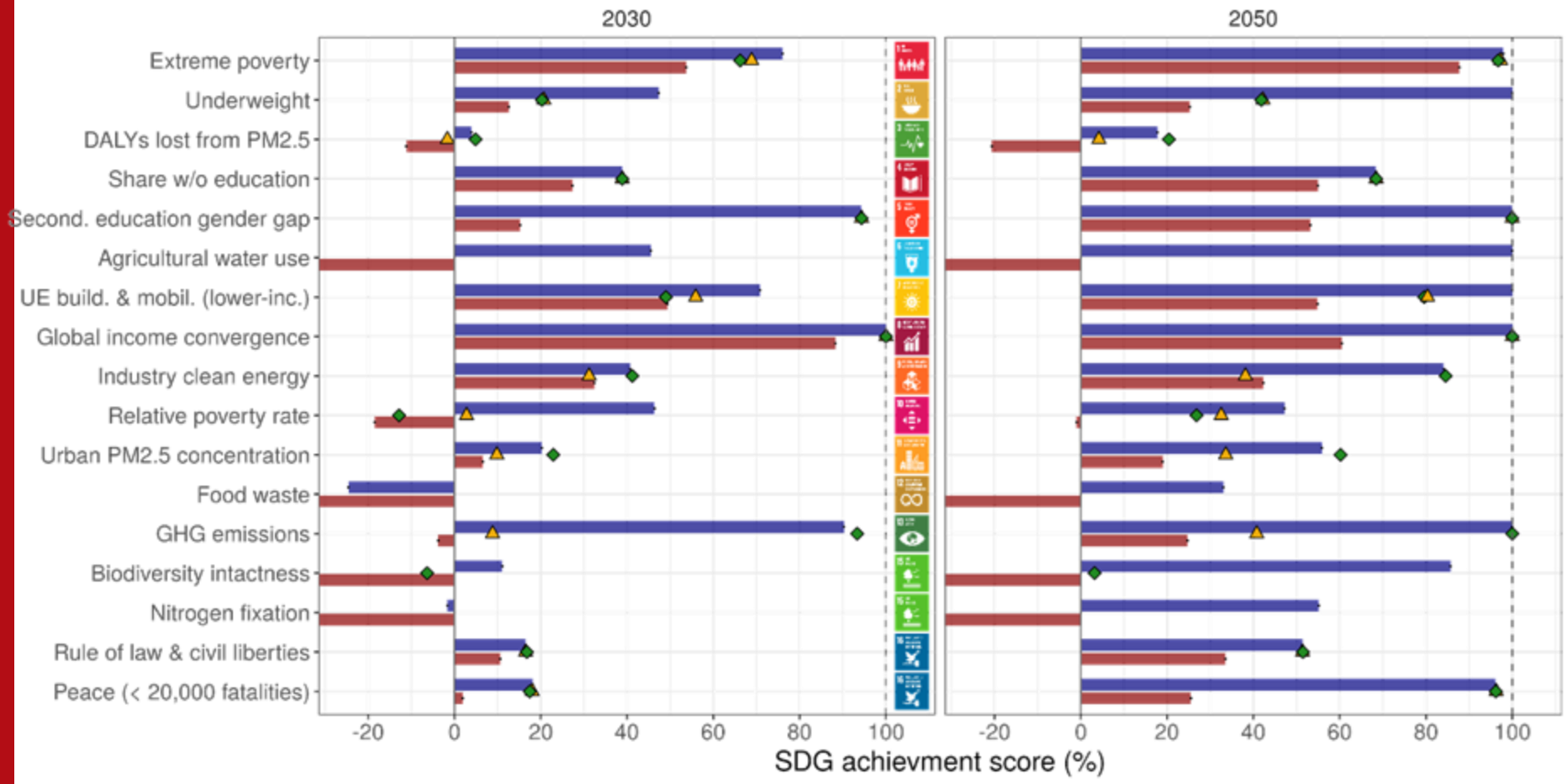


SDP energy demands:

- ambitious reductions in high-income regions
- higher, SDG-compatible energy demands in low-income regions
- Trade-off: higher energy expenditures in near term (compensated, see below)

Soergel et al. (2021), Nature Climate Change

Global SDG achievement and gaps



SD scenario -NDC trends continued

- SDP scenario improves substantially over reference scenario across nearly all SDGs.
- Nonetheless: many targets are difficult to meet by 2030.
- Further progress until 2050 can close most of the gaps.

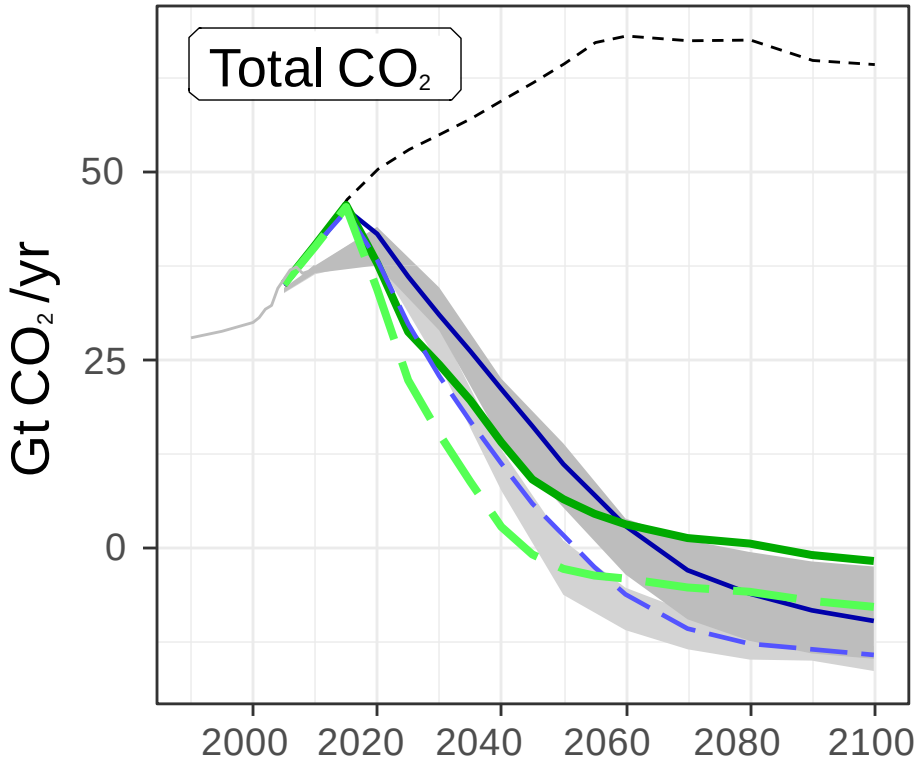
Soergel et al. (2021), Nature Climate Change

Sustainability benefits and sustainability risks of deep decarbonization: do policy assumptions matter?

		Default
		Carbon price increasing at 5% p.a. "cost-effective"
Stabilization target (CO_2 budgets 2011-2100 in Gt)	**Reference** (no mitigation)	**REF_Def**
	Well below **2°C** limit (1000)	**2°C_Def**
	1.5°C limit (400)	**1.5°C_Def**

Bertram et al. (2018)

Different CO_2 emission profiles



REF_Def (No-policy baseline)

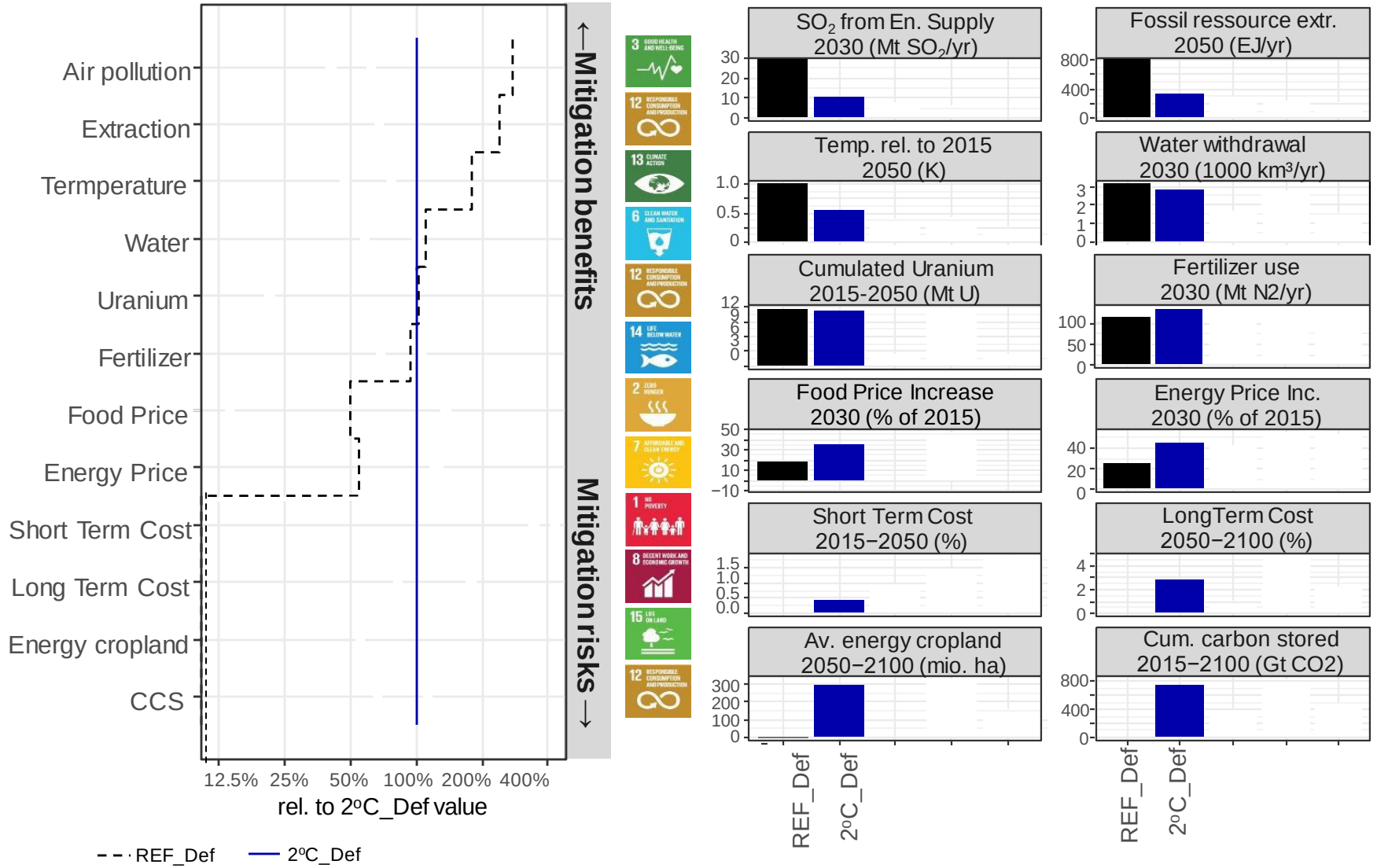
2°C_Def (2°C w. c-price only)

2°C scenarios from Rogelj et al 2015

EDGAR

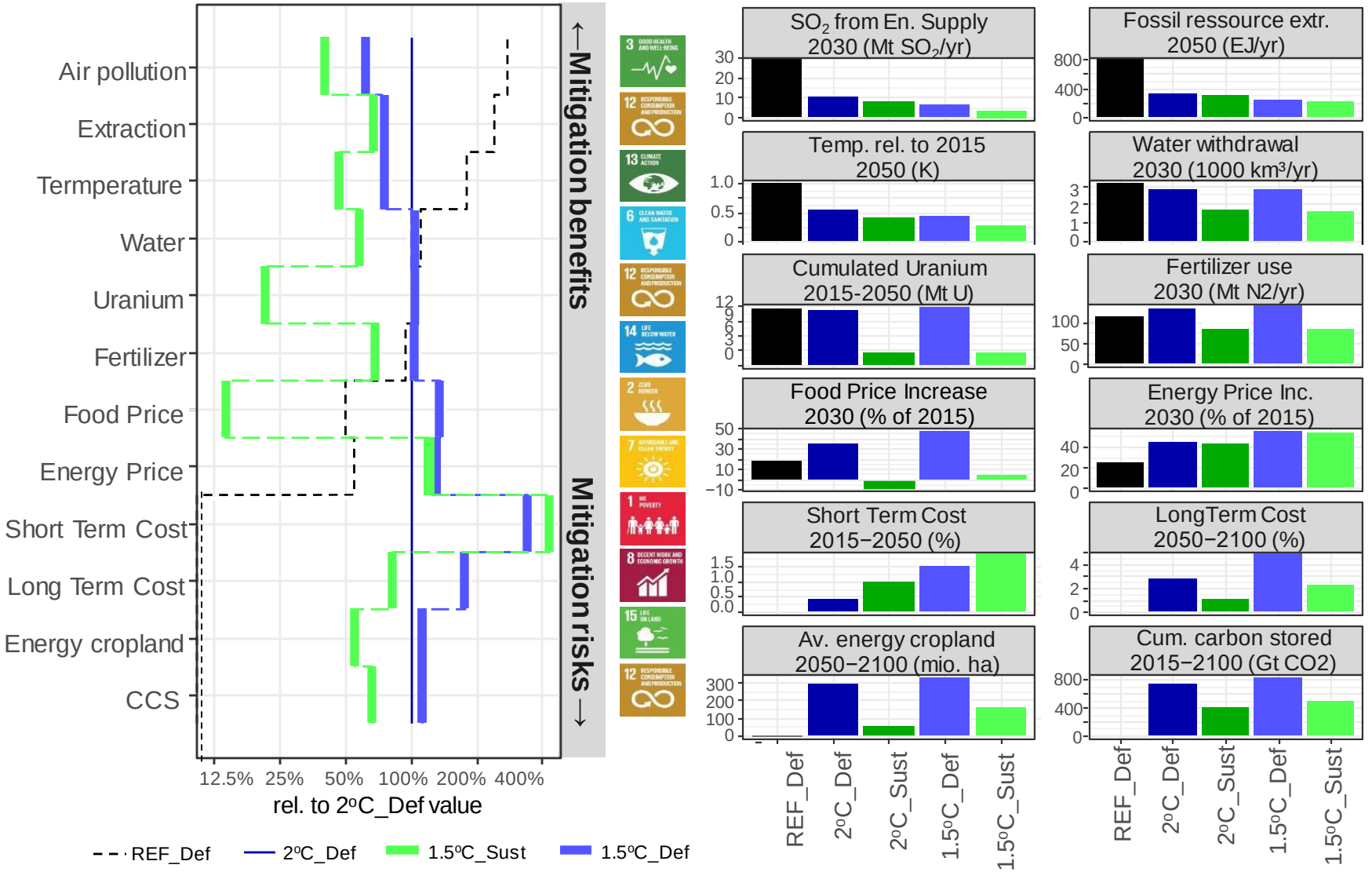
Bertram et al. (2018)

Different profiles in sustainability indicators



Bertram et al. (2018)

Different profiles in sustainability indicators



Bertram et al. (2018)