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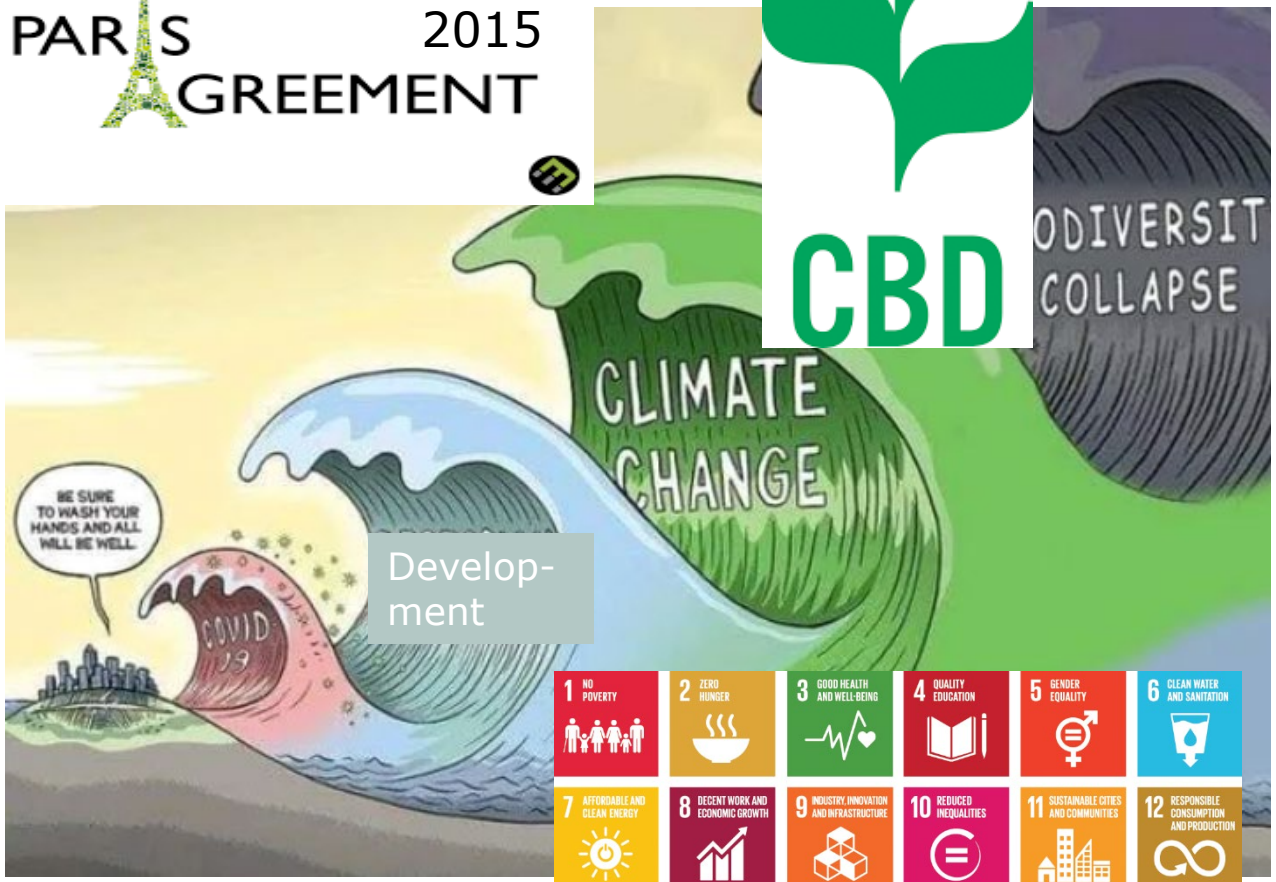
Use of IAMs to analyse SDGs, Circular Economy and biodiversity

Detlef van Vuuren

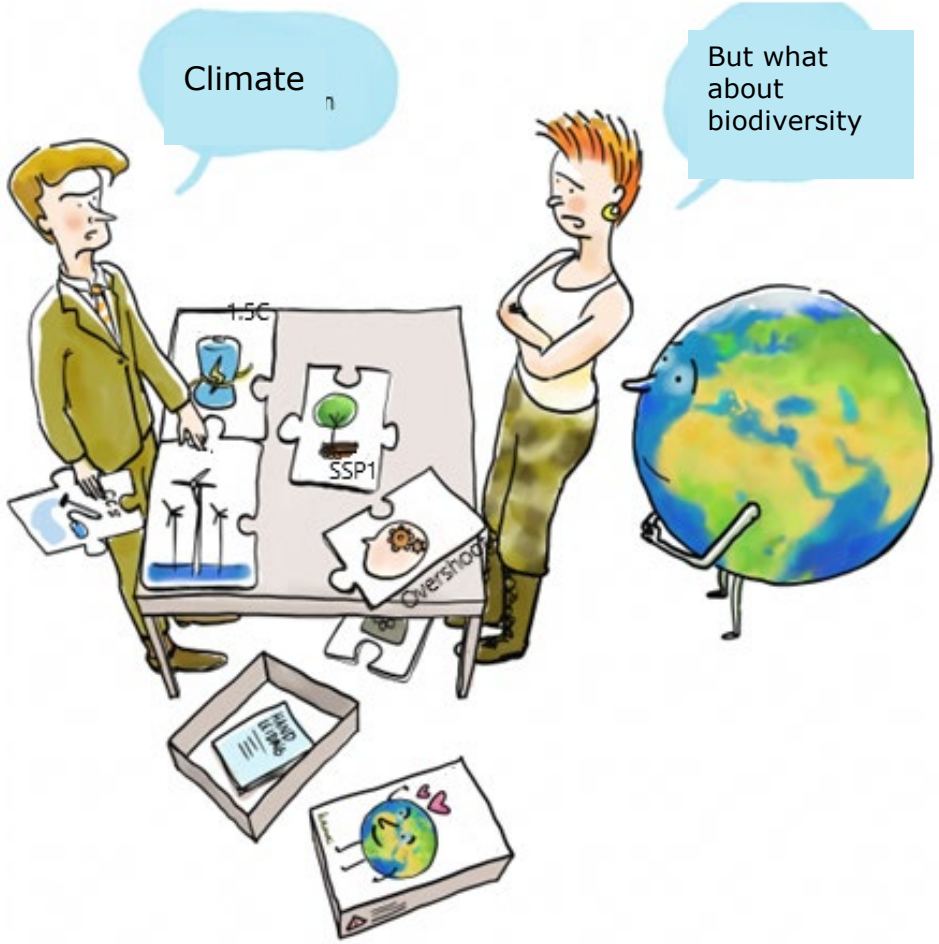
Multiple crises world

PARIS AGREEMENT 2015

CBD



Develop-
ment



Sustainable development

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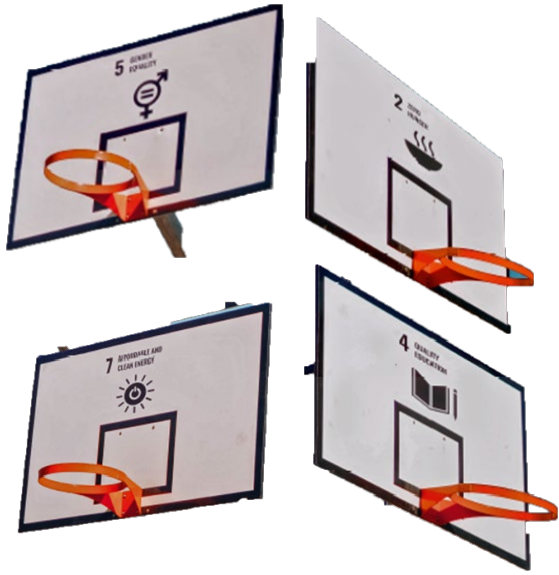

Sustainable development goals (SDGs)

What would it take to achieve this comprehensive set of development and environmental goals**…..** **simultaneously?**

Sustainable development

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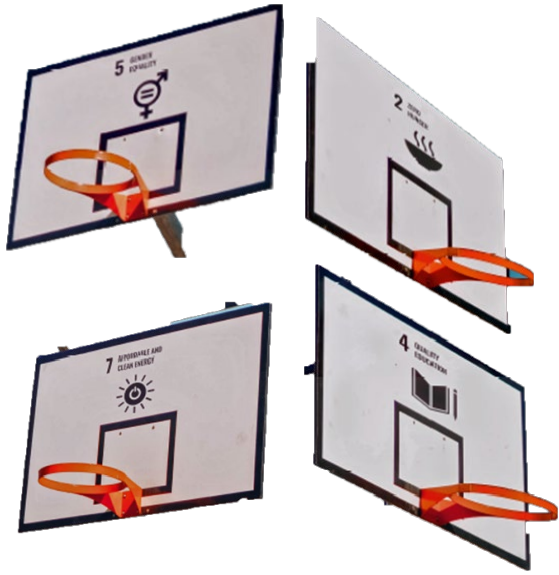

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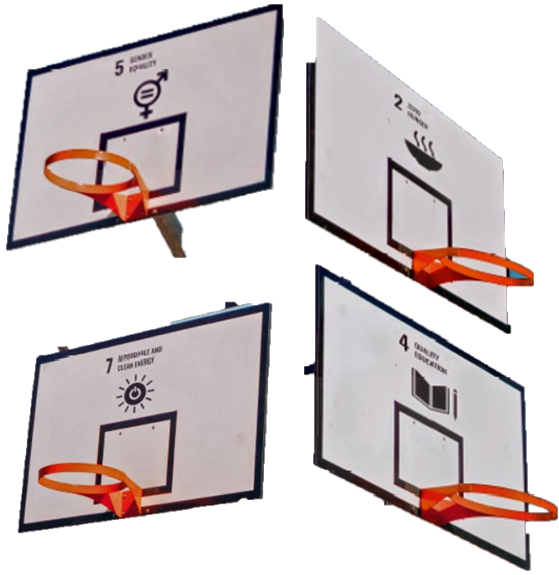

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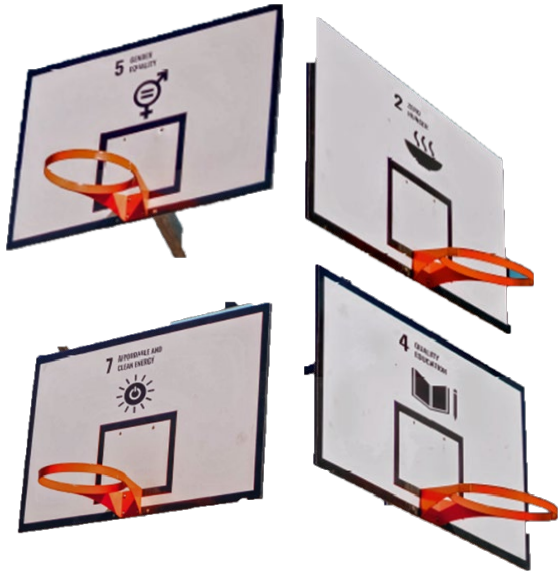

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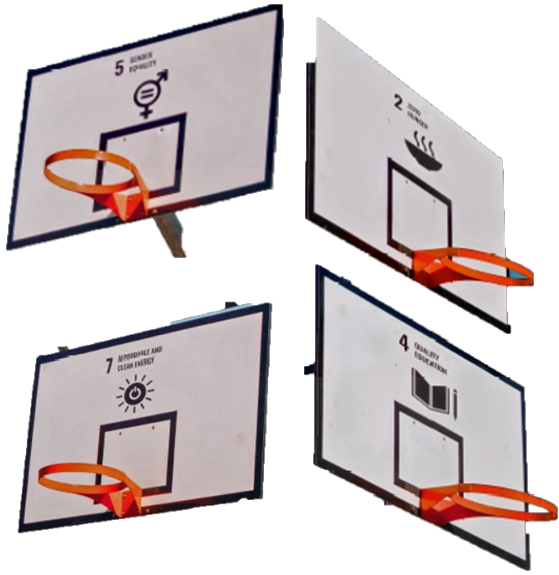

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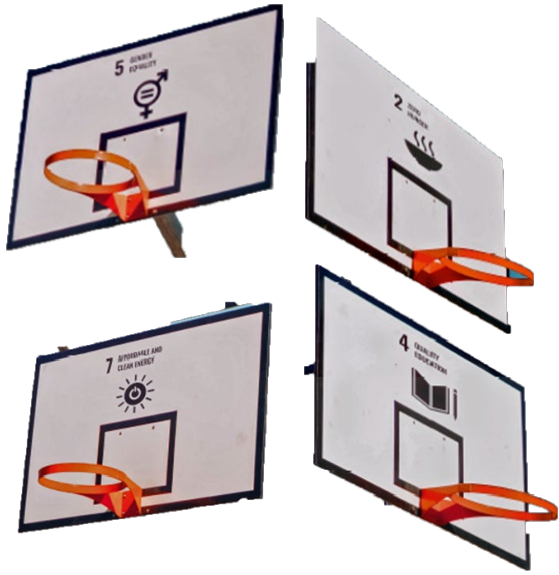

- **Progress on SDGs so-far: Very limited!**

- **Literature: Urgent need for better, quantitative understanding of… .**

- **the required effort to achieve SDGs**
  - Different options; Assess synergies and trade-offs; policy coherence
- **the congruence between different sustainability themes**
  - Comprehensive view on the connections and causal links

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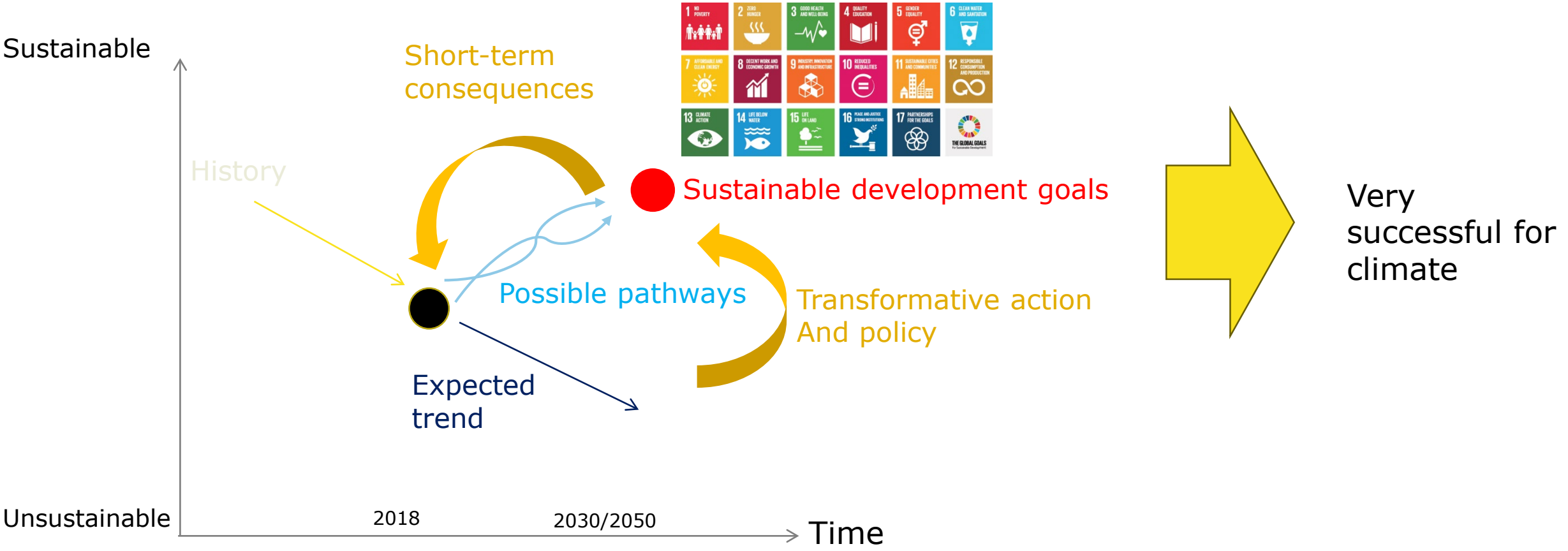
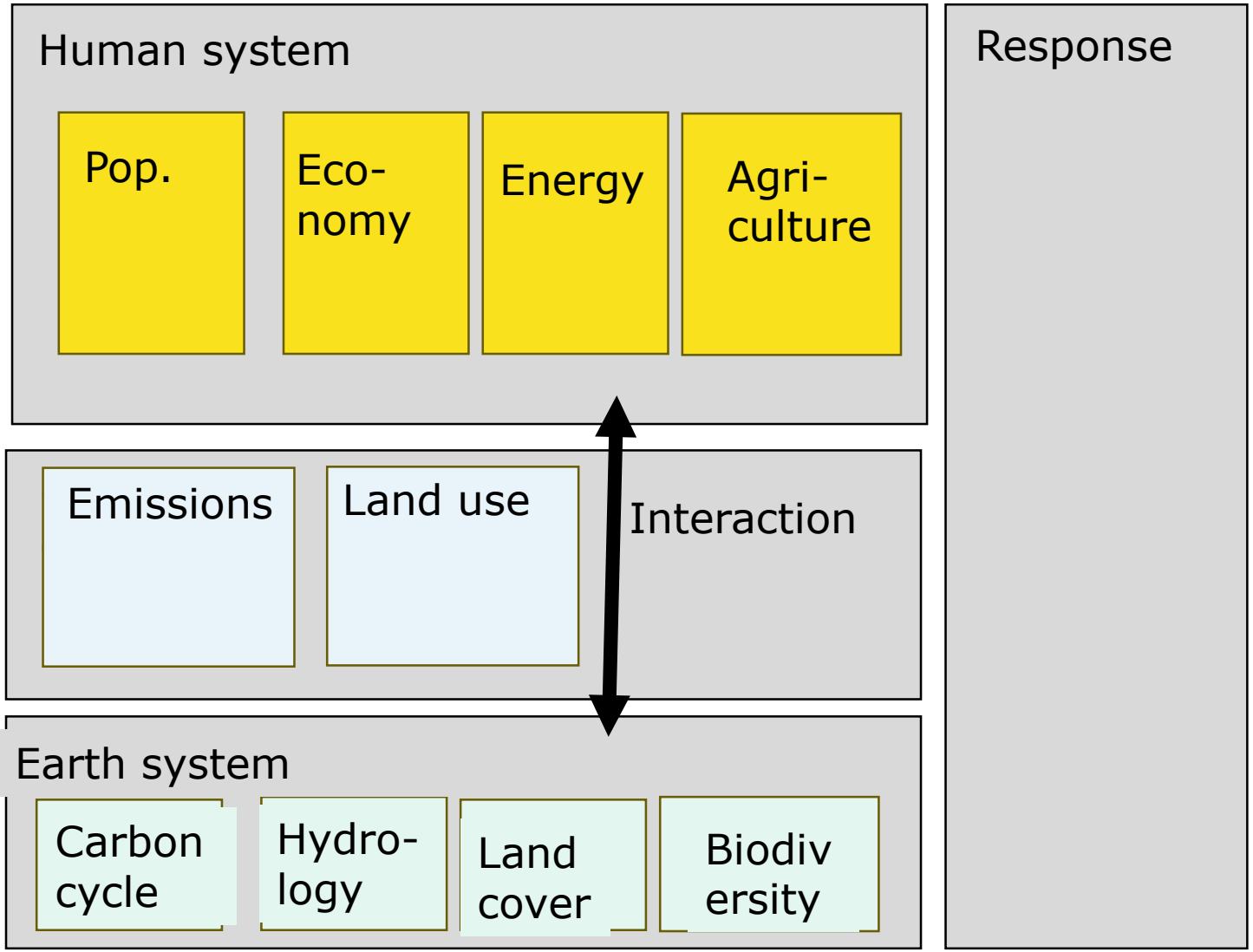
Scenario analysis



Very successful for climate

Source: Van Vuuren et al., 2015. *Technological Change & Social Forecasting*; 98, pp 303-323.
Van Vuuren et al. 2007. *PNAS*. vol. 105 no. 40. 15258–15262

Typical IAM model



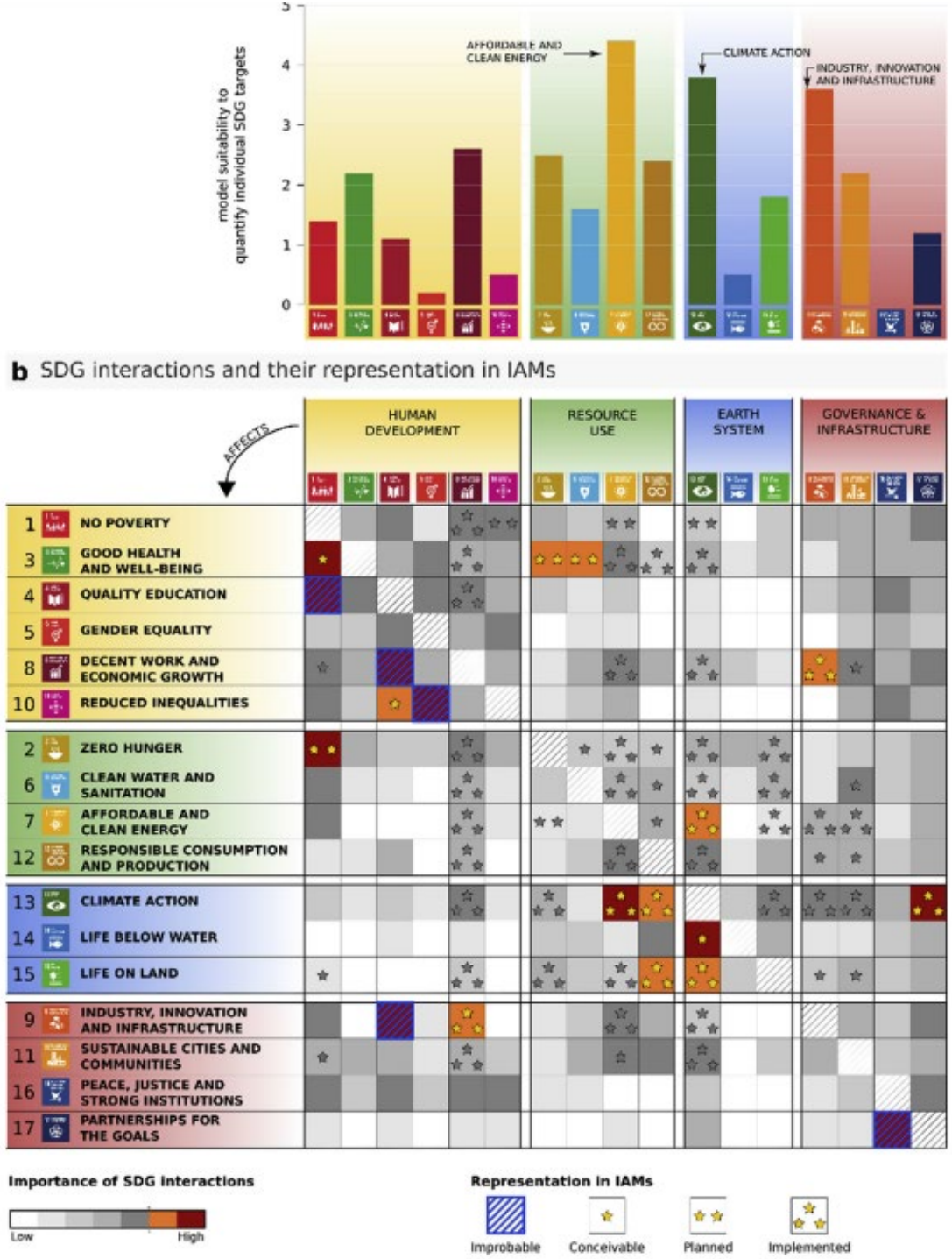
Typical IAM model

Human development and equity

Efficient and sustainable resource use

Protecting natural environment

Good governance & infrastructure



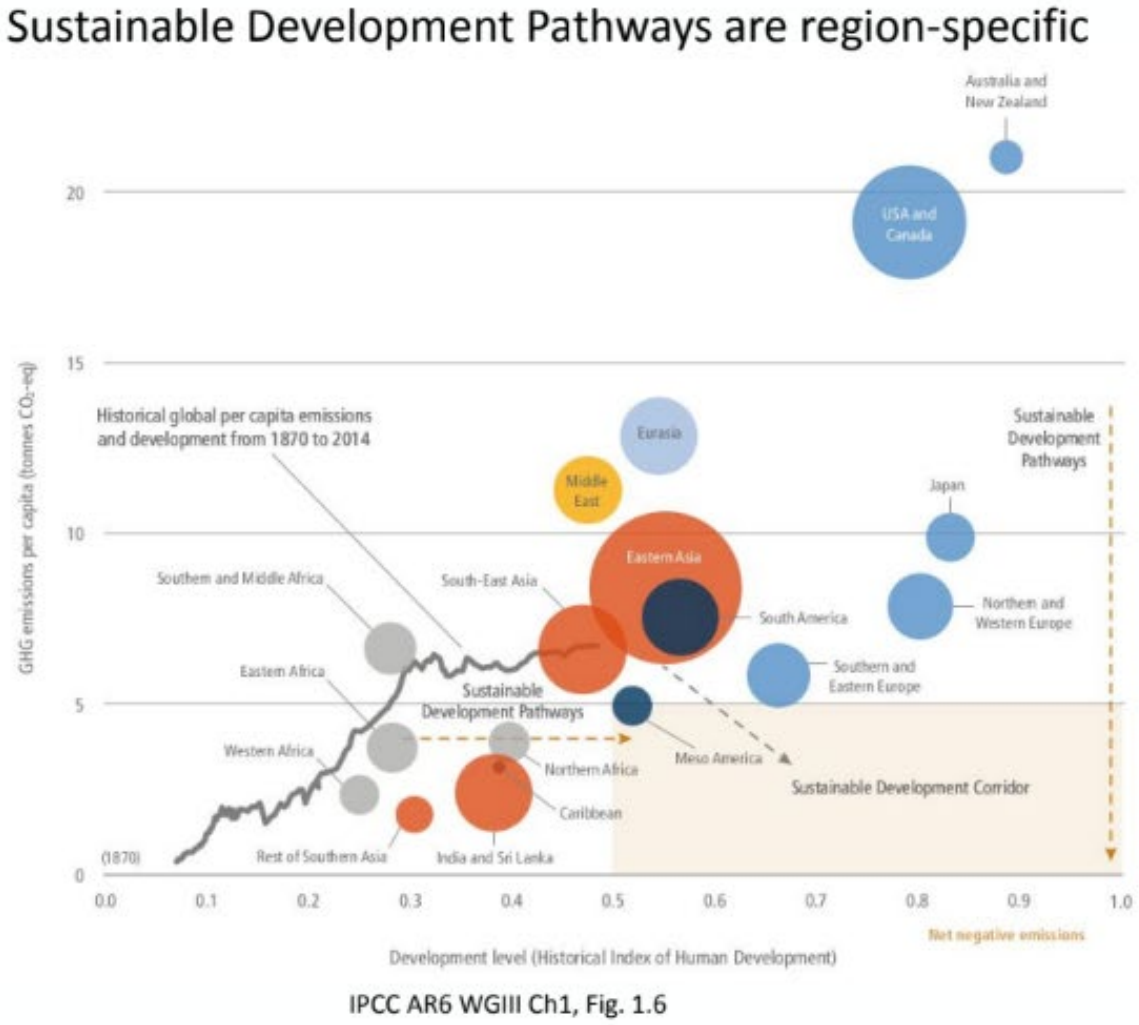
SDG interactions and IAM coverage

IAMs could coverage several interactions, but at the moment still more limited

Other tools also needed

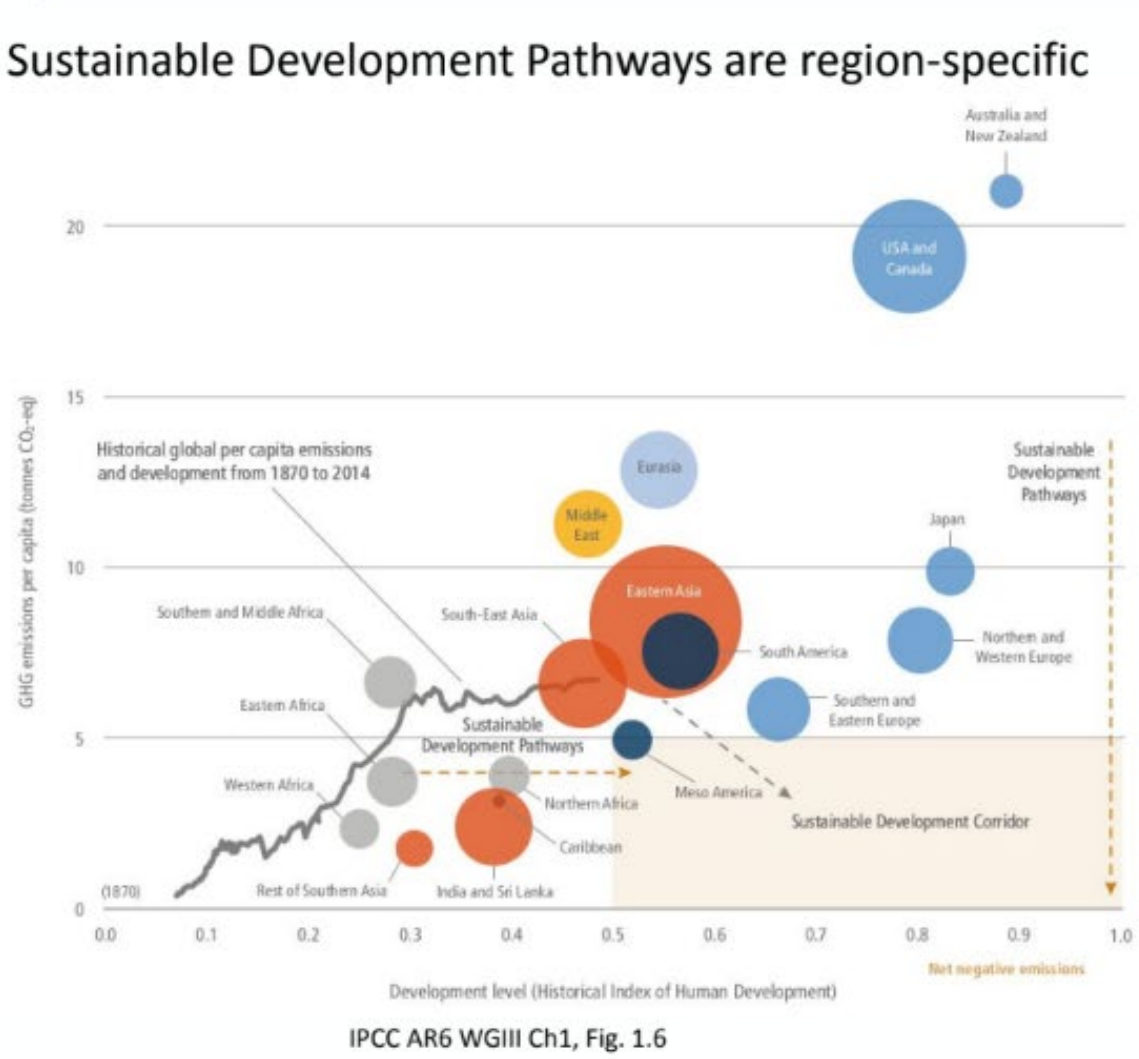
Van Soest et al.

Sustainable development pathways (SDPs)

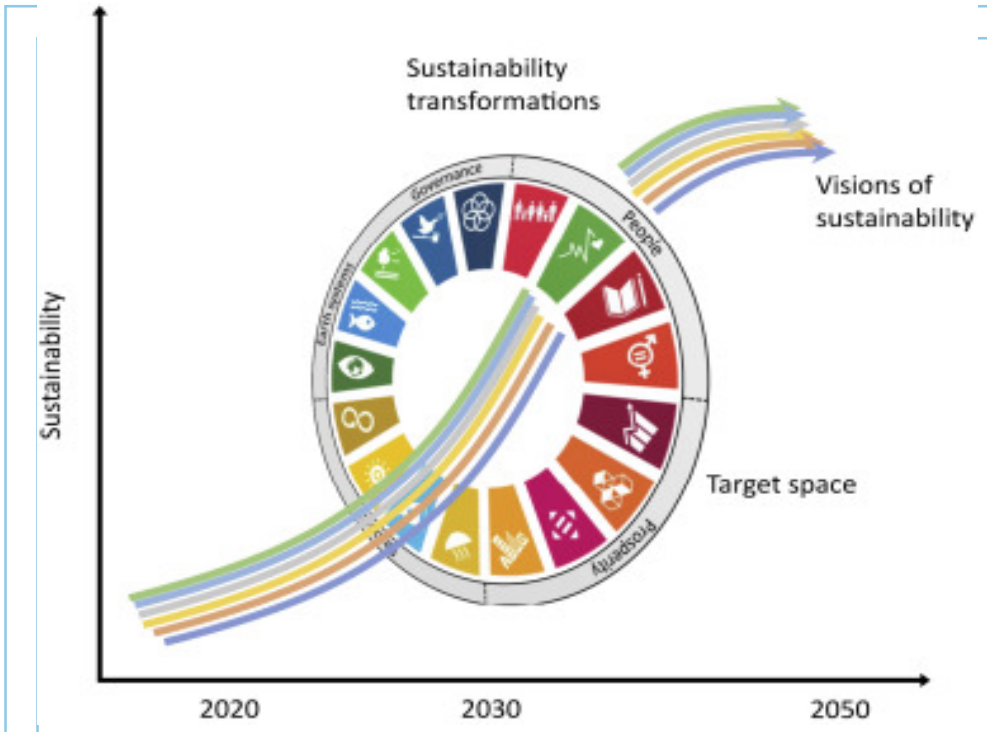


IPCC AR6 WGIII Ch1, Fig. 1.6

Sustainable development pathways (SDPs)



IPCC AR6 WGIII Ch1, Fig. 1.6



SDPs reach sustainability goals

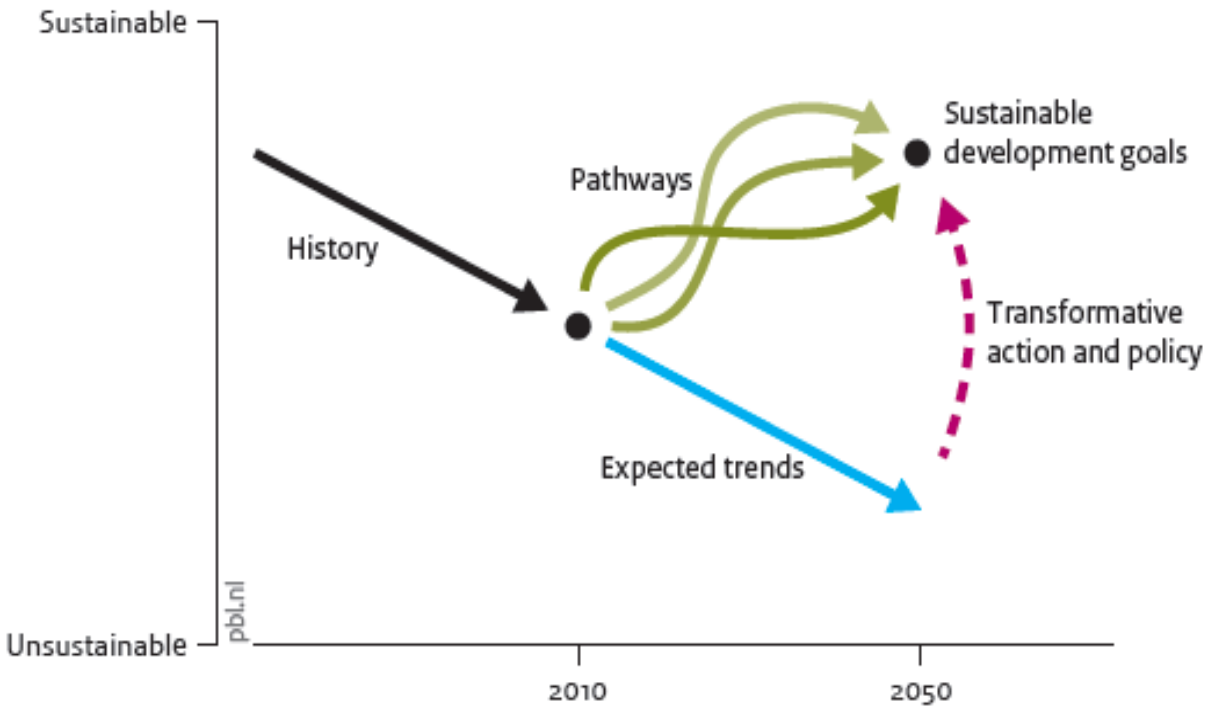
Explore different routes

Example:

Roads from Rio+20

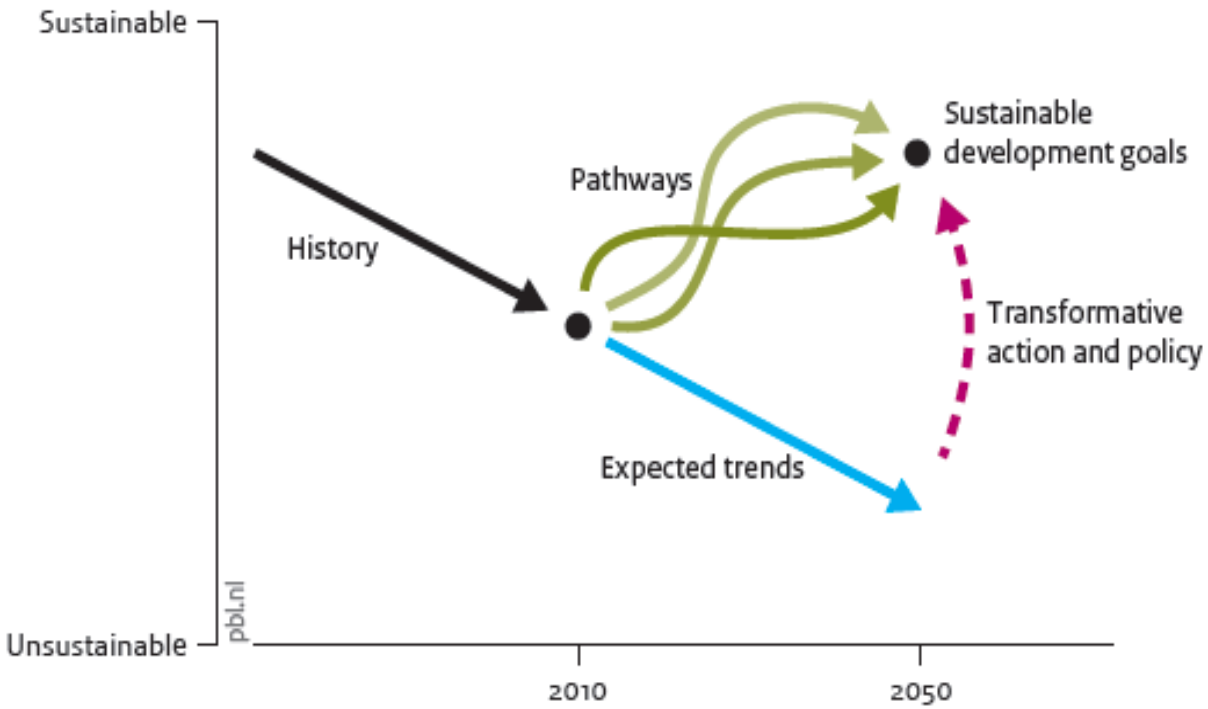
- Support for the Rio+20 conference
- How to achieve SD?

Roads from Rio



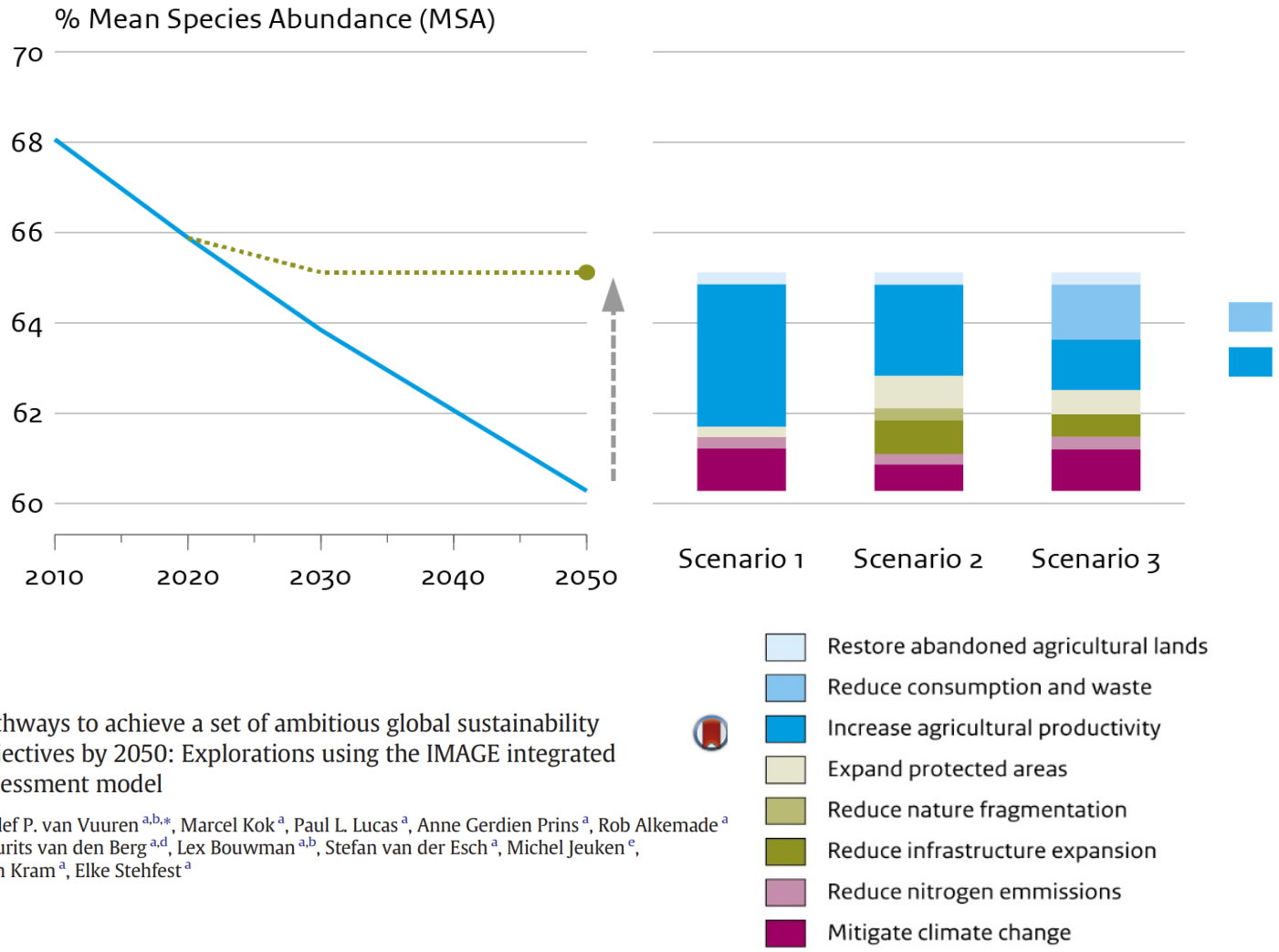
- Eradicating poverty:
  - Full access in 2050
    - modern energy,
    - food
    - water
    - Improve health
- Conserve Earth's ecosystem.
  - Climate change 2°C
  - Reduce air pollution to WHO guideline levels
  - Stop degradation of ecosystems
  - Reduce nitrogen unbalance
  - Reduce water stress

Roads from Rio+20



Pathway	Main assumptions
Global Technology	Large-scale, technologically optimal solutions; intesive agriculture, international coordination
Decentralised Solutions	Local energy production, multi-functional agriculture, local policies
Consumption change	Dietary change, less energy-intensive lifestyle, further pressure released through technology

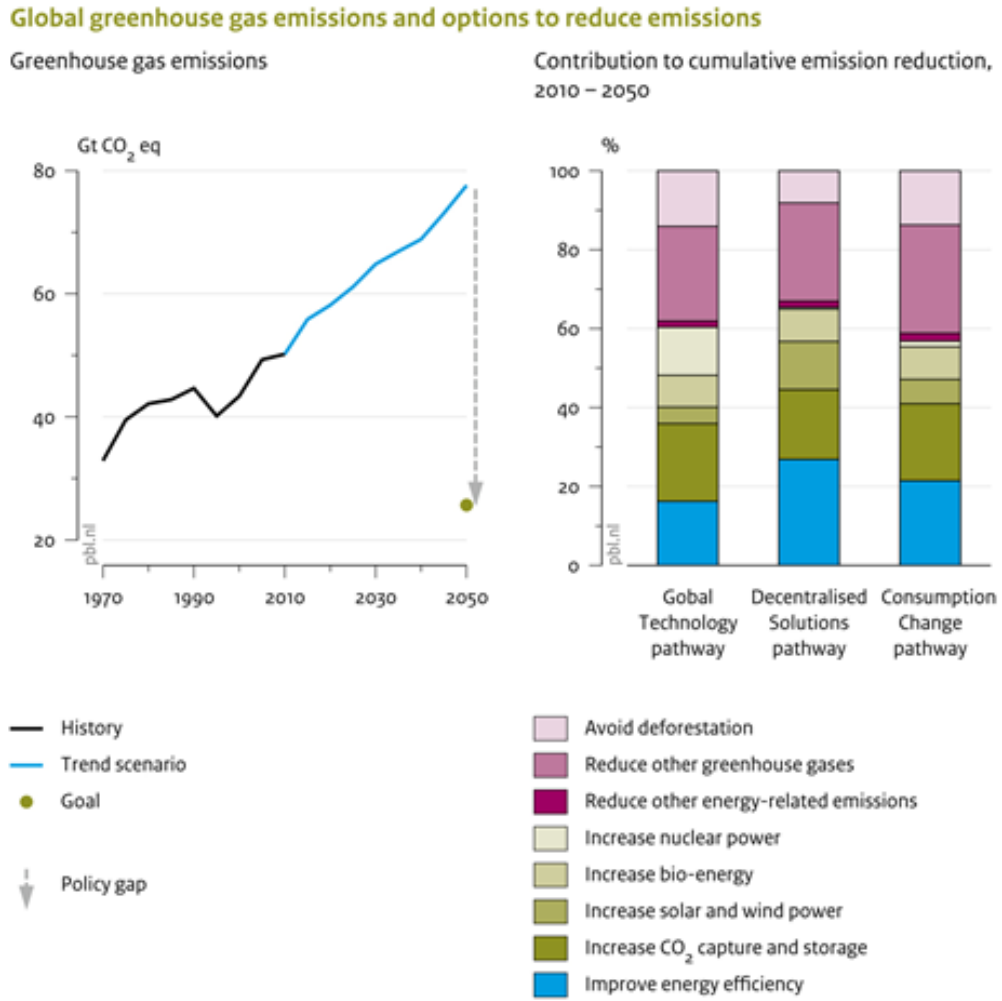
Biodiversity



Pathways to achieve a set of ambitious global sustainability objectives by 2050: Explorations using the IMAGE integrated assessment model

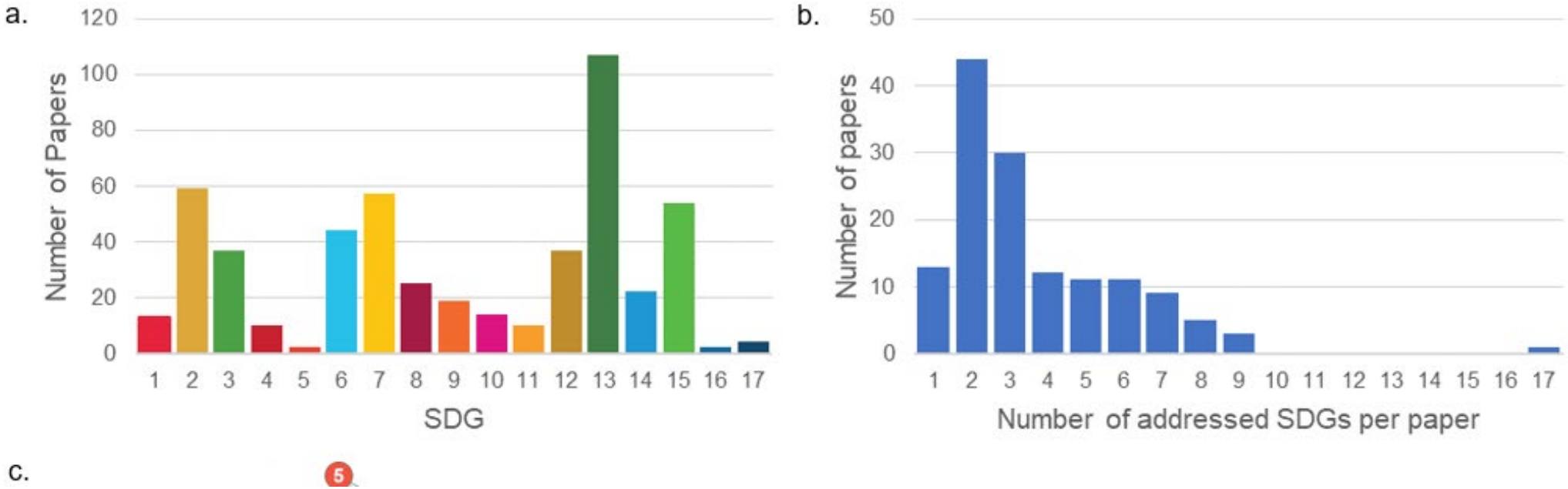
Detlef P. van Vuuren [a,b,*], Marcel Kok [a], Paul L. Lucas [a], Anne Gerdien Prins [a], Rob Alkemade [a] Maurits van den Berg [a,d], Lex Bouwman [a,b], Stefan van der Esch [a], Michel Jeuken [e], Tom Kram [a], Elke Stehfest [a]

Climate

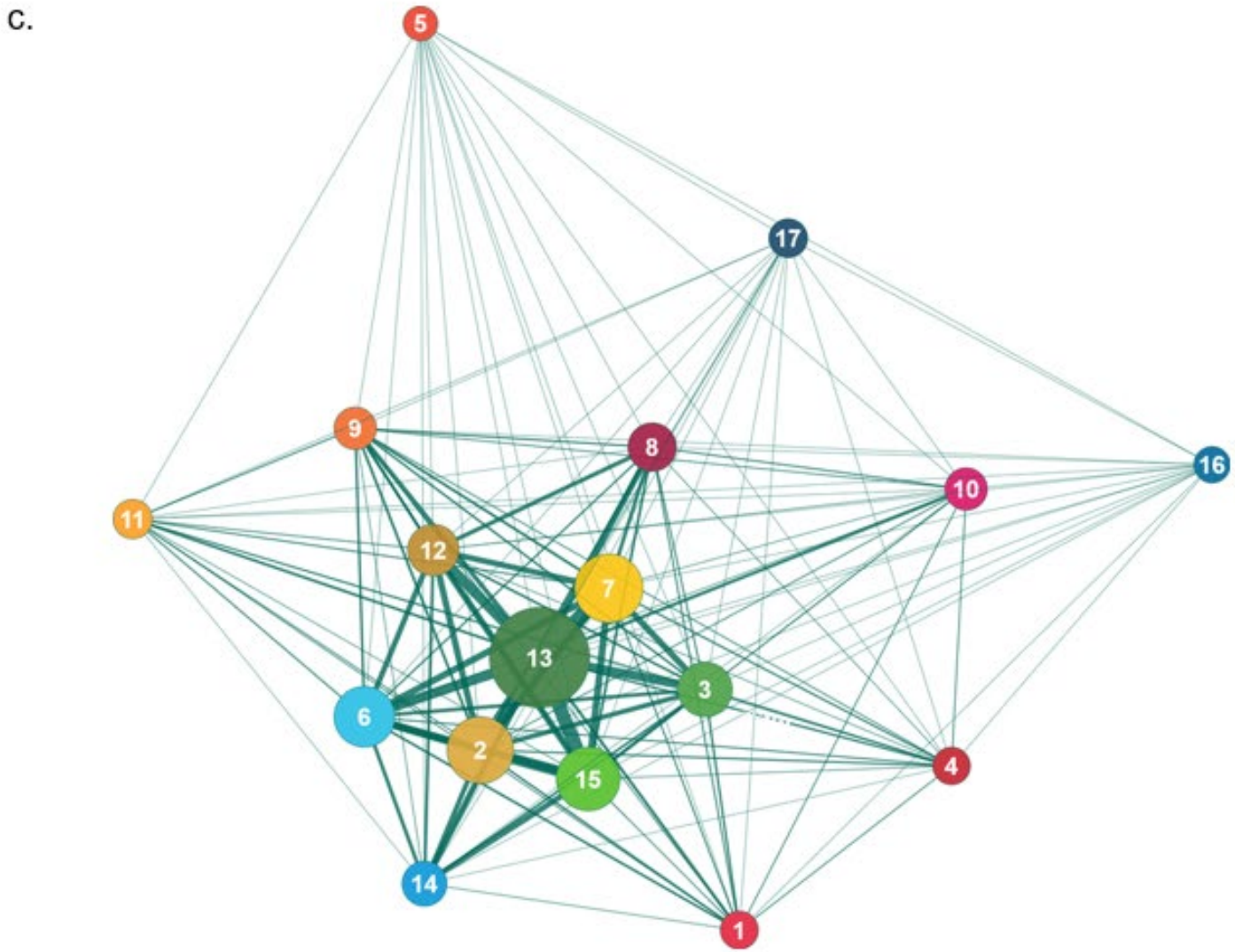


Literature on SDPs

140 SDG scenario papers in literature



Literature on SDPs

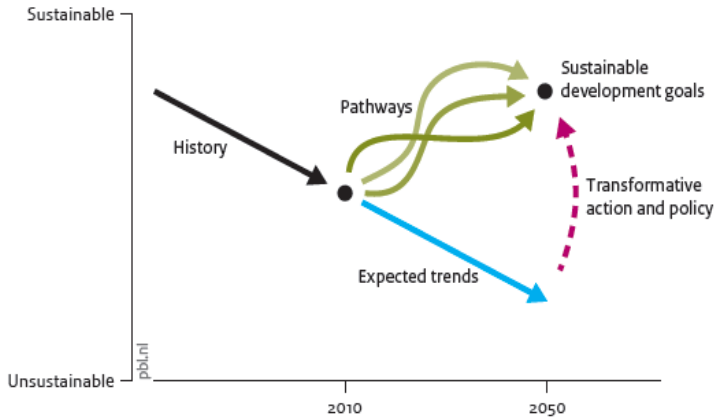


Literature on SDPs

Exemplary studies

- Hardly any study with target achievement for all SDGs
- Studies use mostly different indicators or target values
- Also quite different methods

Some form of community development needed



Study	Moallemi et al.[22]		Soergel et al.[10]		Moyer et al.[23]		Van Vuuren et al.[25]		Van Vuuren et al.[21]		Grubler et al.[15]		Randers et al.[24]	
Scenario	SSP1*		SDP (based on SSP1)		CC+DS+G		CC/DS/GT		SSP1*		LED		BAU	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S
SDG 1				1		1						3	2	
SDG 2		4 6 7 9 10 11 12		13		14		4 8 14 15		5 9		9	16	
SDG 3		17 18 19		20		15		20 21 22 23		22 23		21 22	17	
SDG 4		25 26 27		28		24							25	
SDG 5				31									32	
SDG 6				33		36 37		34 35 36					37	
SDG 7	38 39 40 41	42 43 44 45		46		46		47 48 49		38 45 47		38 50 51	48	
SDG 8		52 53		55									54	
SDG 9				56						57			58	
SDG 10				60									61	
SDG 11				62									62	
SDG 12		63 64 66		67				64 67 69		67		59	68	
SDG 13	71 72 73 74	75 76 78		74 78		73		74 77 78		74 75 78		75 82	78	
SDG 14				80									79	
SDG 15		81 82 83		84 85				83		81 82		81 82 86	87	
SDG 16				88 89									90	
SDG 17				91									92	

Recent activities

IPCC-AR6

SHAPE

SDG-MIP

IPCC AR6

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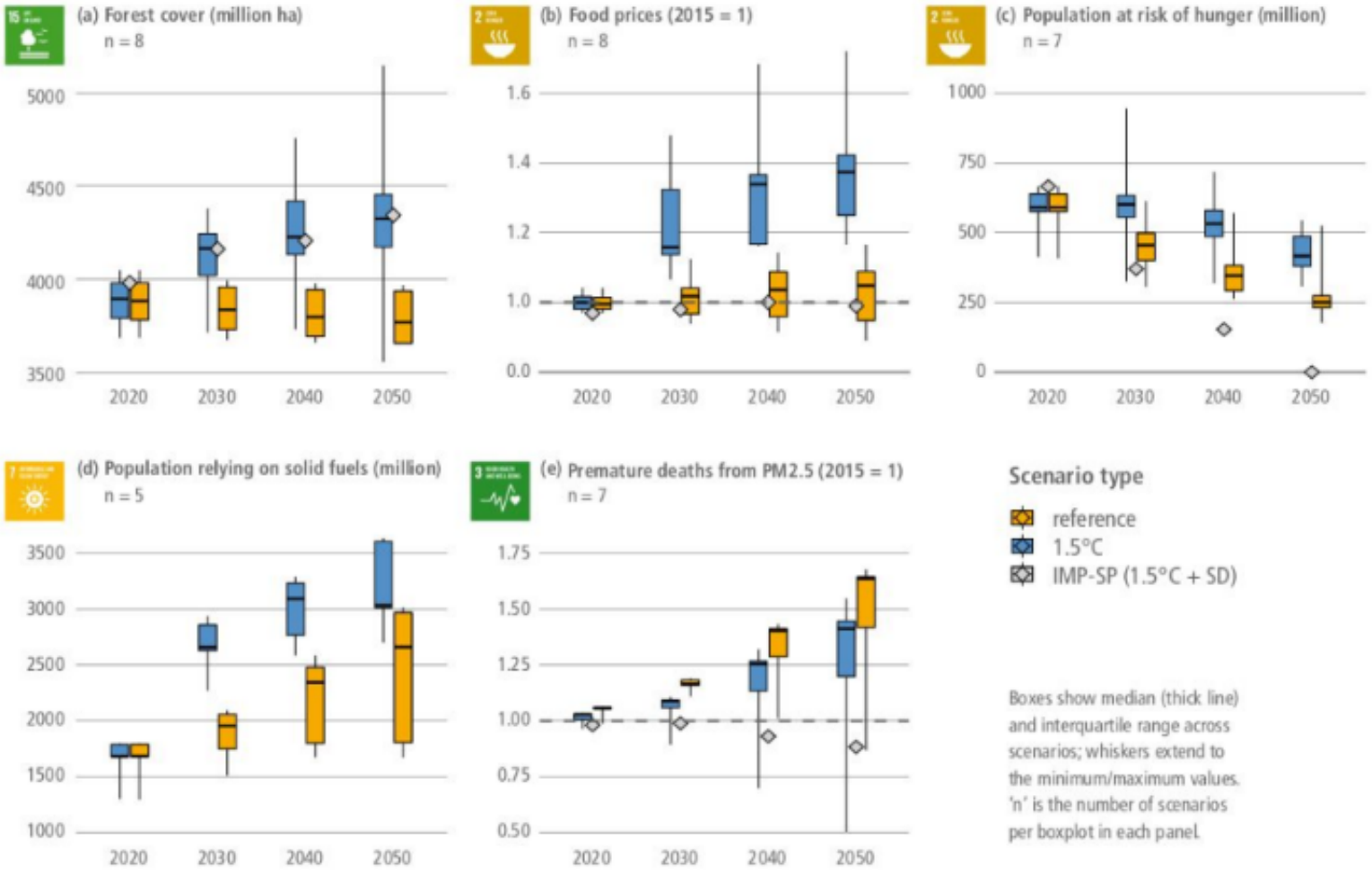
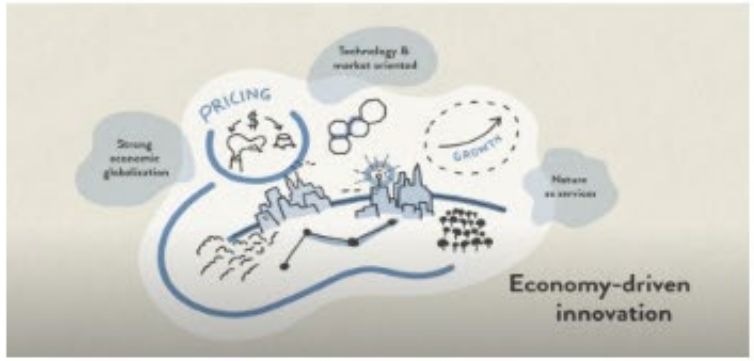


- AR6-DB: rather limited availability of SDG indicators for most scenarios
- with available indicators: multi-(model,scenario,indicator) analysis of **mitigation-SDG interactions**
- **Illustrative Mitigation Pathway *"Shifting Pathways"*** (IMP-SP) links climate action with SDGs
- Key insight: **Targeted SD policies can boost co-benefits of mitigation policies, and compensate for adverse side effects**

SHAPE SD narratives

reflecting different perspectives on how to pursue SD



Illustrations by Elsa Wikander / Azote

Economy-driven Innovation (EI)

- Technology, innovation and efficiency
- Continued economic growth
- Pricing (e.g. carbon, biodiversity loss, …) as important policy instrument

Resilient Communities (RC)

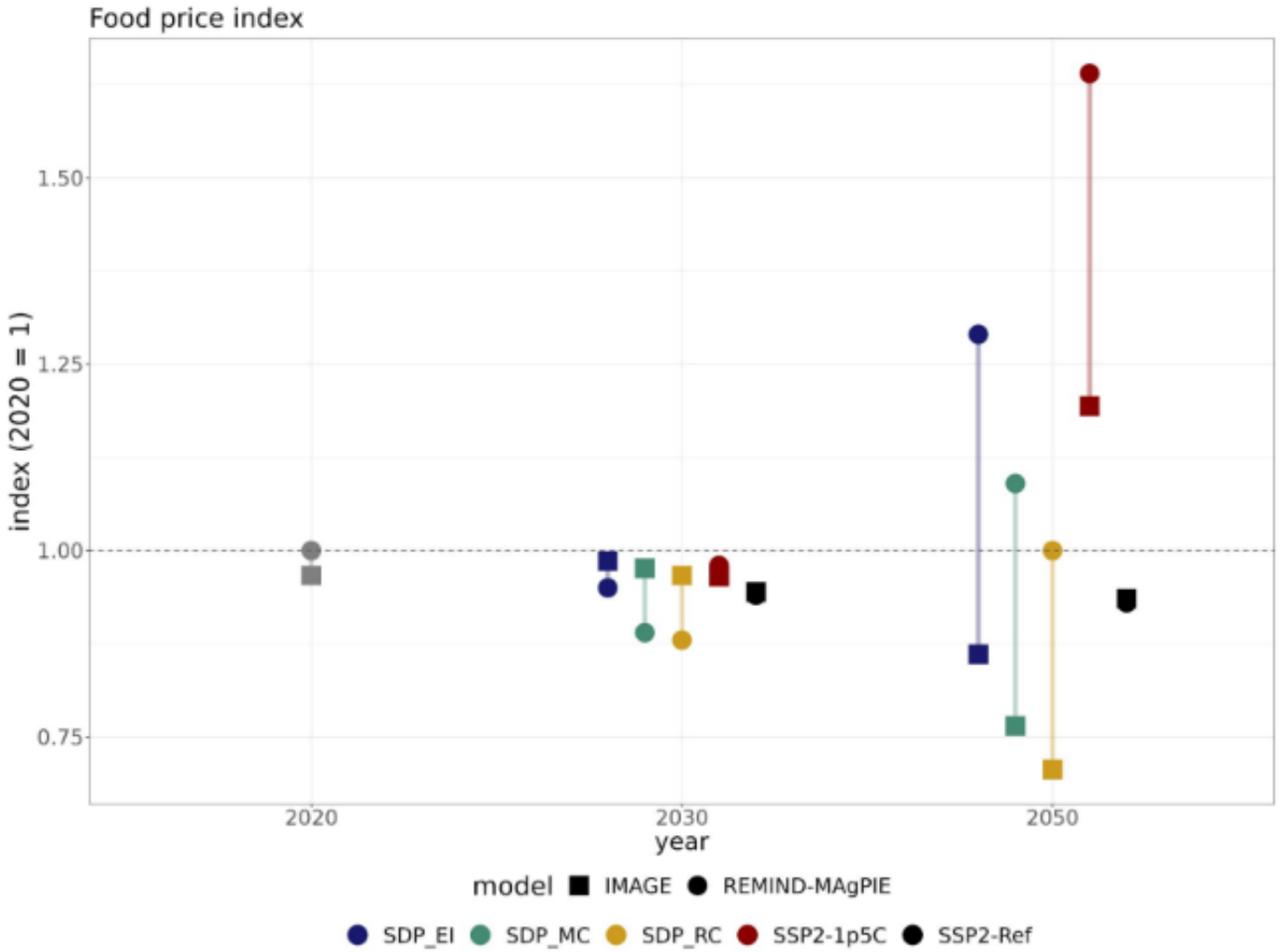
- Solidarity, well-being, equitable sharing of resources
- Post-growth (in high-income countries)
- Lifestyle change, low material consumption patterns

Managing the Global Commons (MC)

- Strong international & national institutions
- Moderate economic growth, orientation towards human services
- Strong regulatory policies

Food security

Food price index



- ***"Climate-only"*** scenario: increased food prices (pricing of agr. emissions & land competition)
  -> trade-off climate vs. food security

- **SDPs scenarios:** Additional SD interventions **reduce/avoid food price increase**

- RC: Strongest **dietary change** and food waste reduction lead to lower food prices
  -> synergy with food security

NAVIGATE

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Climate policy

2.6 W/m^2 target

SDG measures

Food	Heathy (EAT-Lancet) diet, reduce food waste
Water	Efficiency improvements, environmental flow constraints, piped water access, wastewater treatment
Energy	Maximized electrification, phase-out traditional bio, cooling gap
Life on land	Protected natural land (>30%)

Based on: Doelman et al. 2022, MESSAGE-ACCESS, Van Vuuren et al., 2019, Parkinson et al., 2019, Frank et al., 2021, Hasegawa et al., 2015, Pastor et al., 2019

Climate impacts

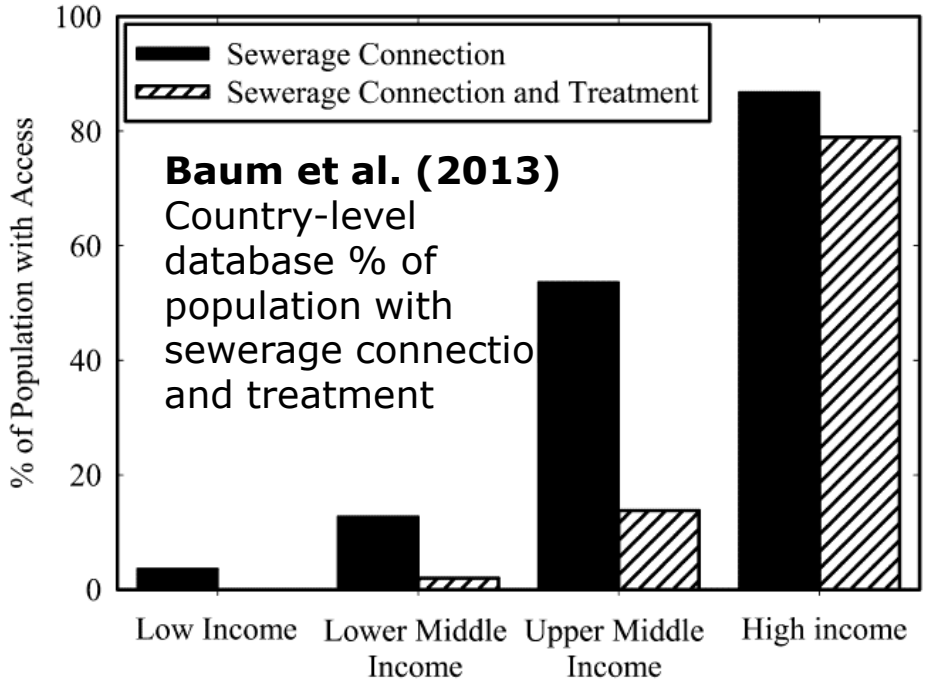
RCP 2.6, 6.0

- Hydrology: Precipitation pattern/runoff, groundwater intensity
- Crop Yield changes
- Renewable energy
- Cooling/heating demand
- Desalination potential
- Power plant cooling capacity

Based on: *ISIMIP 2b (Frieler et al. 2017),Byers et al., 2018, Gernaat et al., 2021 etc.)*

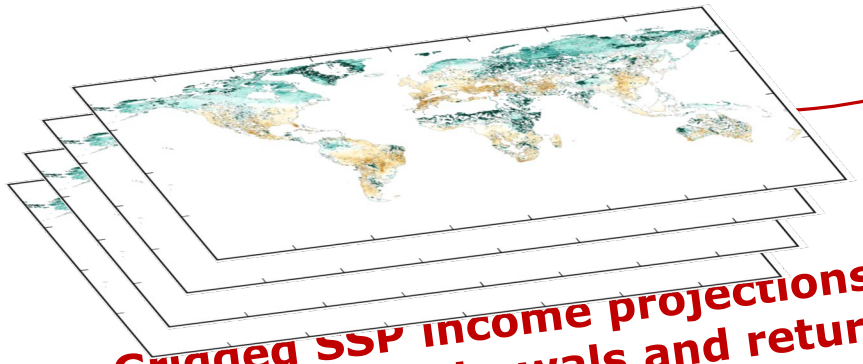
NAVIGATE

Projecting infrastructure demand under clean water goals

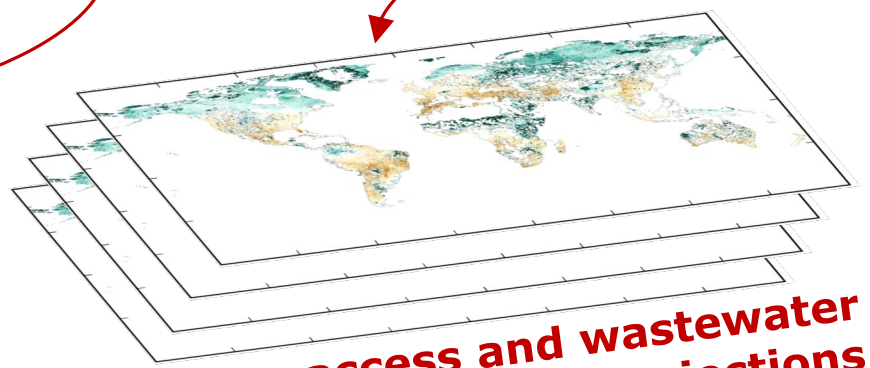


% connected / treated is a function of income-level and historical level

F(....)



Gridded SSP income projections, municipal withdrawals and return flows

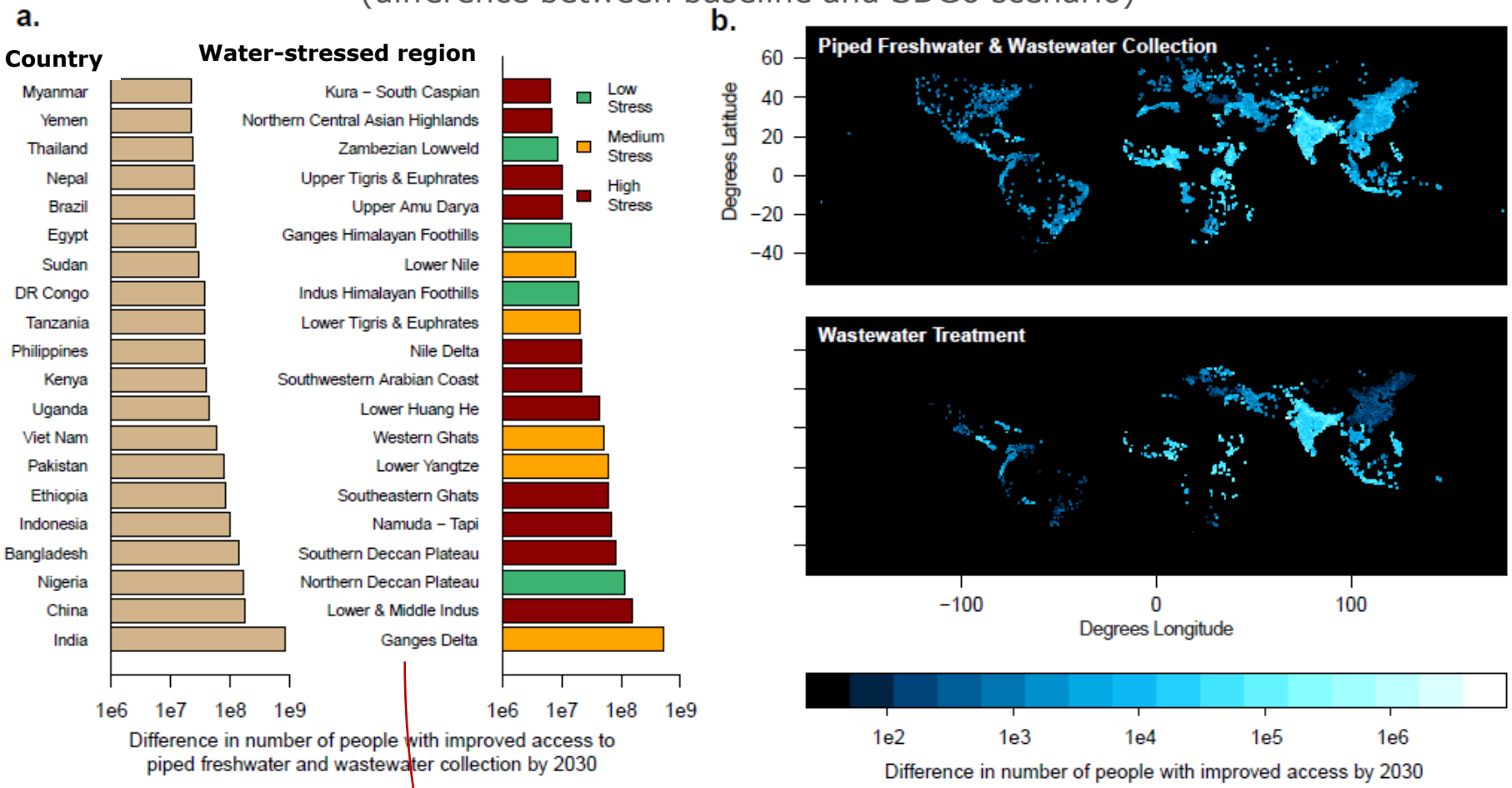


Gridded piped water access and wastewater treatment and recycling projections

Source: IIASA

Projecting infrastructure demand under clean water goals

(difference between baseline and SDG6 scenario)



Water-stressed regions need to find alternative sources of freshwater supply to meet increasing demands!

Source: IIASA

SDG-MIP

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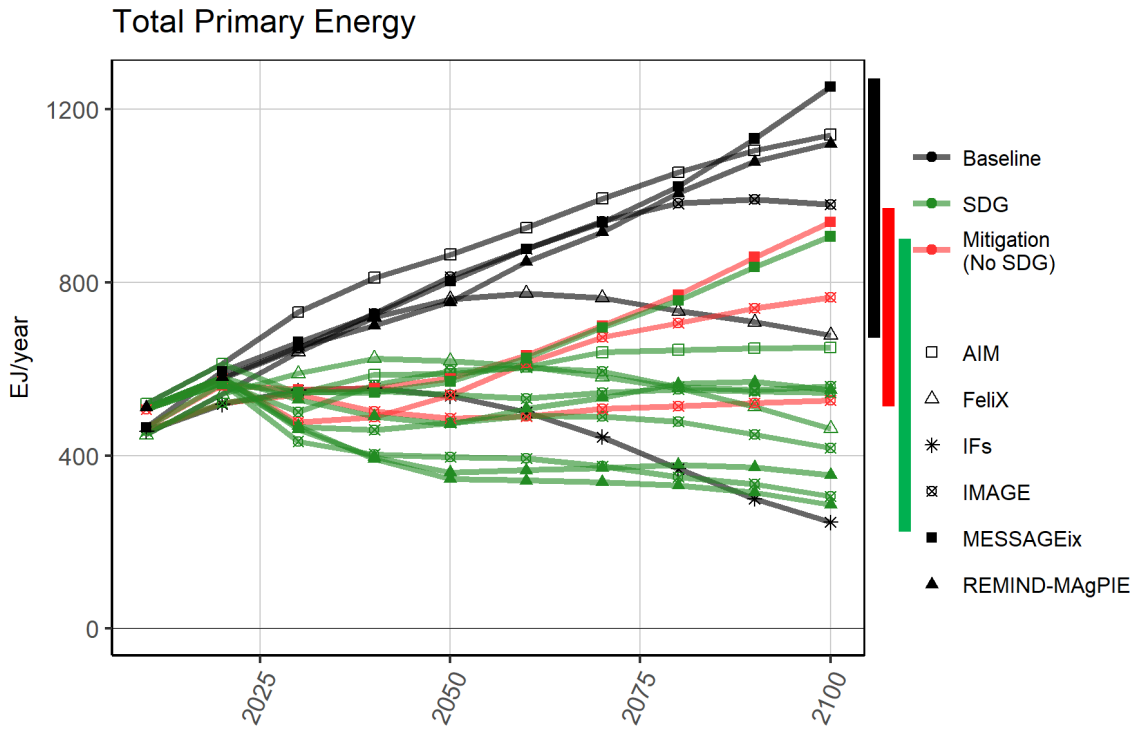
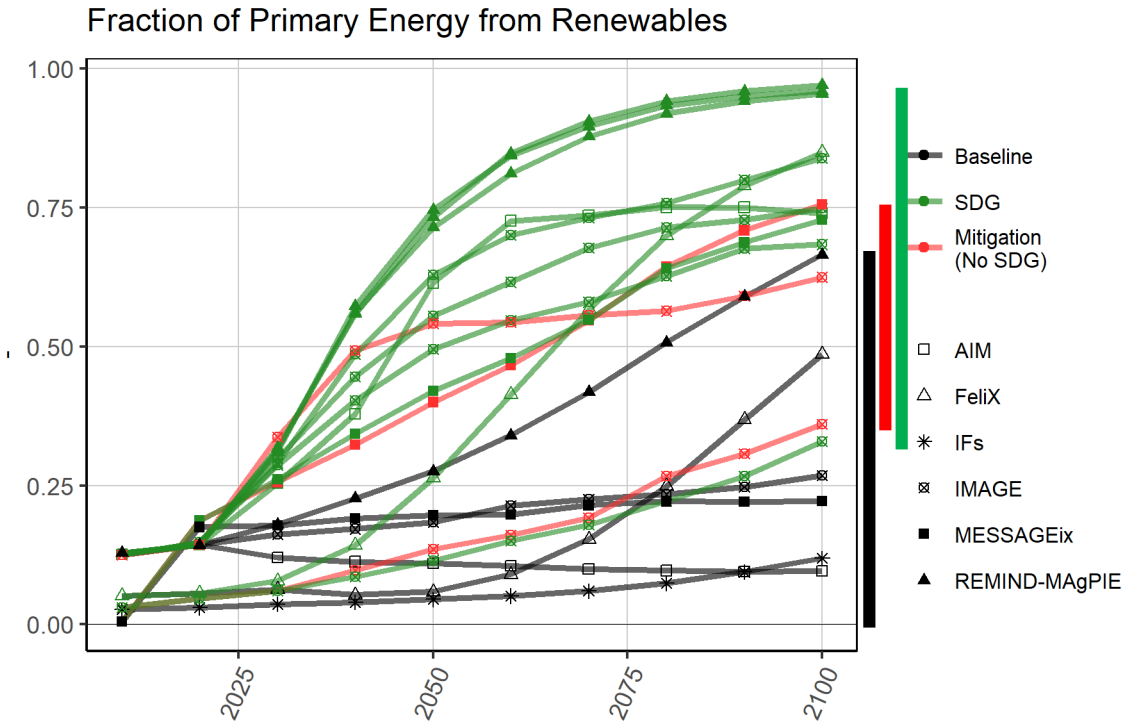
Observations

- **Baseline** relatively close in all models
- **SDG**/**Mitigation** shows much lower energy demand, and **SDG** below **Mitigation**.
- Use of renewables also (generally) highest in **SDG**
  - *One IMAGE scenario adopts high fossil-CCS*





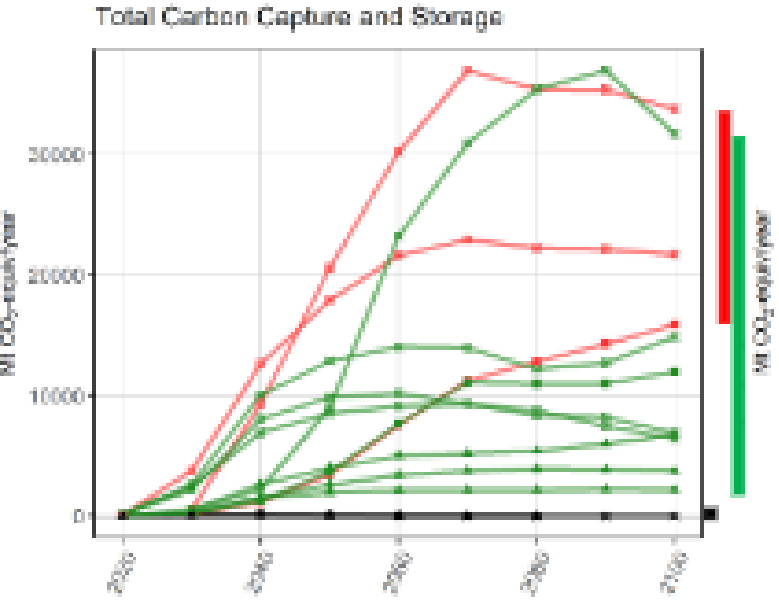
Carbon Removal

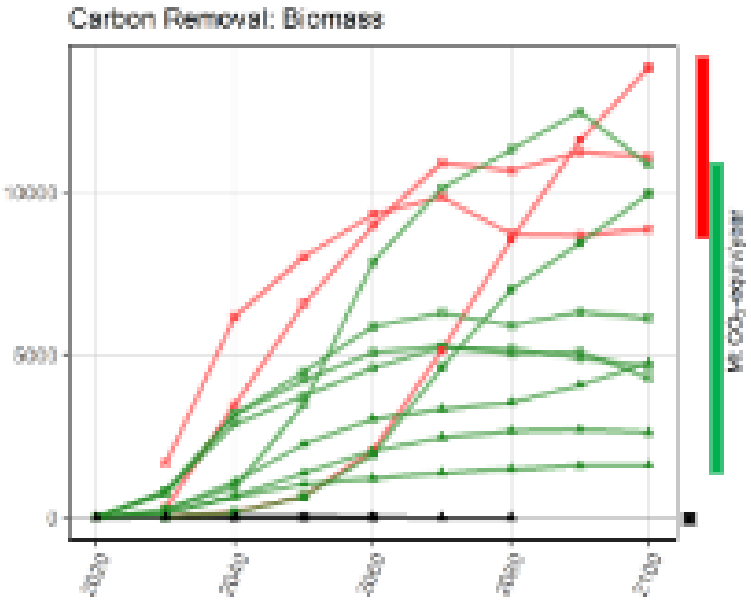
PBL Netherlands Environmental Assessment Agency

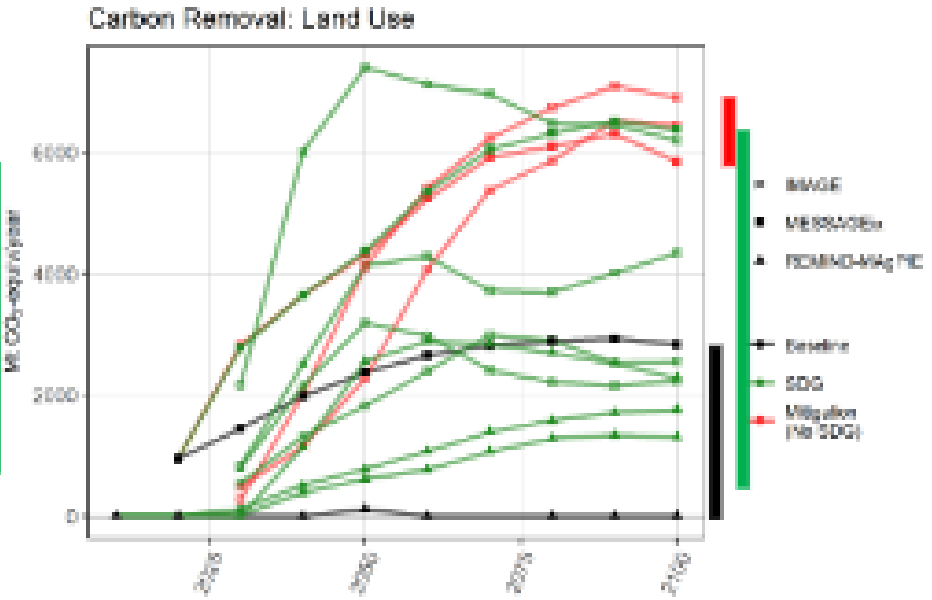
13 CLIMATE ACTION

Observations

- Generally lower CCS in **SDG** scenarios
  - *Lower dependence on BECCS and AFOLU CDR*



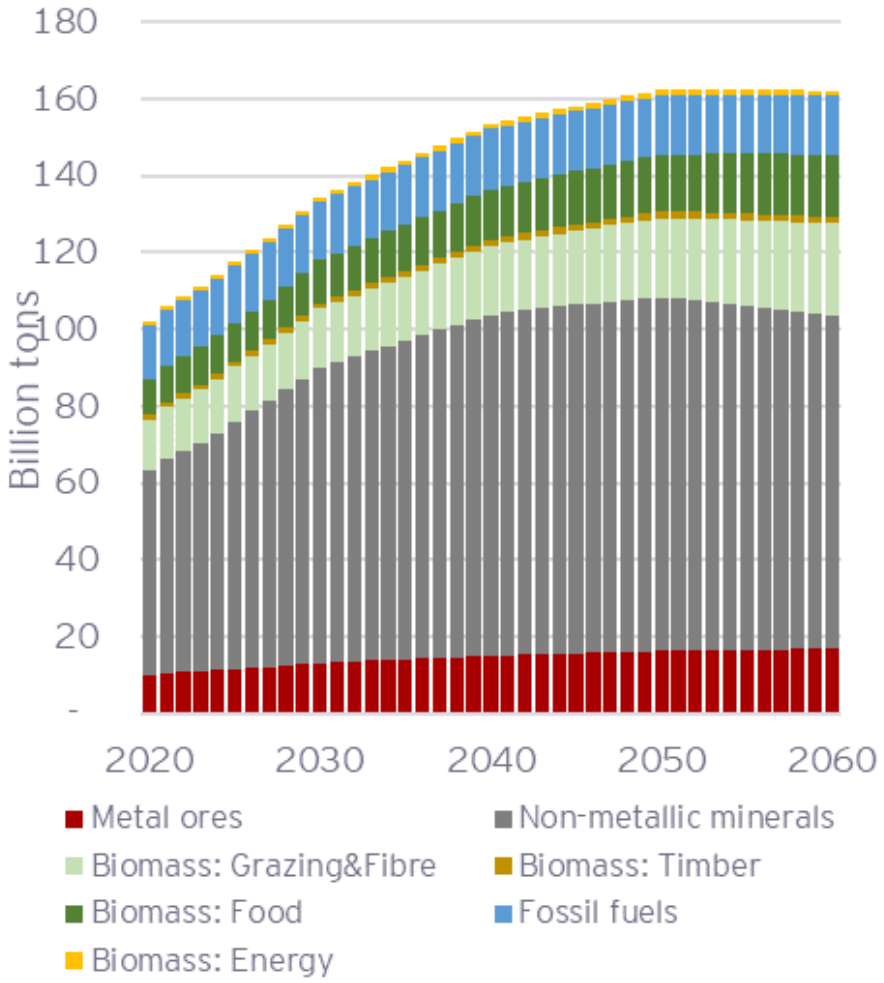




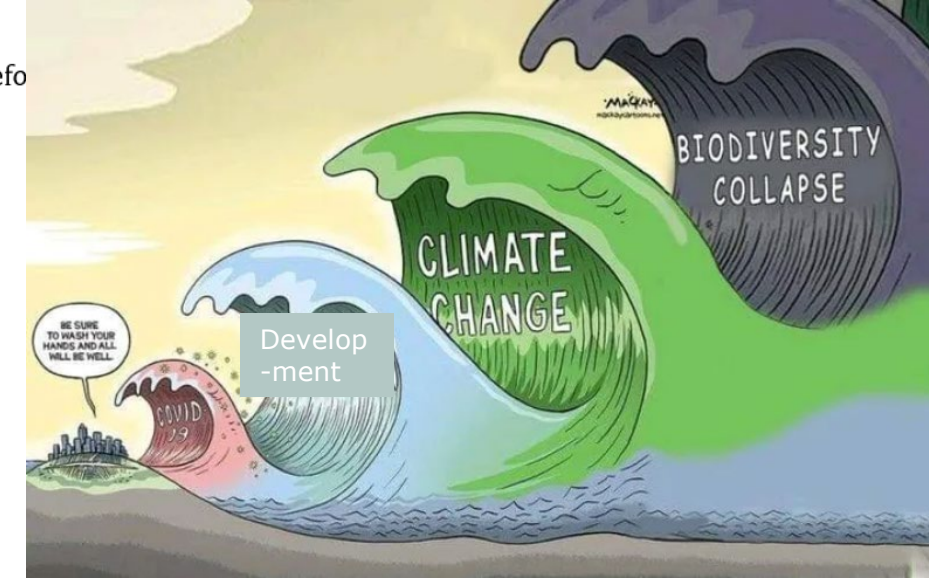
Climate solutions will only work if perceived fair

- Development perceived more urgent… so joint agenda needed.

2. Circular economy

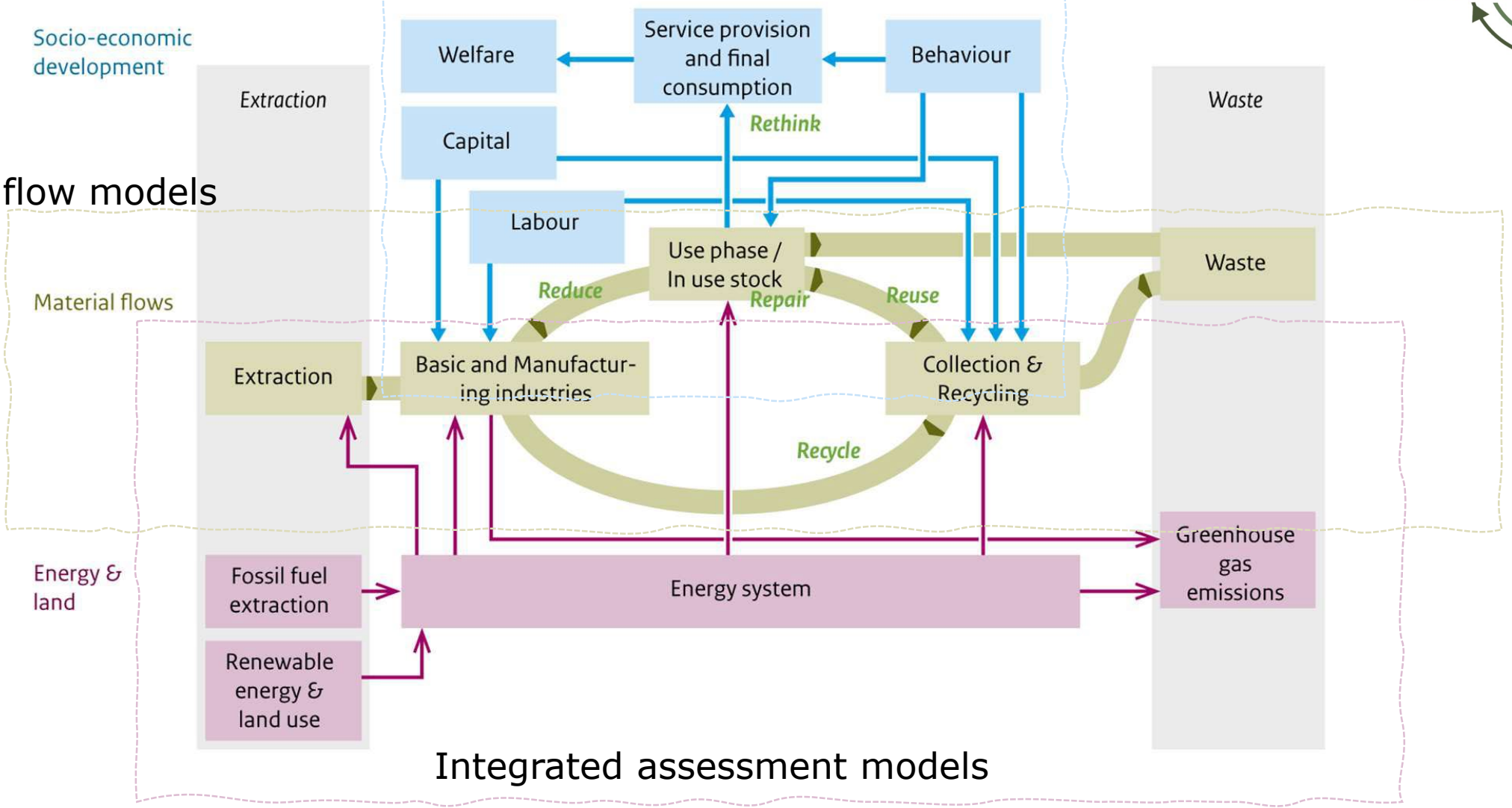


Pollution
Resource depletion
Energy use



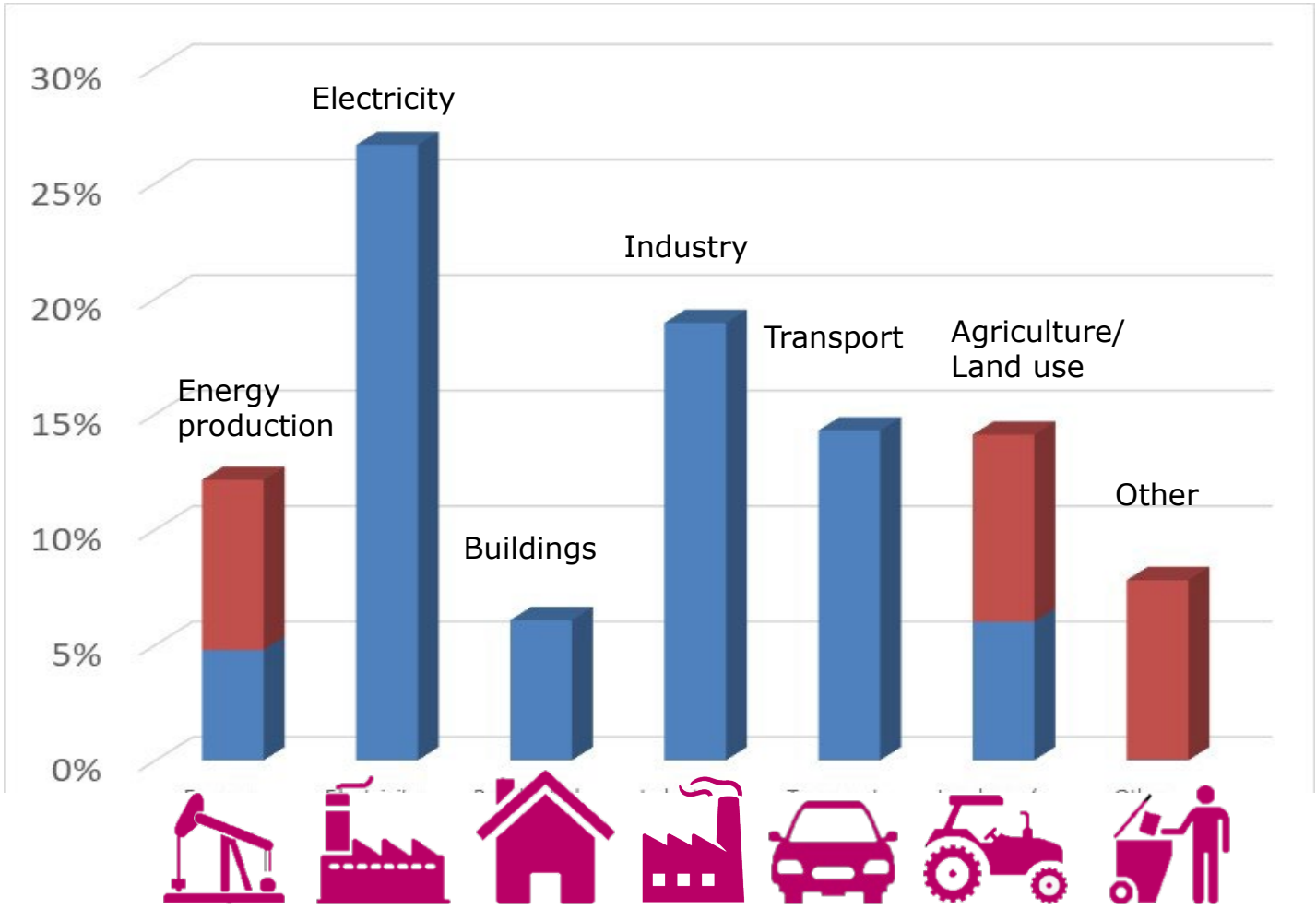
Macro-economic models

Material flow models

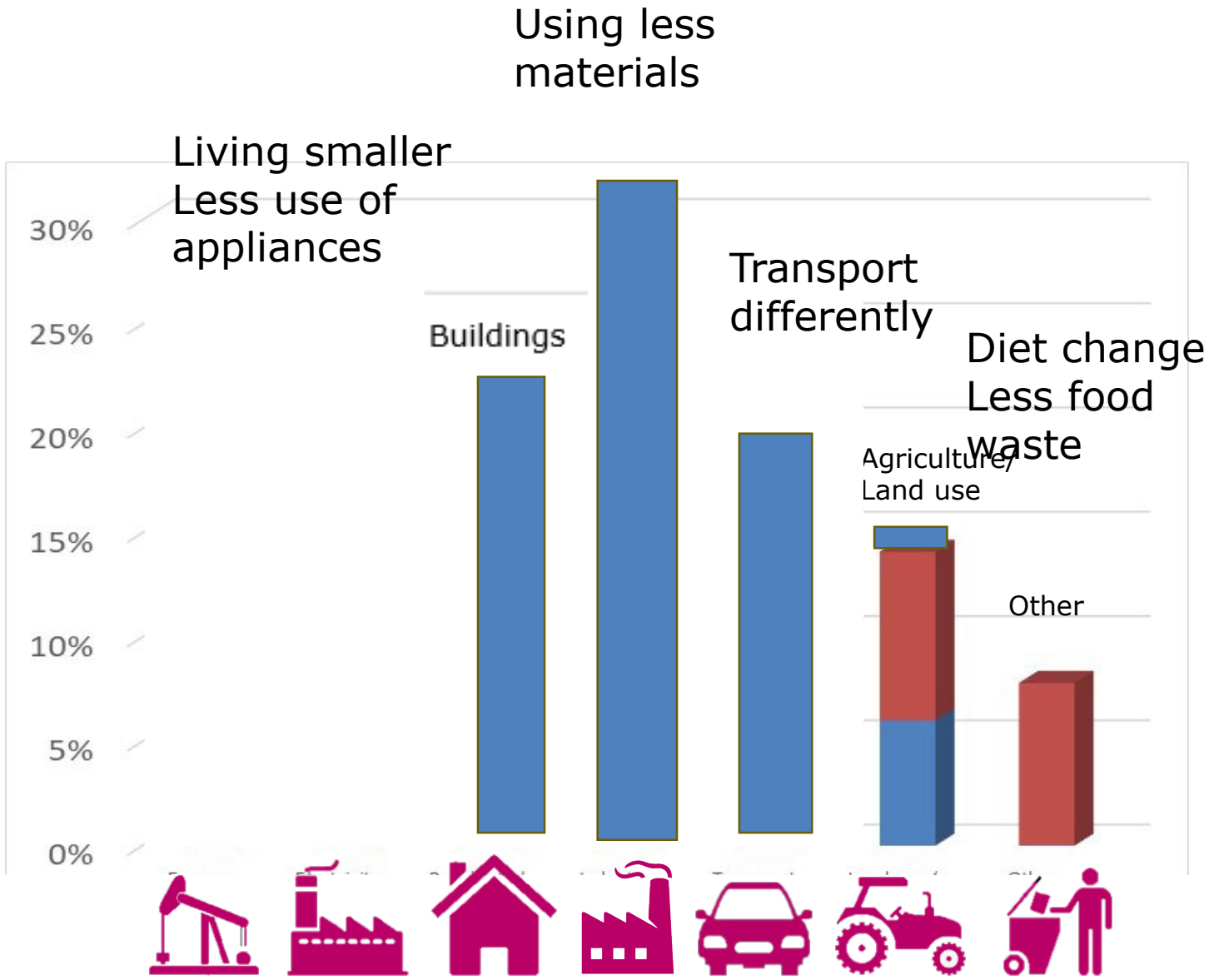


Integrated assessment models

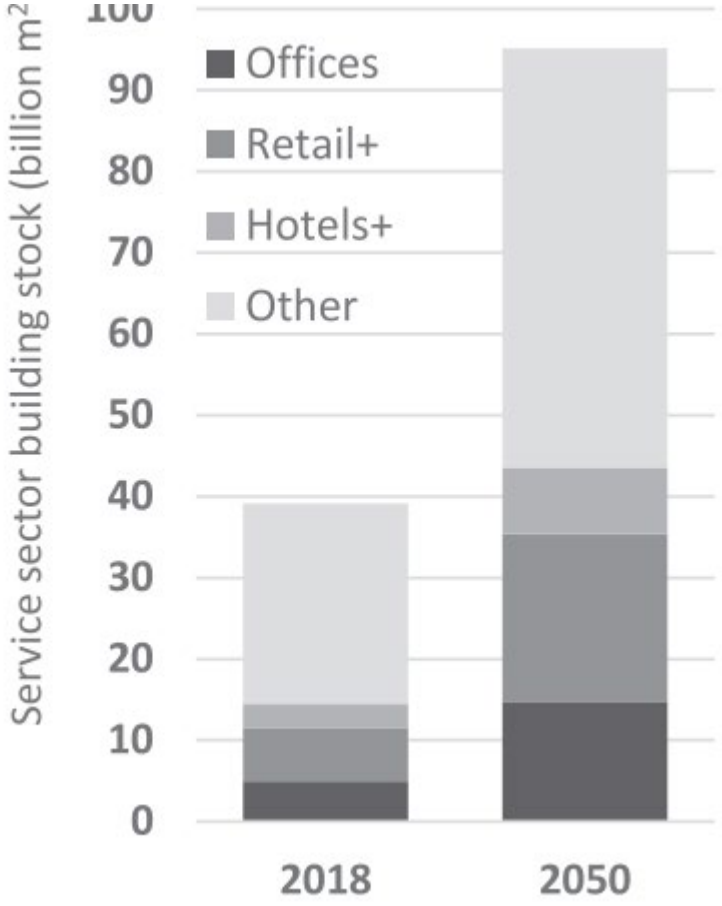
Green-house gas emissions

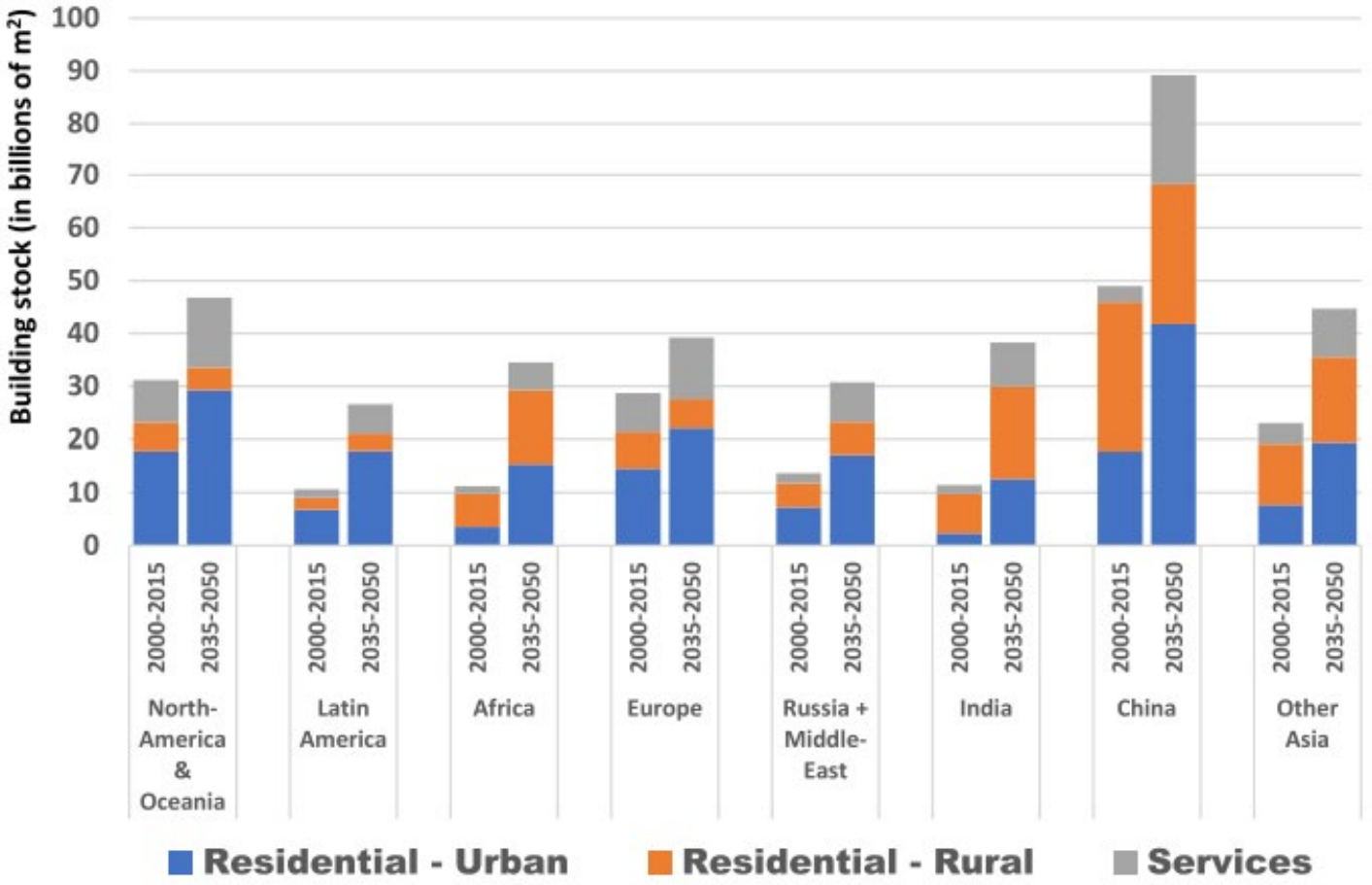


Green-house gas emissions

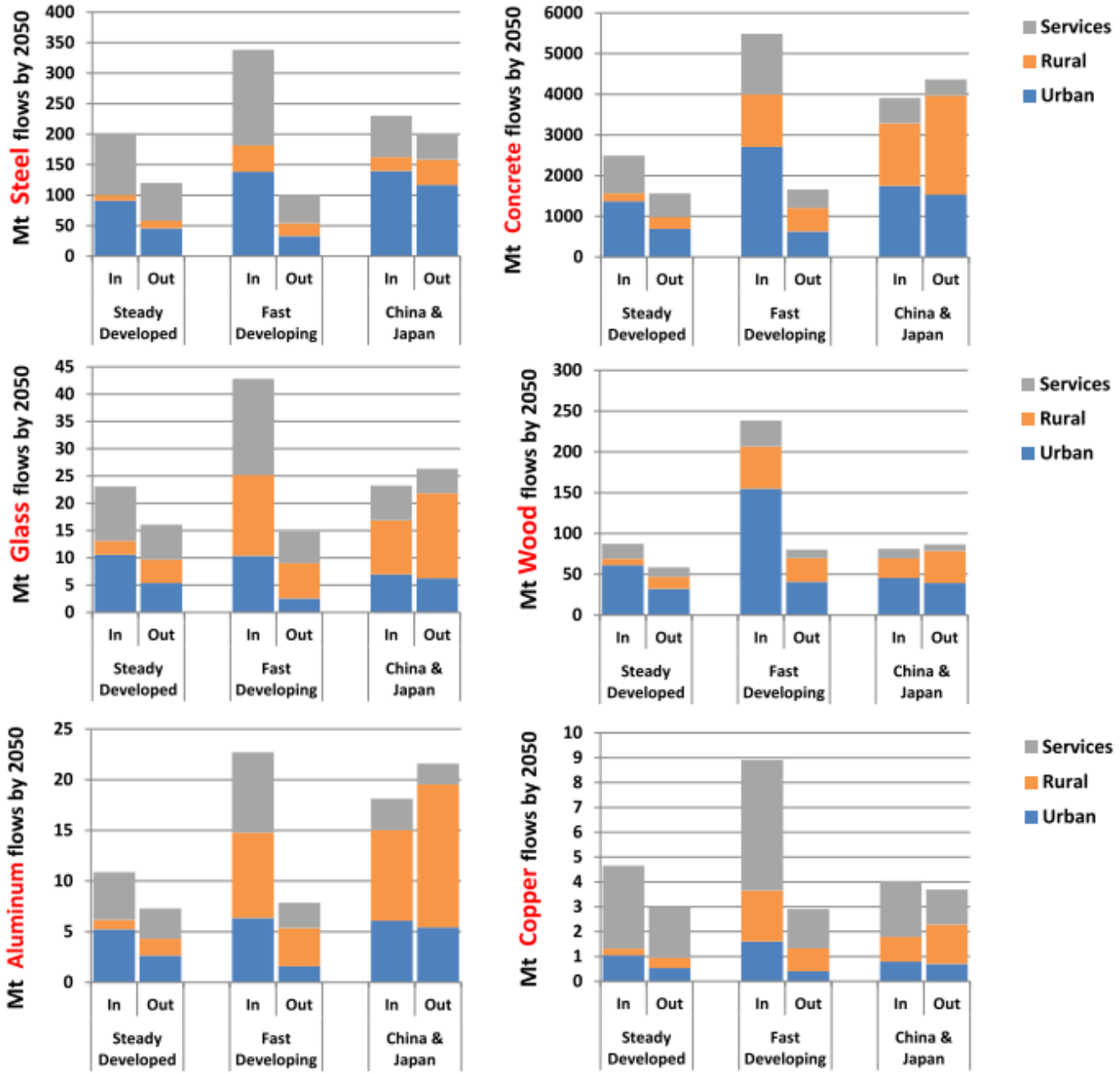


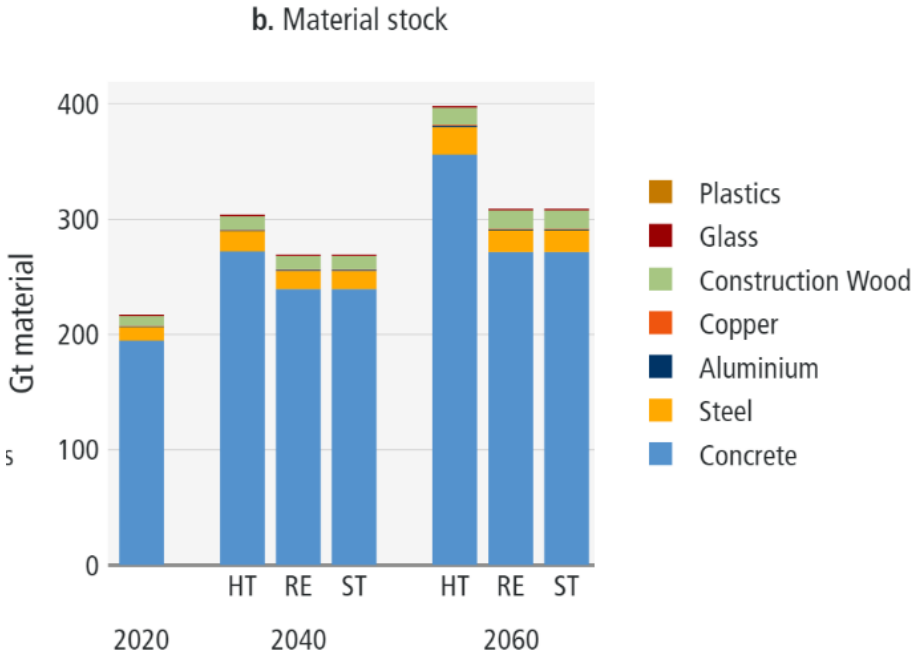
Building stock



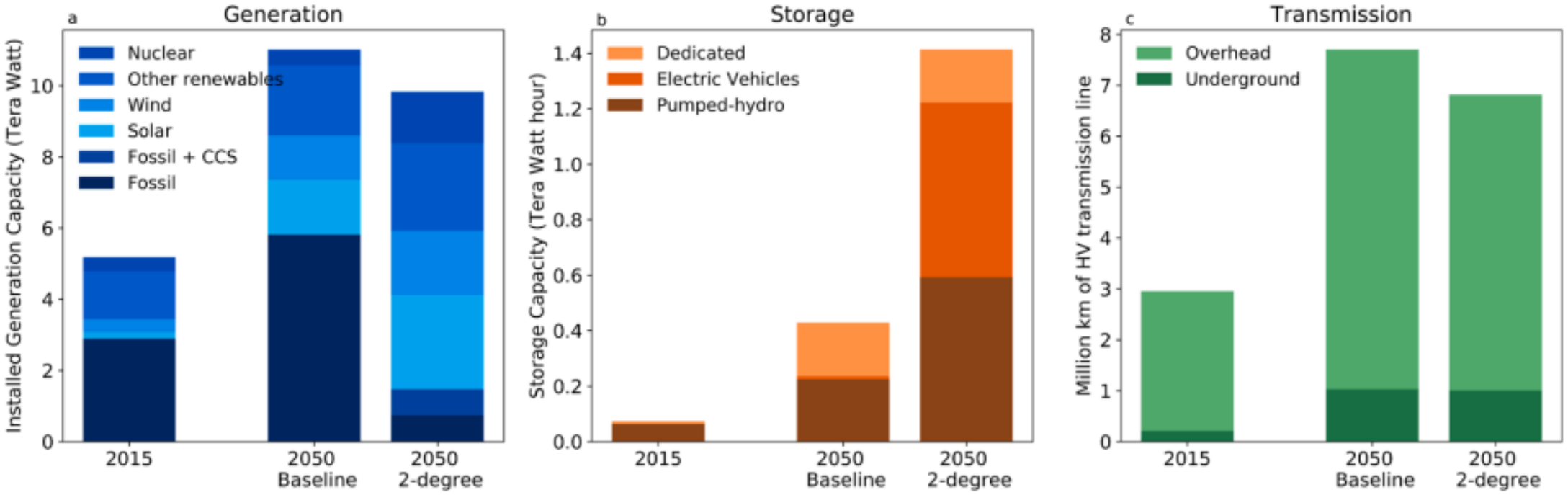


Building stock

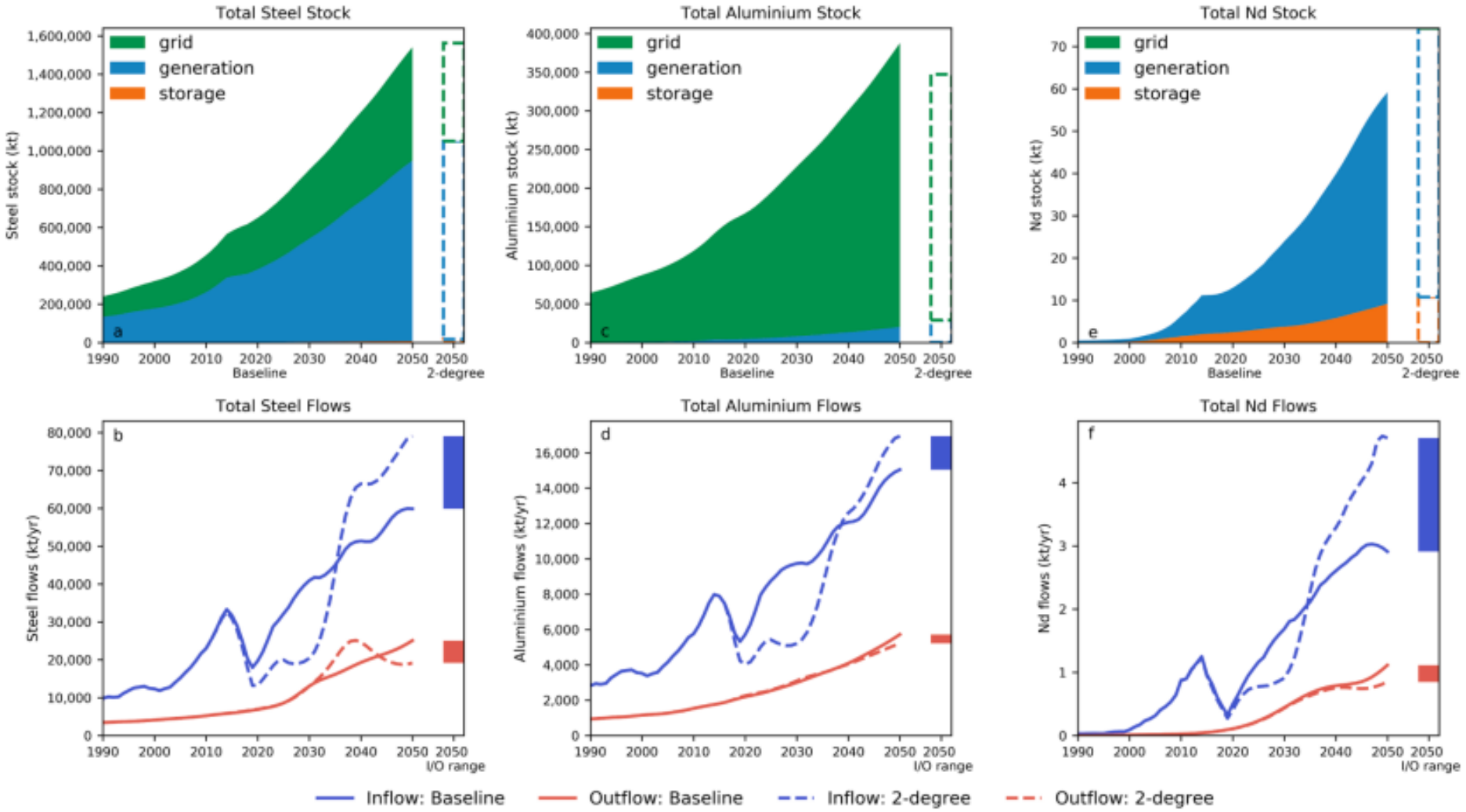




Material consequences of the energy transition

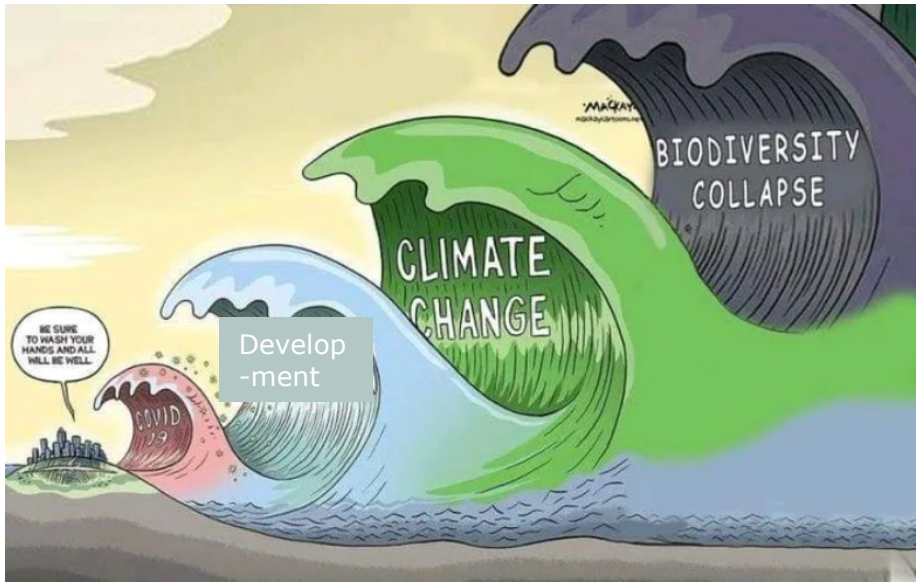


Material consequences of the energy transition



	2015					2050 Baseline					2050 2-degree				
	Stock	Inflow	Outfl.	O/I	CP	Stock	Inflow	Outfl.	O/I	CP	Stock	Inflow	Outfl.	O/I	CP
	Mt	**kt/yr**	**kt/yr**	**%**	**%**	**Mt**	**kt/yr**	**kt/yr**	**%**	**%**	**Mt**	**kt/yr**	**kt/yr**	**%**	**%**
Steel	521	28,787	5,608	19%	1.8%	1,456	58,546	23,288	40%	3.8%	1,413	75,130	19,133	25%	4.8%
Aluminium	132	7,029	1,676	24%	14.7%	365	14,427	5,270	37%	30%	319	16,095	4,924	31%	34%
Concrete	4,772	184,782	31,173	17%	.69%	9,199	207,895	100,068	48%	.77%	8,396	227,571	85,347	38%	.85%
Glass	3	209	35	17%	.3%	23	1,257	255	20%	2%	41	2,662	263	10%	4%
Cu	38	2,086	571	27%	11.9%	98	4,256	1,828	43%	24%	91	4,934	1,611	33%	28%
Nd	0.009	1.0	0.04	3%	5.4%	0.055	3	1	32%	16%	0.064	4.4	0.8	18%	24%
Co	0.19	8	2.1	25%	7.9%	0.44	14	7	49%	13%	0.11	3.7	3.9	104%	3.4%
Pb	2.5	109	34	31%	2.1%	12.6	588	118	20%	11%	11.5	718	116	16%	15%

3. Biodiversity



Shifting to biodiversity

Planbureau voor de Leefomgeving

Economic activity

Population

Infrastructure

Goods

Energy system

Food system

Nitrogen deposition

Fragmentation

Pollution

Overexploitation/hunting

Disturbance

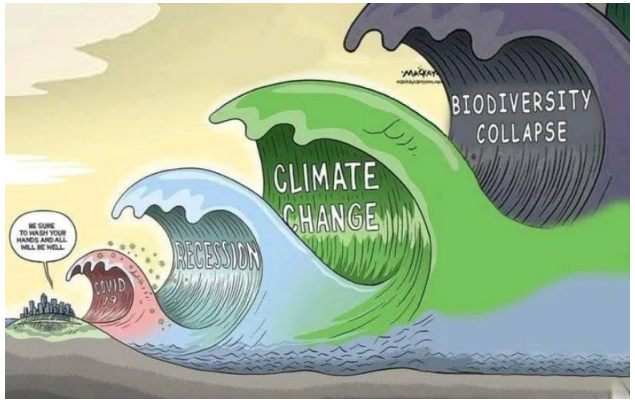
Climate change

Biodiversity change

CDR

Land use change

More food



Bending the curve (biodiversity)

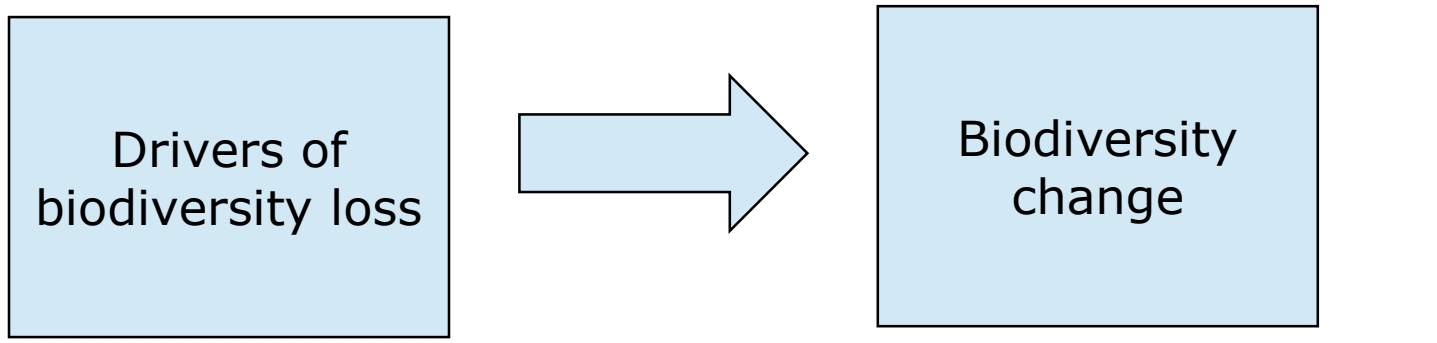
Planbureau voor de Leefomgeving

Bending the curve of terrestrial biodiversity needs an integrated strategy

David Leclère, Michael Obersteiner, ... Lucy Young + Show authors

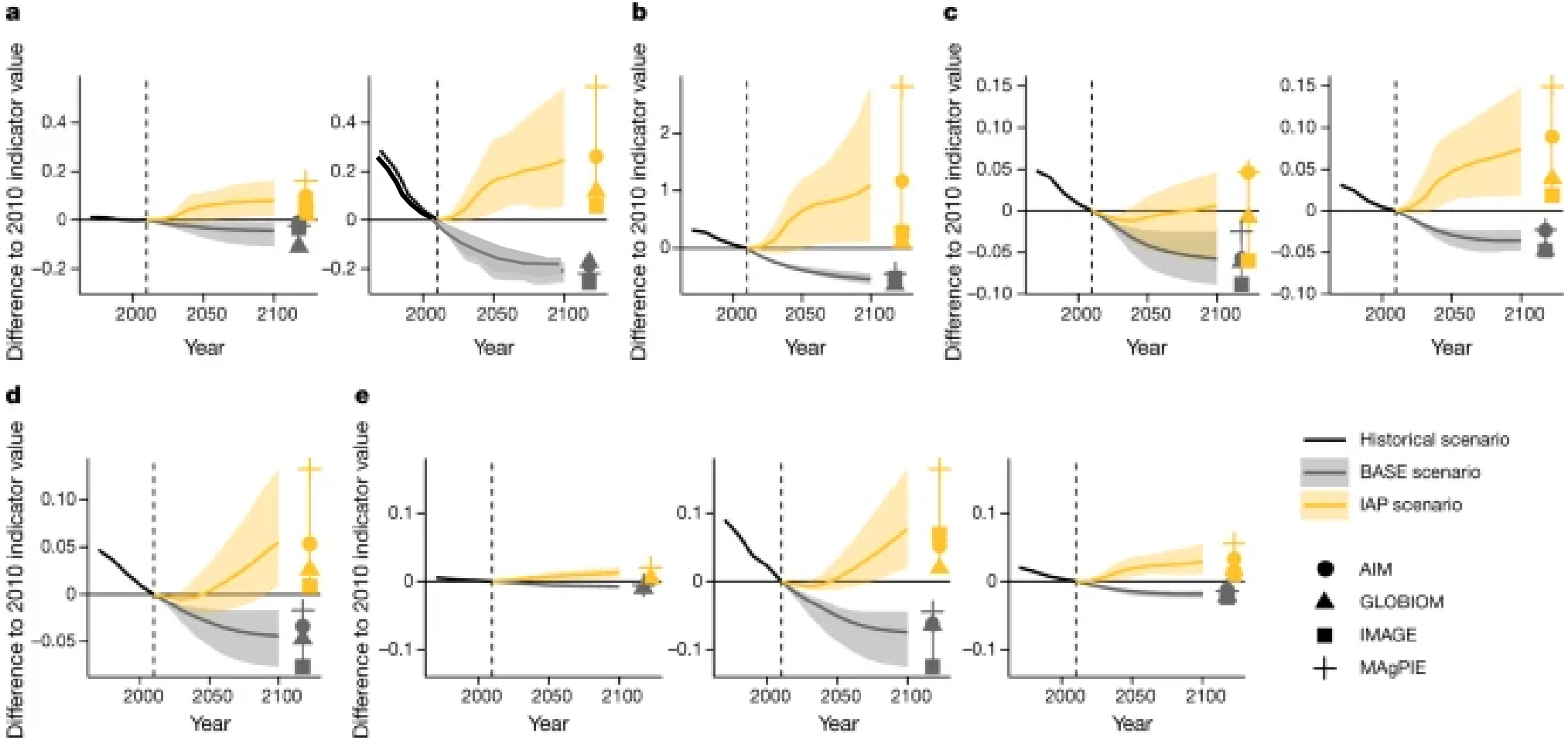
Nature **585**, 551–556 (2020) | Cite this article

How could strategies to achieve ambitious climate goals look like?



- Four integrated assessment models (IMAGE, AIM, GLOBIOM,MagPIE), describing future land use

- Eight biodiversity models


a
b
c
d
e
Difference to 2010 indicator value
Year
2000
2050
2100
Historical scenario
BASE scenario
IAP scenario
AIM
GLOBIOM
IMAGE
MAgPIE

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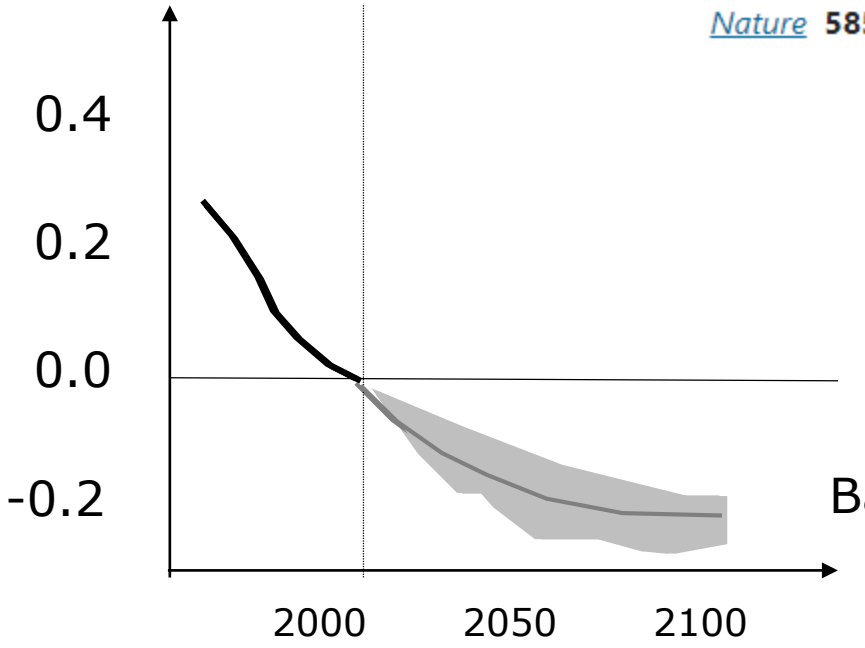
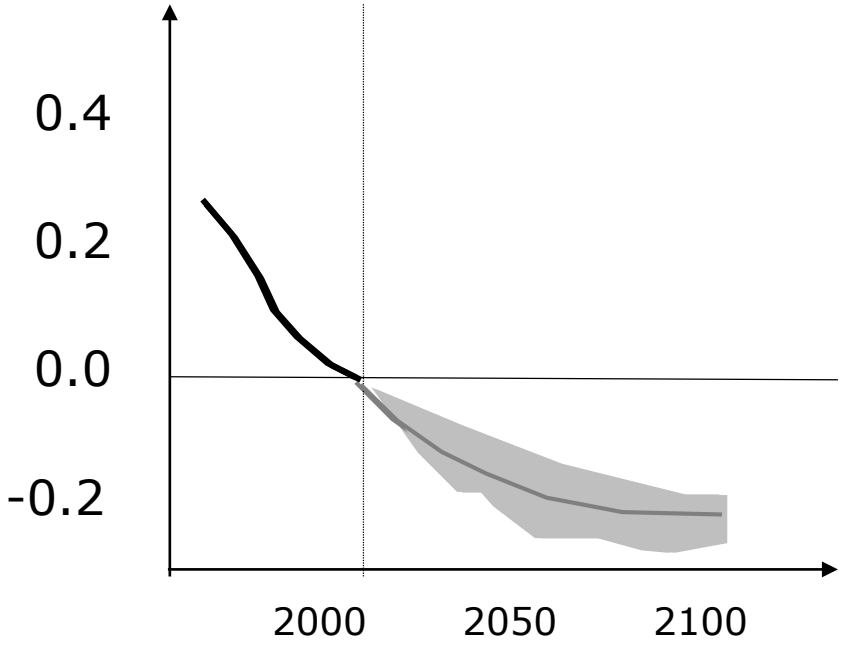
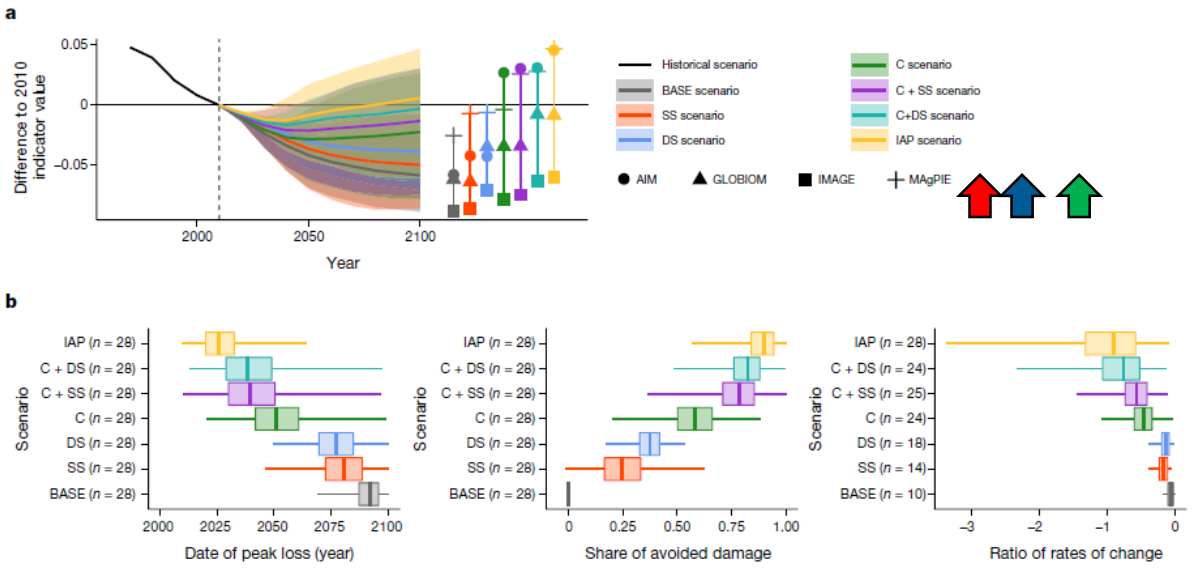


Measures		
Supply side	• Sustainable yield increase • Open trade	• SSP2 → SSP1
Demand side	• Reduced food waste • Diet shift	• 50% shift from animal → plant (*) • 50% red waste
Conservation	• Protected areas • Restoration	• Conservation priority areas

Biodiversity value





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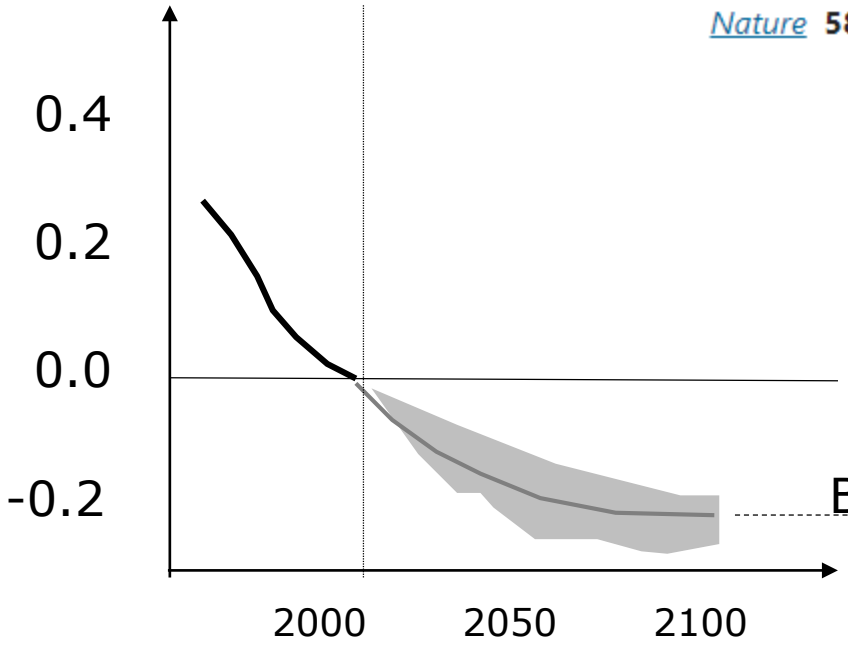

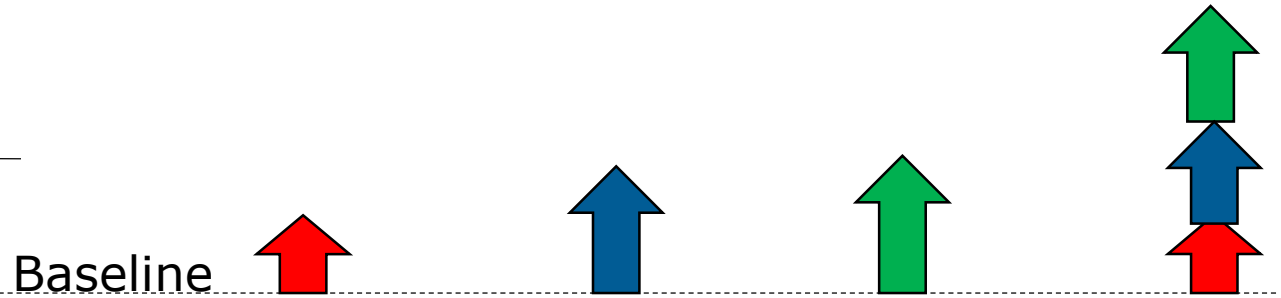

Supply-side

- Yield increase
- Optimise trade

Demand-side

- Reduced waste
- Diet shift

Conser-vation

- Increase protected areas
- Restoration

Bending the curve (biodiversity)

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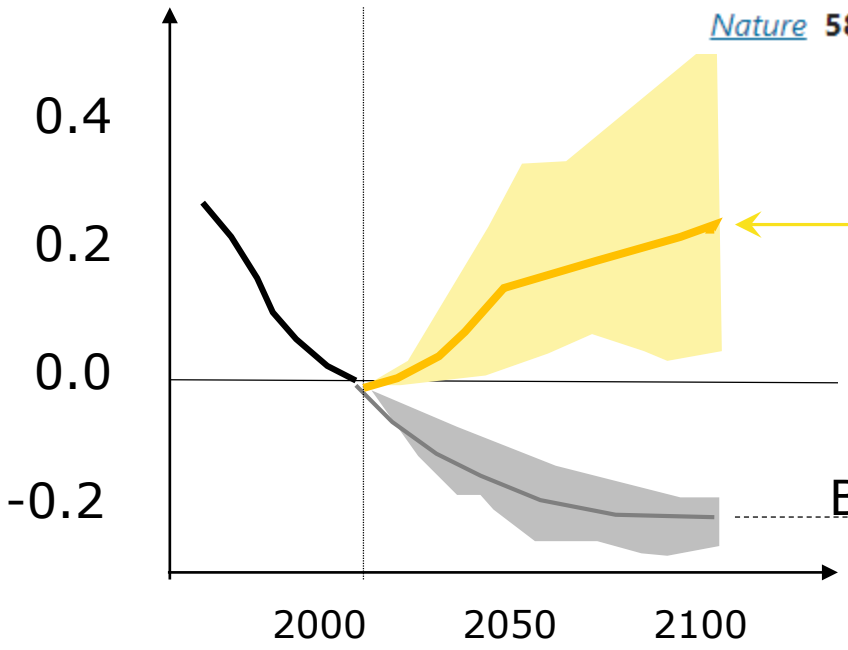
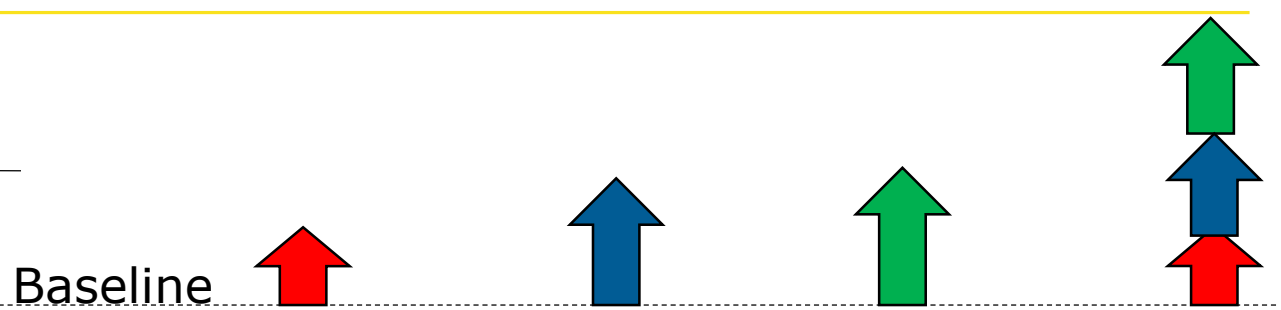




Supply-side

- Yield increase
- Optimise trade

Demand-side

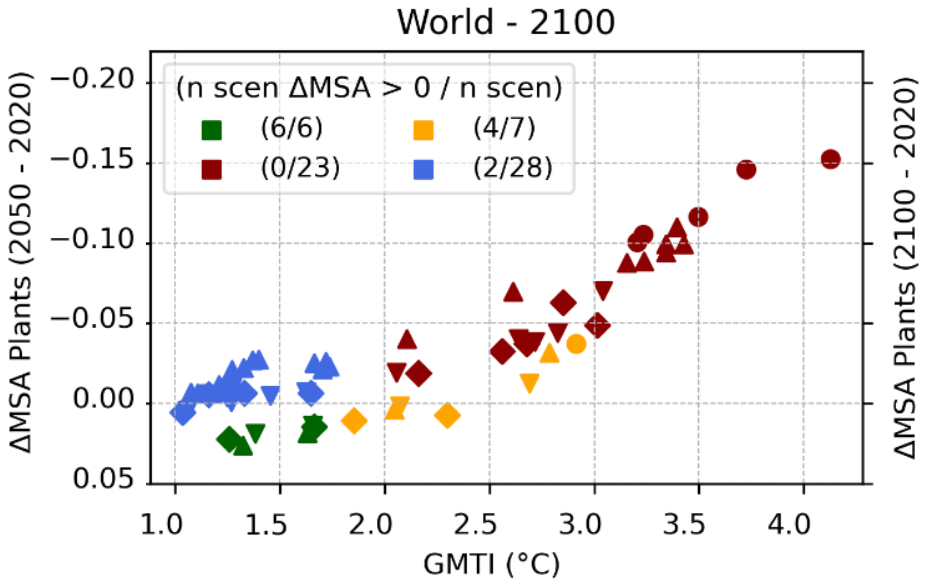
- Reduced waste
- Diet shift

Conser-vation

- Increase protected areas
- Restoration

Through further sustainable intensification and trade, reduced food waste and more plant-based human diets, more than two thirds of future biodiversity losses are avoided and the biodiversity trends from habitat conversion are reversed by 2050 for almost all of the models.

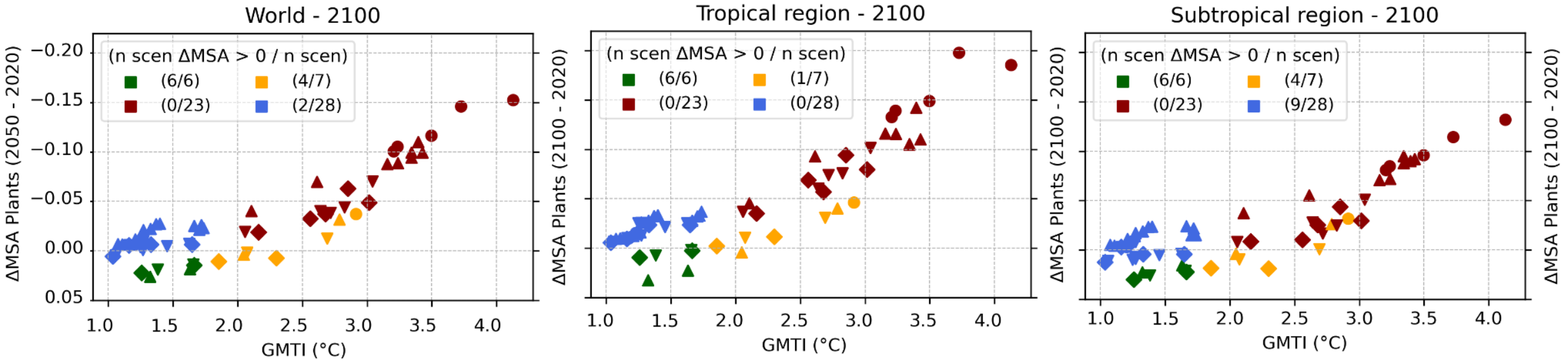
Climate change & loss of biodiversity in IMAGE scenarios



- No stringent policy
- Stringent climate policy
- Stringent biodiversity policy
- Both

Ambrosio et al, forthcoming

Climate change & loss of biodiversity in IMAGE scenarios



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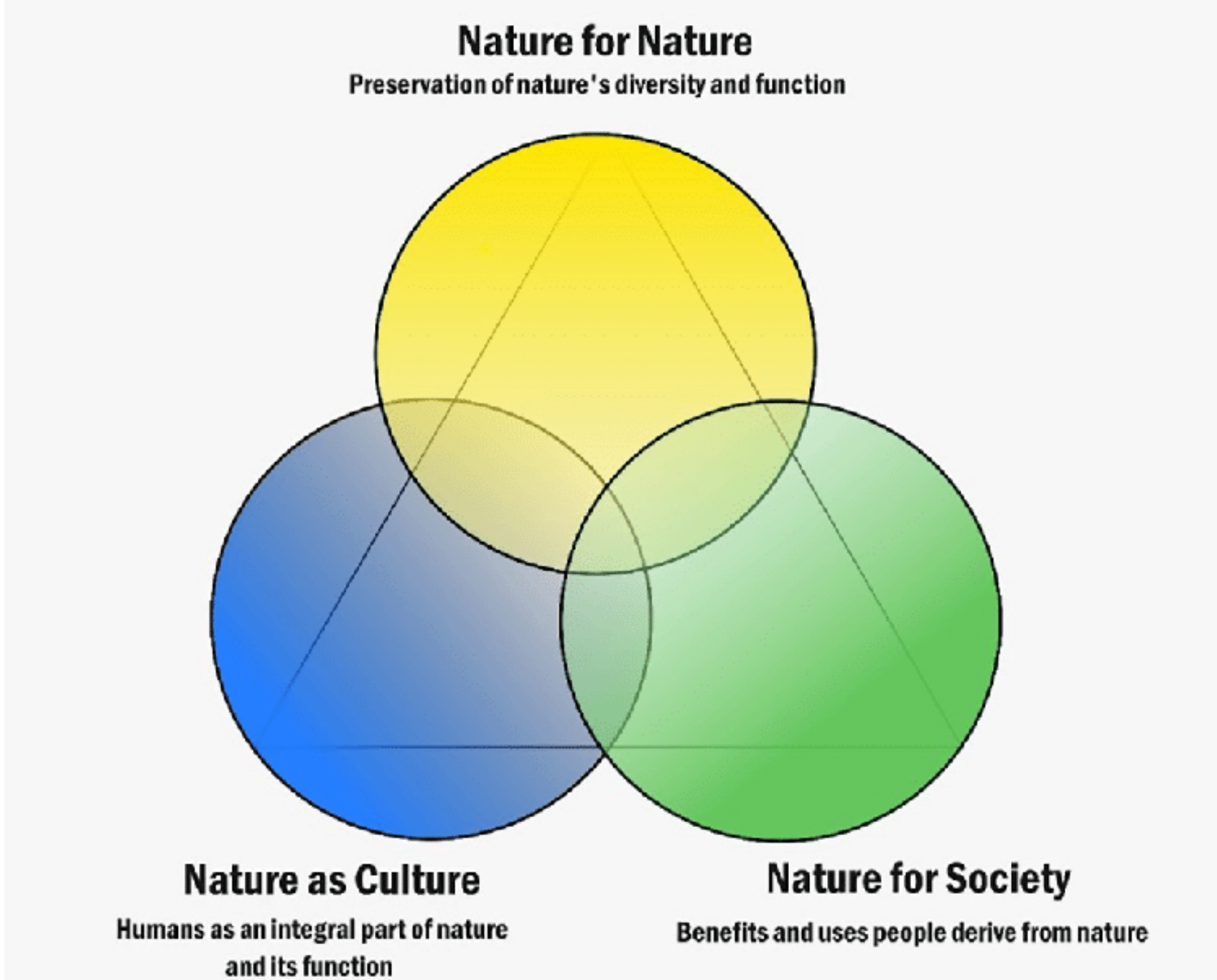
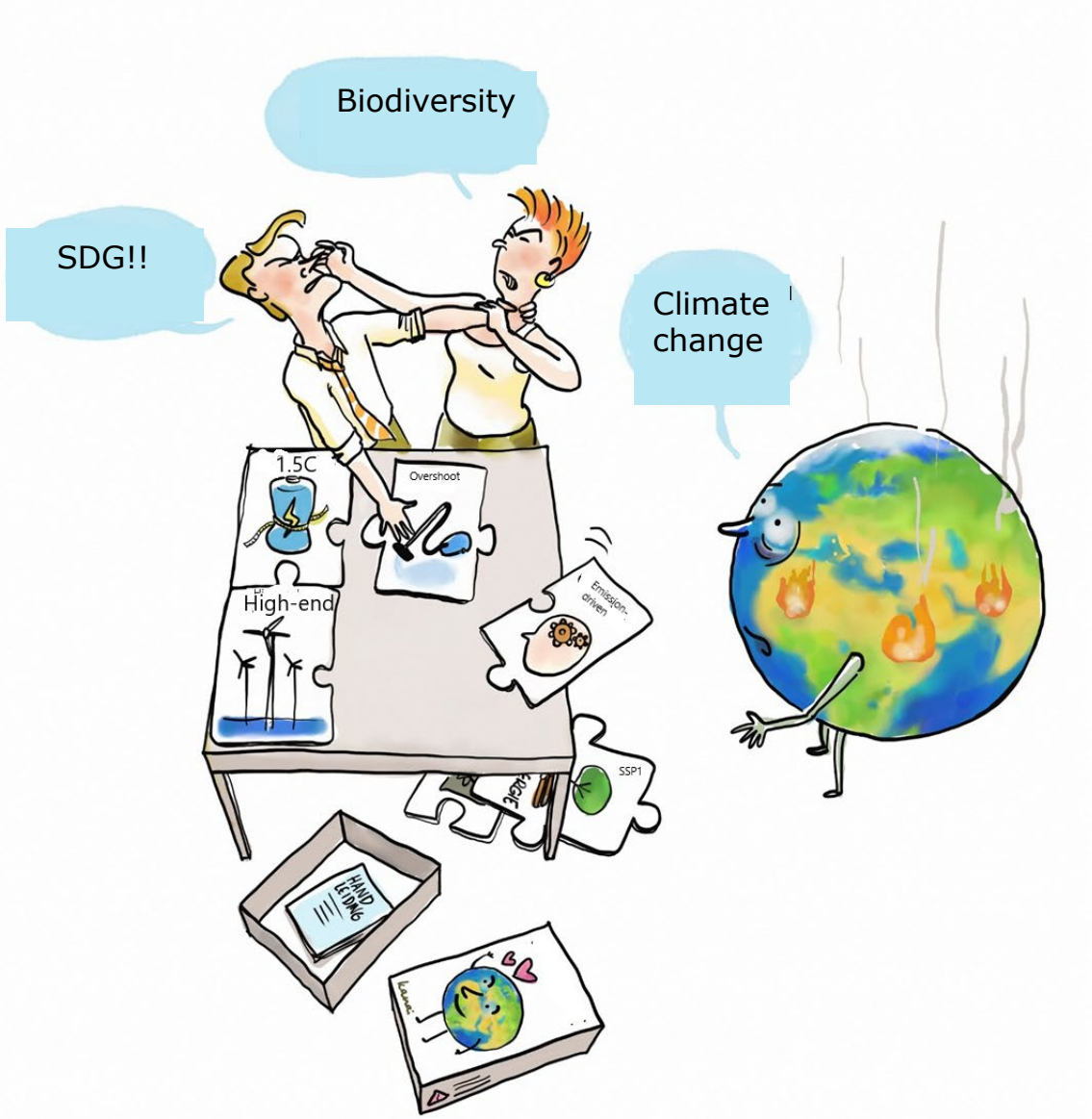

Nature for Nature
Preservation of nature's diversity and function
Nature as Culture
Humans as an integral part of nature and its function
Nature for Society
Benefits and uses people derive from nature

Integrated analysis

- More integrated scenarios looking at multiple issues
- Some trade-offs, lots of synergy