Including water, energy and land climate impacts and adaptation strategies in IAM scenarios

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Climate impacts in policy analysis

1. Top-down economic assessments of climate impacts, e.g. damage functions, SCC

2. Bottom-up biophysical approaches in specific sectors: crop yields and food production, power plant capacity and cooling potential, health-related mortality

3. Our research: water, energy, land policy analysis with Integrated Assessment Model (MESSAGEix-GLOBIOM).

   → **we integrate different biophysical climate impacts into a single framework**

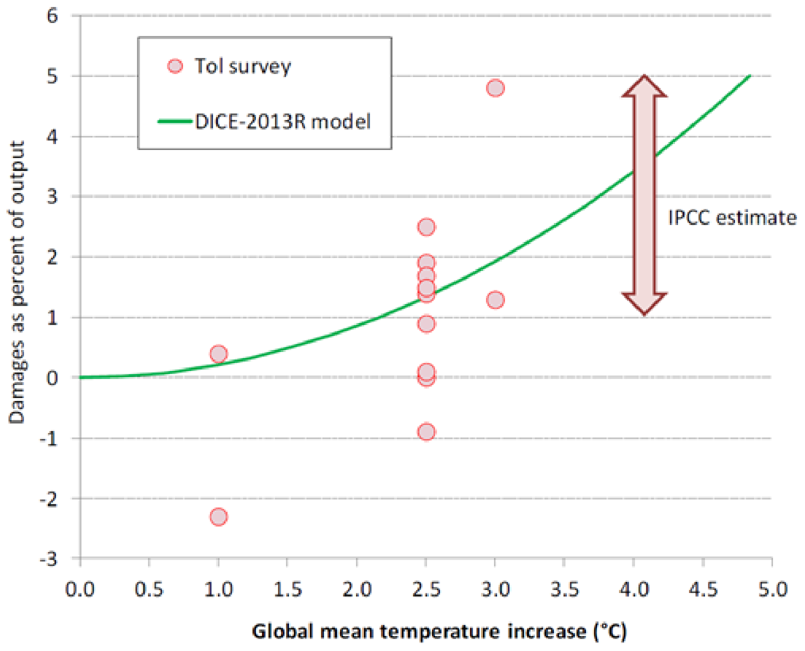


Figure 2. Estimates of the Impact of Climate Change on the Global Economy
This figure shows a compilation of studies of the aggregate impacts or damages of global warming for each level of temperature increase (dots are from Tol 2009). The solid line is the estimate from the DICE-2013R model. The arrow is from the IPCC (2007a). [impacts_survey.xlsx]

Approach: MESSAGEix-GLOBIOM IAM

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.)*

Climate Feedback: hydrology, runoff, groundwater

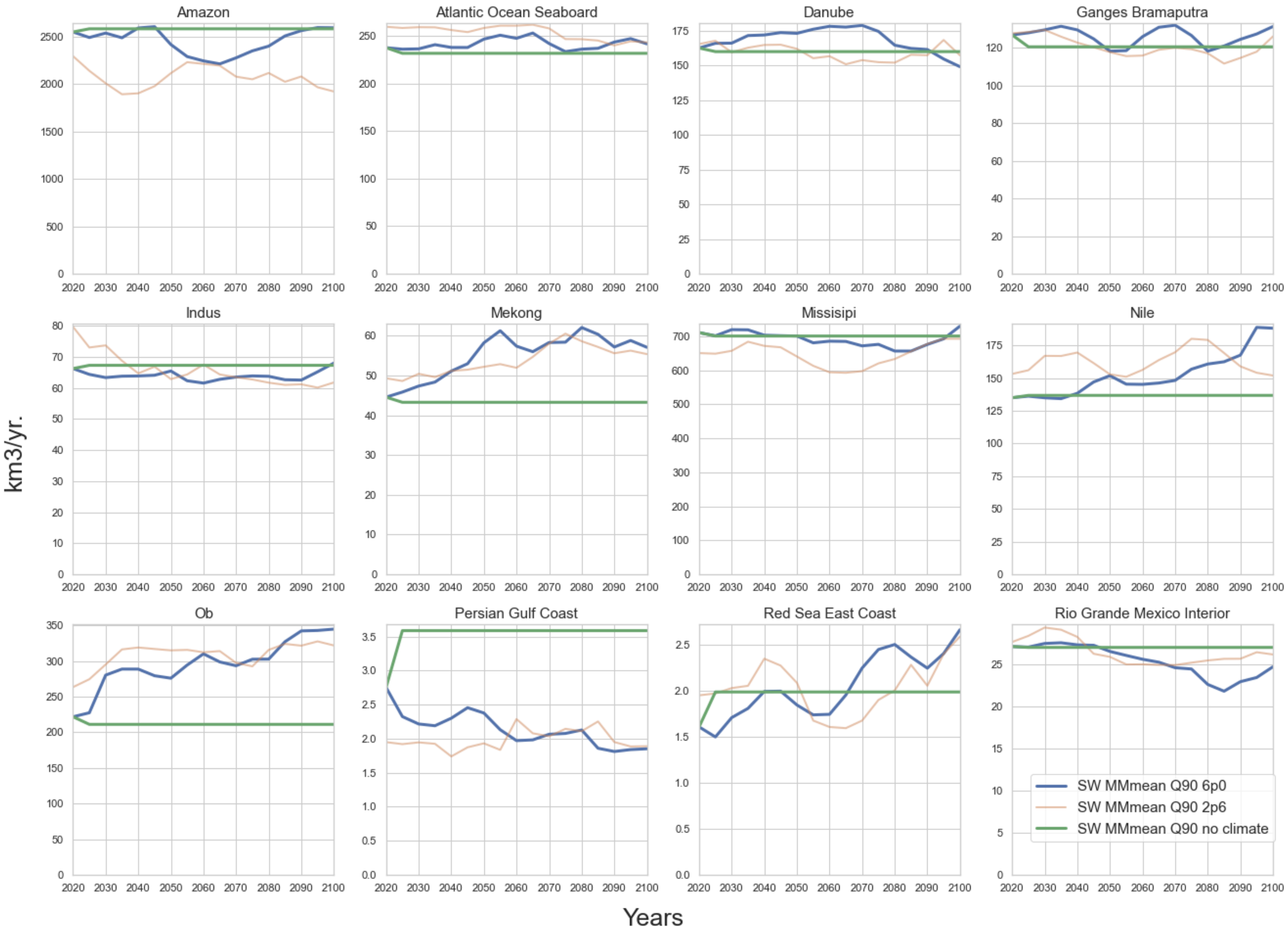
Hydrology includes some of the most uncertain variables for Climate Impact assessment.

SDG→ impacts on SDG 6 water access targets & SDG 2 sustainable food production

Adaptation→ non-conventional water sources: desalination, water recycling, deep groundwater (depletion)

Limitation: our modelling framework does not include sub-annual timesteps on the water balance (except for irrigation in GLOBIOM). → we use the q90 values of runoff to test system resilience.

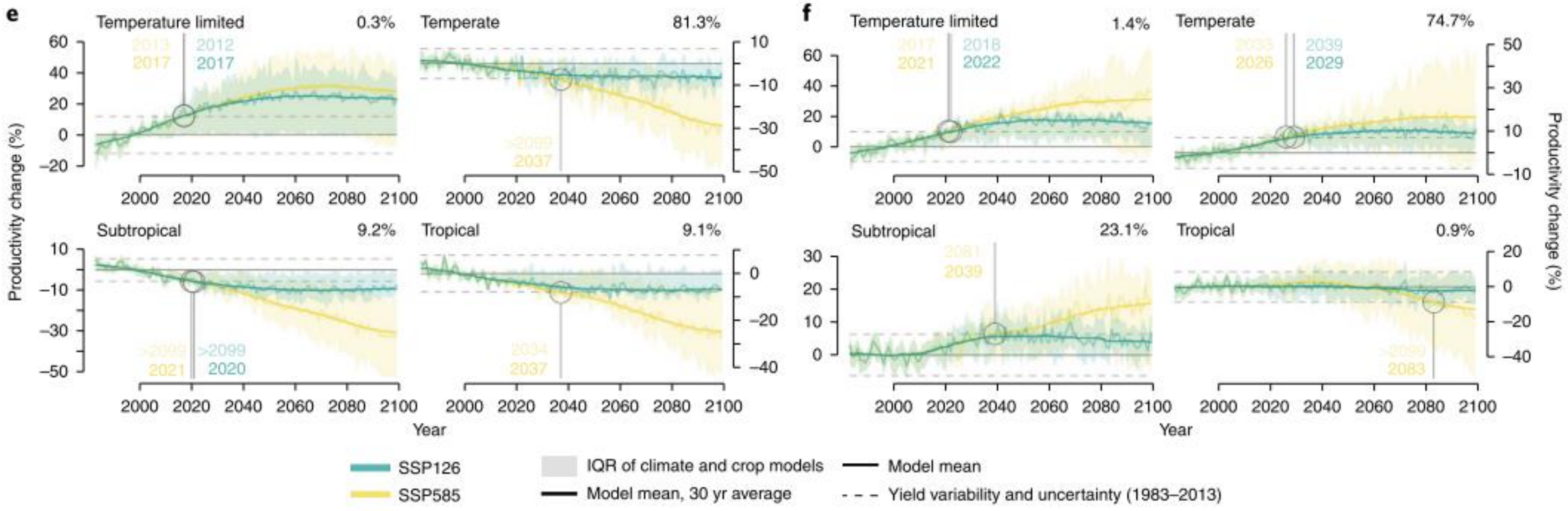
Runoff data from LPJmL, ISIMIP2b (gfdl-esm2m, hadgem2-es, ipsl-cm5a-lr climate models)



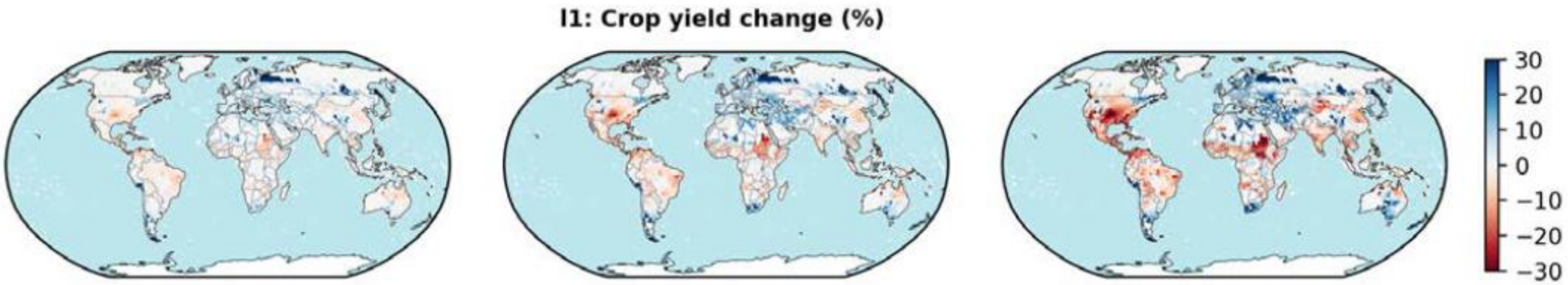
Climate Feedback: Crop yields

Very region-dependent, some regions will gain yield, other will have yield losses.
EPIC crop model (ISIMIP, LPJmL input) → MESSAGEix-GLOBIOM

SDG→ affect SDG 2, 15 crop choices and SDG6 irrigation water withdrawals
Adaptation→ crop shift, irrigation vs rainfed



Regional productivity time series for maize (e) and wheat (f) stratified for the four major Koeppen–Geiger climate zones (temperature limited, temperate/humid, subtropical and tropical). From Jägermeyr et al., 2021, *Nature Food*

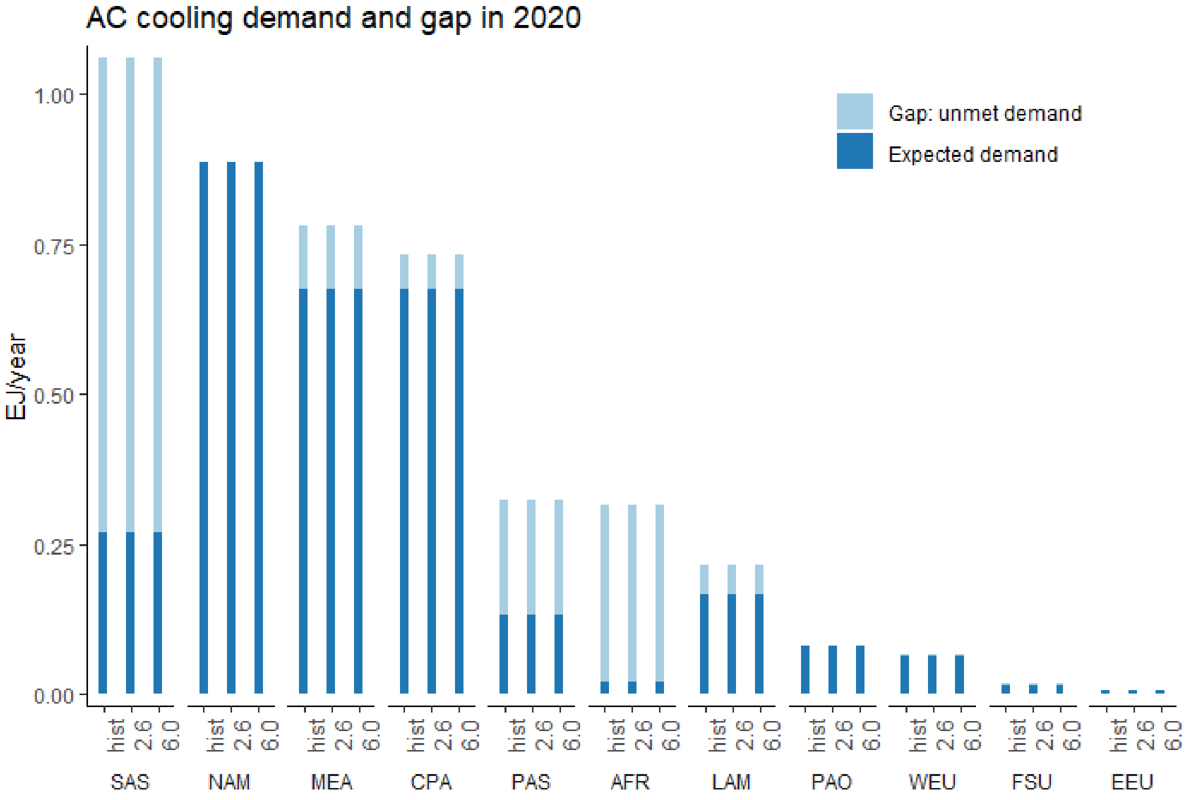


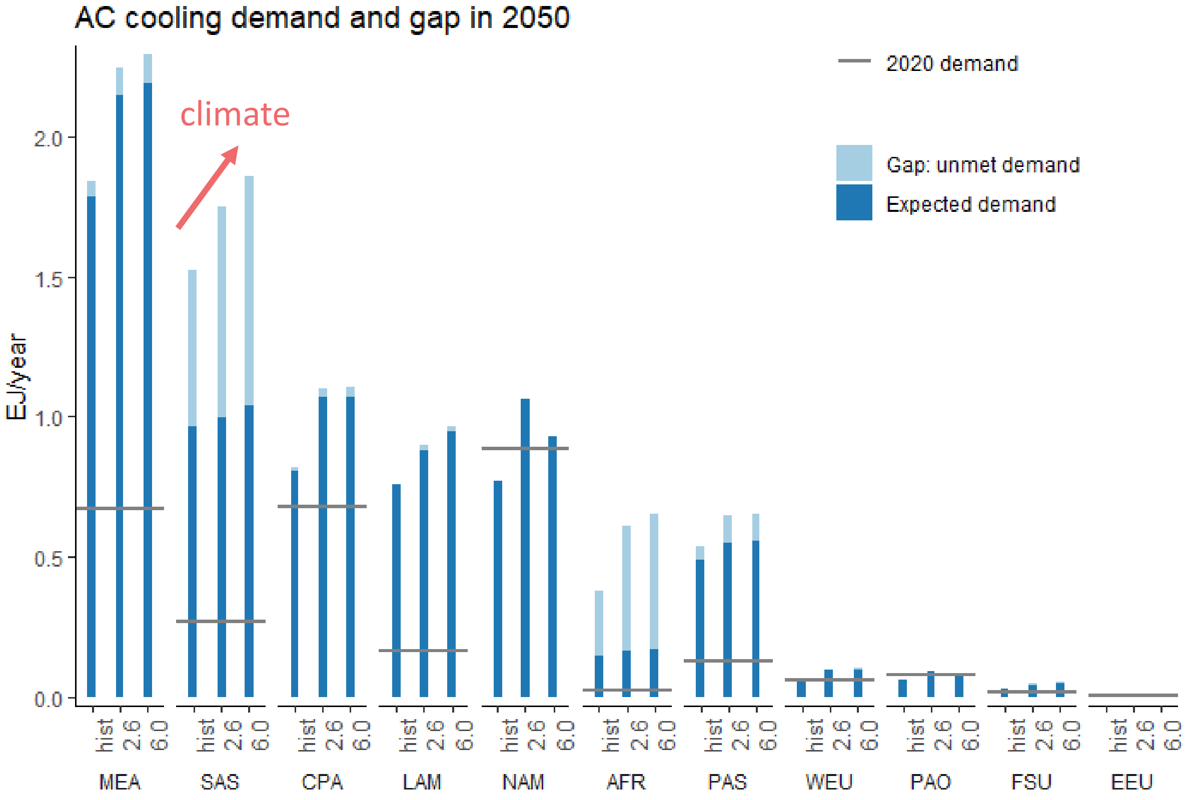
Crop yields change 1.5, 2.0 and 3.0°C GMT change (left to right), from Byers et al. 2018, *ERL*

Climate Feedback: AC cooling demand and gap

Cooling demand is likely to increase. South Asia and Africa have large % of population with not adequate cooling (Gap: unmet demand). Different climate affects GMT and CDD

SDG→ interactions with SDG 7, energy access, higher energy requirements for RCP 6.0





SSP2 projections from Mastrucci et al. 2021, Climatic Change

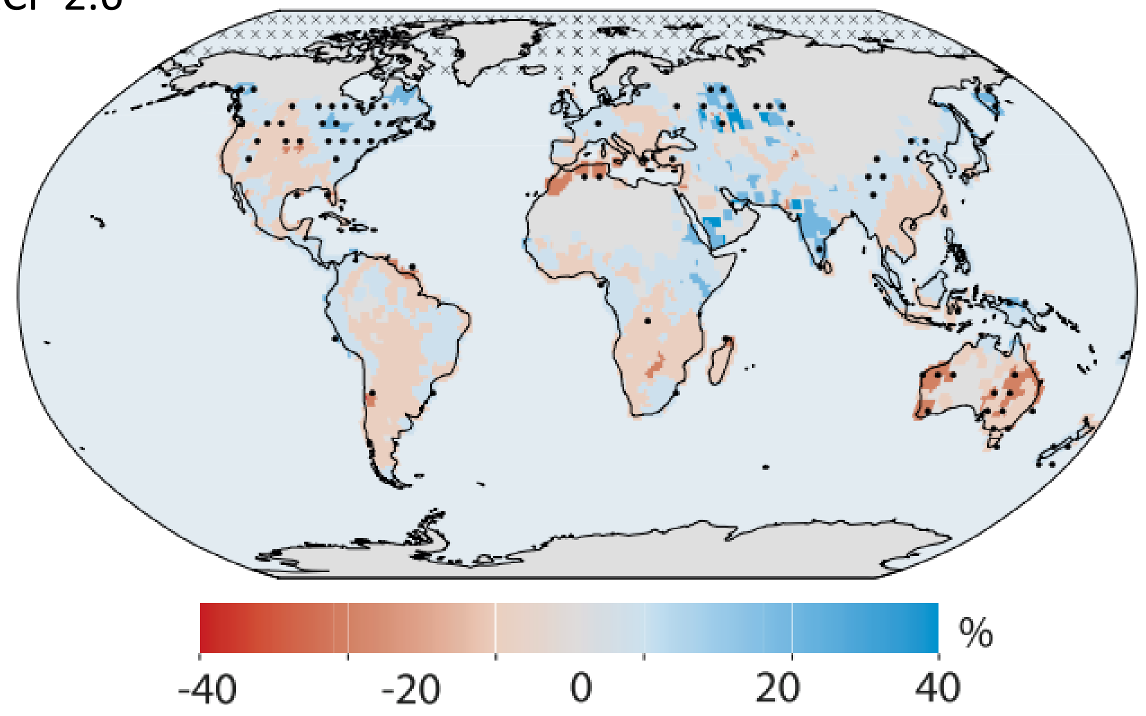
Climate Feedback: Hydropower potential

Some regions can experience higher precipitation patterns in the coming decades under RCP 6.0, with a potential increase in hydropower capacity. Other areas will suffer of water scarcity and increased droughts.

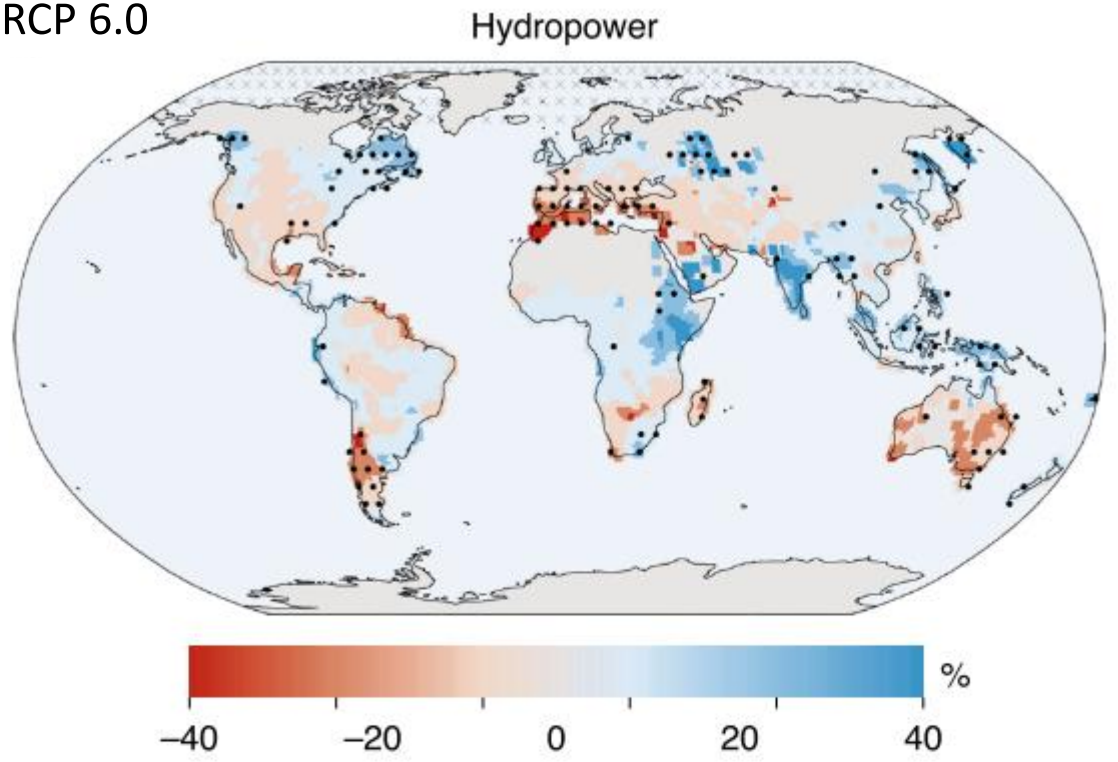
SDG→ Both benefits and trade-off with SDG 7 and SDG 13

Adaptation→ expand hydro, other energy sources

RCP 2.6

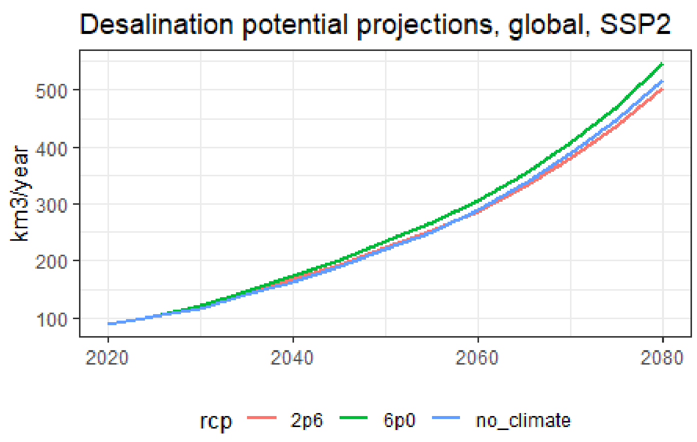


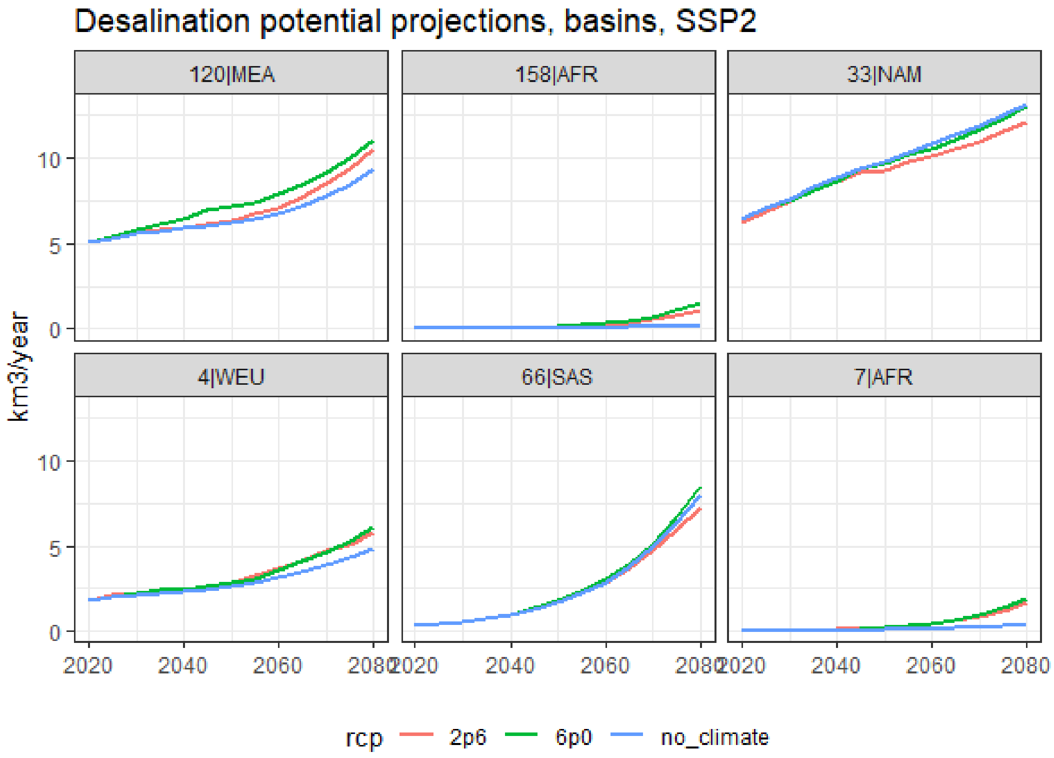
RCP 6.0



The differences in the multi-model mean (over GCMs GFLD-ESM2M, HadGEM2-ES, IPSL-CM5A-LR and MIROC5) of the historical period (1970–2000) compared with the future period (2070–2100). **Gernaat et al., 2021** ***Nature Climate Change***

Climate Feedback: Desalination potential





Desalination potential as response to economic and governance implementation capacity, and water stress

- Regression analysis: log_desal ~ log_gdp + gov + log_wsi + log_coast
- Increased desalination need/potential

SDG→ Small variations across climate, impacts on SDG 6 costs

Adaptation→ Desalination itself, other water sources

Climate Feedback: Power plants' cooling

Highly studied and discussed, we include assumptions on cooling capacity factor reductions from van Vliet et al., 2021, Global Environmental Change

SDG→ Impacts on SDG 6 water withdrawals and SDG 7, 13 Thermal power plants' reliability

Adaptation→ dry and sea cooling, non-thermal power production

Scenario	Climate Forcing (W/m^2)	SDGs	Impacts
SSP2-noCF	6.0	No additional effort	Frozen to 2020
SSP2-CF	6.0	No additional effort	

SSP2 – Middle of the Road Socio Economic Pathway
CF – Climate Feedback

Approach – SDG implementation

SDG	IMAGE	MESSAGEix-GLOBIOM
SDG2 - Hunger	**Change towards a healthy diet**	
		• < 1% undernourishment goal by 2030 • Decrease of animal calorie intake to 430 kcal/capita/day by 2030 (USDA recommendations for healthy diets)
	Reduce food waste	
	Reduction of food waste based on income level of countries using approach from [Gustavsson, et al. 2011].	50% reduction in food waste compared to SSP2 assumptions

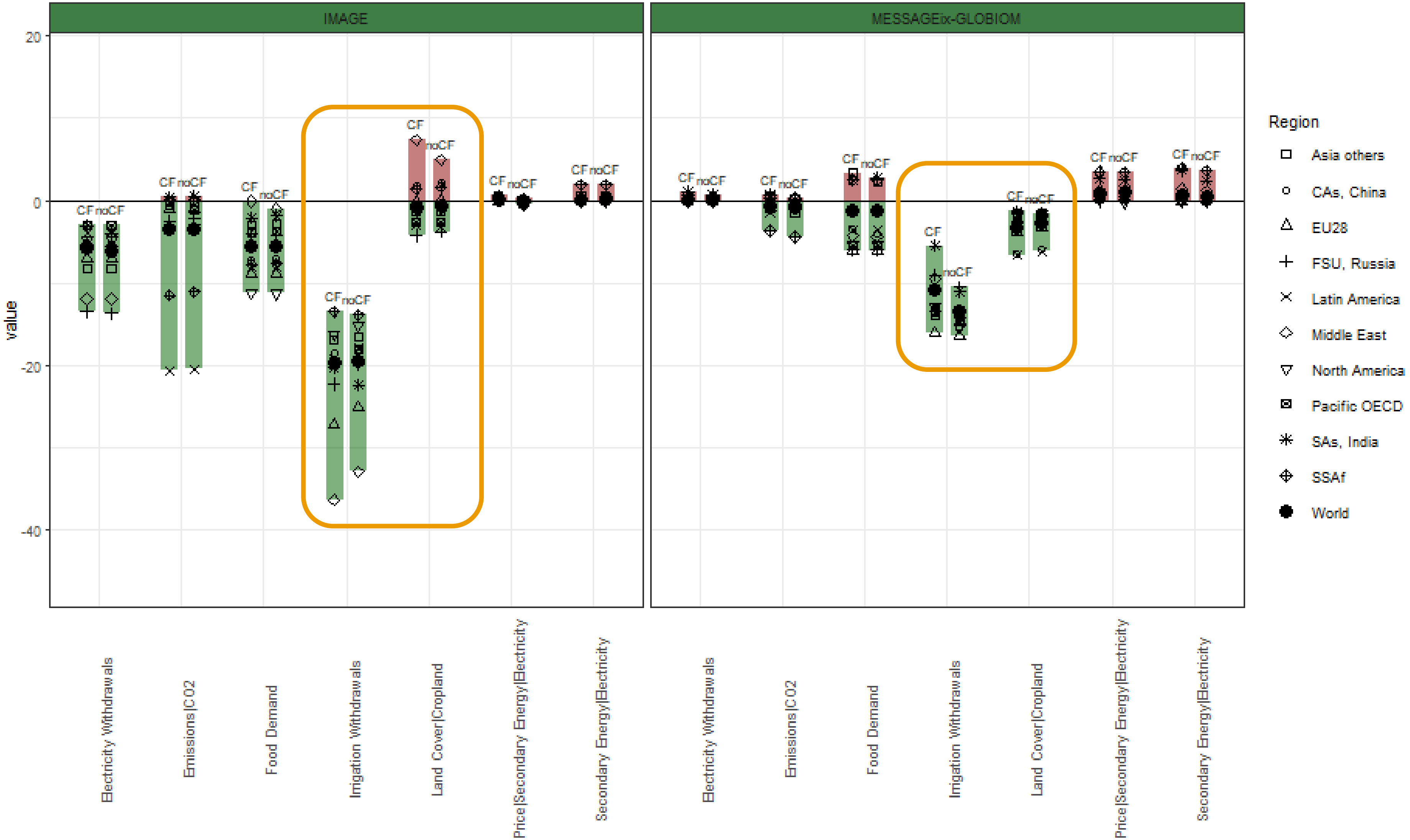
Approach – SDG implementation

SDG	IMAGE	MESSAGEix-GLOBIOM
SDG7 - Energy	**Maximised electricity access**	
	On-grid electrification only, based on SSP1 assumptions (98% in 2030).	Results from the MESSAGEix-GLOBIOM are iterated through the MESSAGE-Access-E-USE (end-use services of energy) model by provision of access targets
	Minimised traditional bio and coal in cooking and heating	
	Improved stoves where this is not feasible . Based on SSP1 assumptions (90% reduction of traditional bio in 2050)	90 % access target to modern cooking energy for cooking by 2030

SDG implications w and w/o climate feedbacks

What are the implications of meeting nexus SDGs (2,6,7,13,15), and how are these affected by climate change impacts (rcp 6.0) ?

Average difference (2030-2100) baseline and SDG (with and w/o CF)



- **CF effects < SDG policy effects**

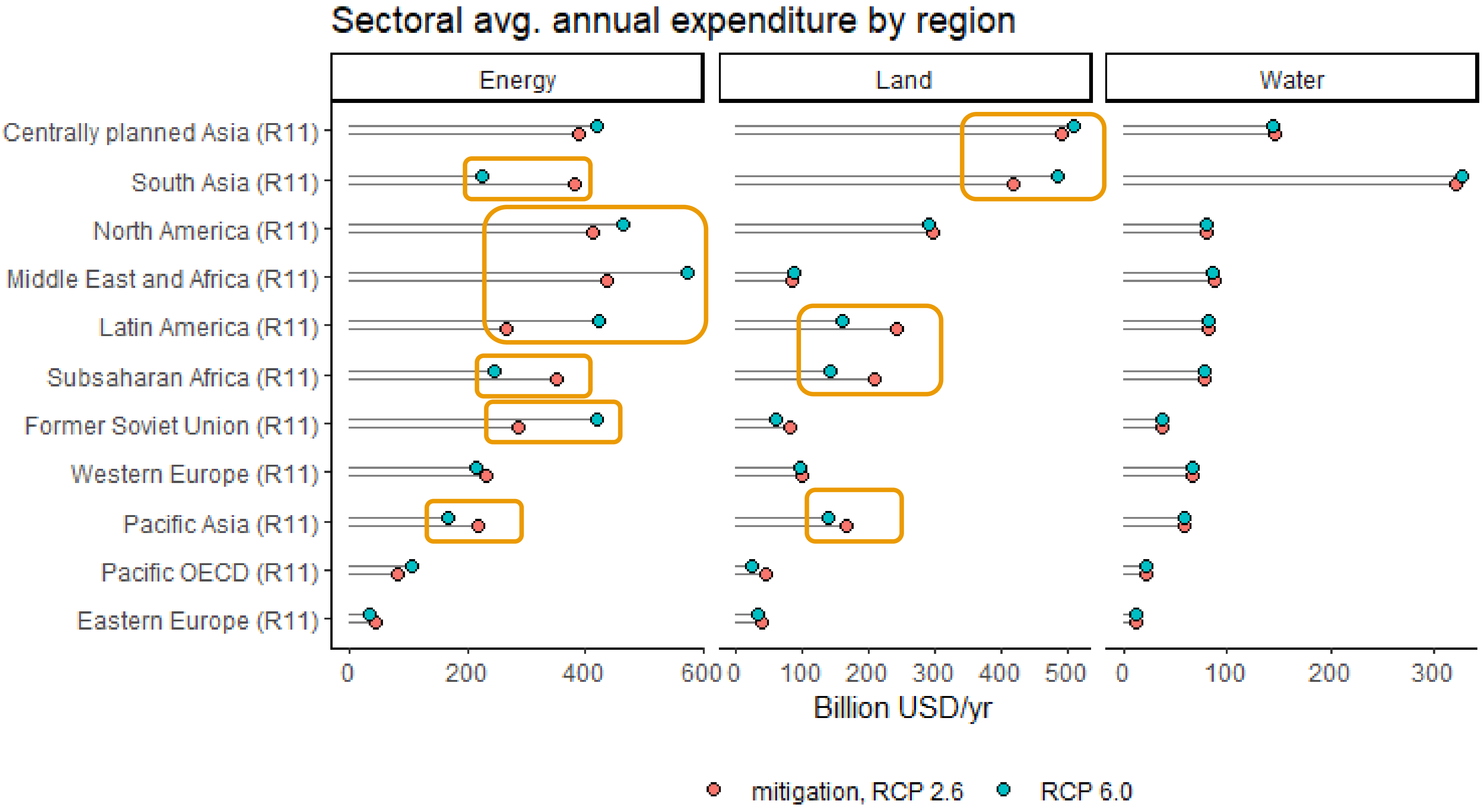
- Major impacts (between 5-20%) for **electricity production**, **land cover** and **irrigation water withdrawals**

- **South Asia, Central Asia, Middle East and Sub-Saharan Africa** show largest benefits from the SDG agenda, but are also the most vulnerable to climate feedback

Preliminary results with avg. annual water availability

Climate mitigation vs adaptation costs

How does a mitigation (rcp 2.6) scenario compare not to a no-policy future (rcp 6.0) once climate impacts are considered?



Energy:
- Reduce exportation
- Renewable expansion higher than savings from fossil fuel

Land:
- Reducing costs: less irrigation withdrawals
- Increasing costs: increase afforestation

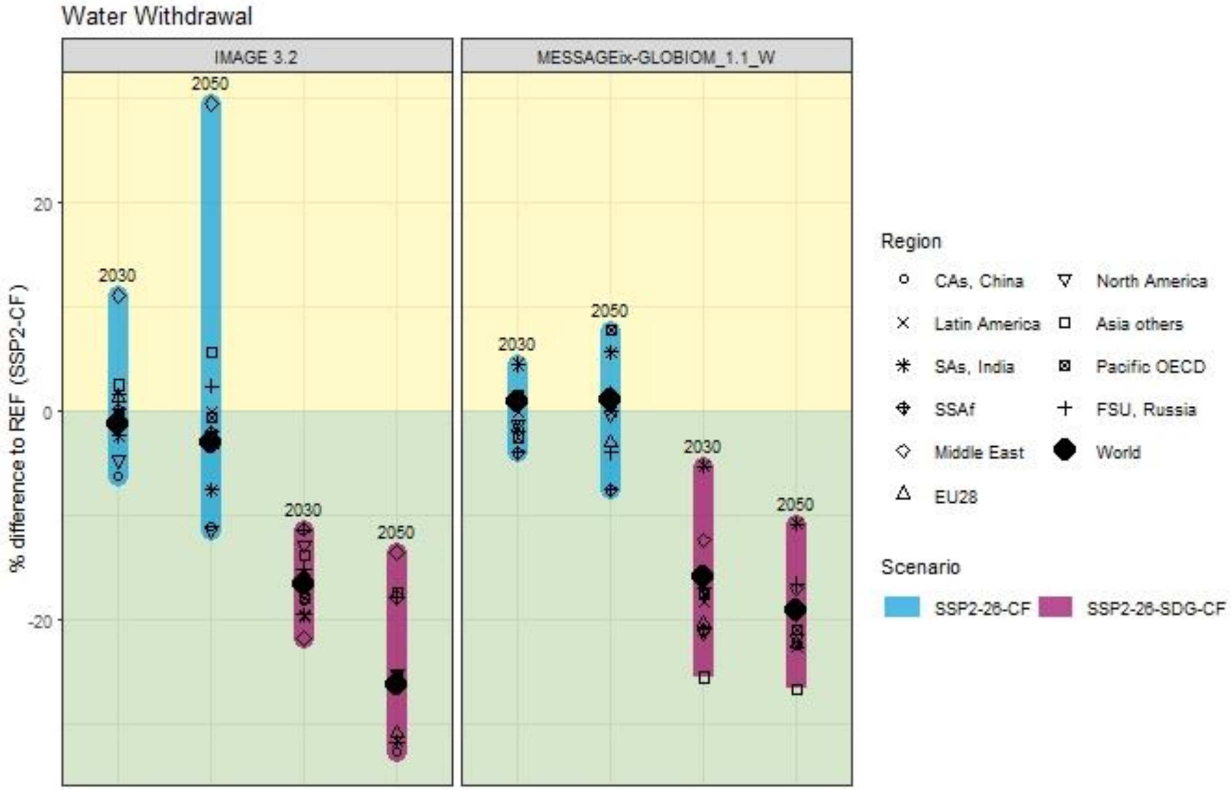
Water:
- Not very sensitive
- Less requirements for water extraction in mitigation scenario

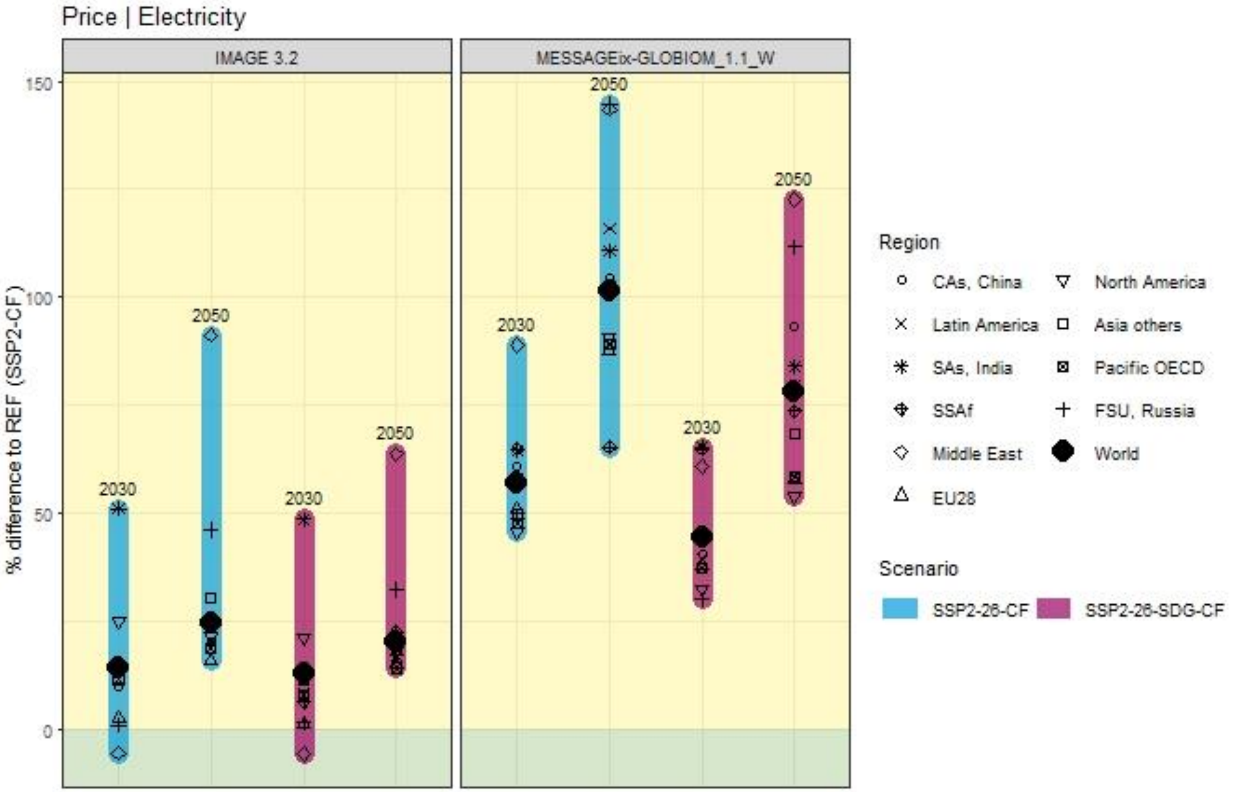
Preliminary results

SDG implications on climate mitigation pathways

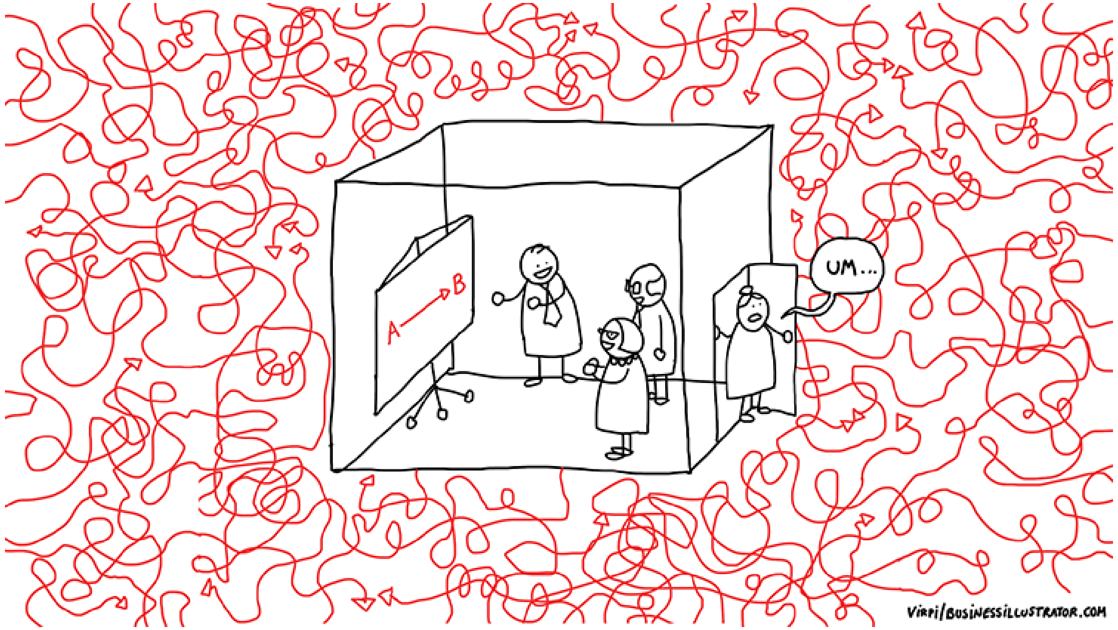
What are the implications of meeting nexus SDGs (2,6,7,13,15), when coupled with climate mitigation policies (considering climate impacts y default)

- Benefits, water use, cropland, energy prices, people relying on fossil fuels in the short term. Mostly benefit from food waste reduction and land related policies
- Energy system investment reduction and energy prices





Final considerations



- Including multi-sector climate feedback in Integrated Assessment Models is doable: it **increases complexity, but improves reliability of climate and SDG policy analyses**.

- It is still to be discussed how **biophysical approaches** to CI assessment **relate to macro-economic assessments**

Work in progress:

- Considerations on **costs and investments** is still work in progress
- Identify **causalities** between CF and changes in SDG targets is complicated due to the large number of sectors and dimensions
- **Model sensitivity** to water climate uncertainty

Thank you!

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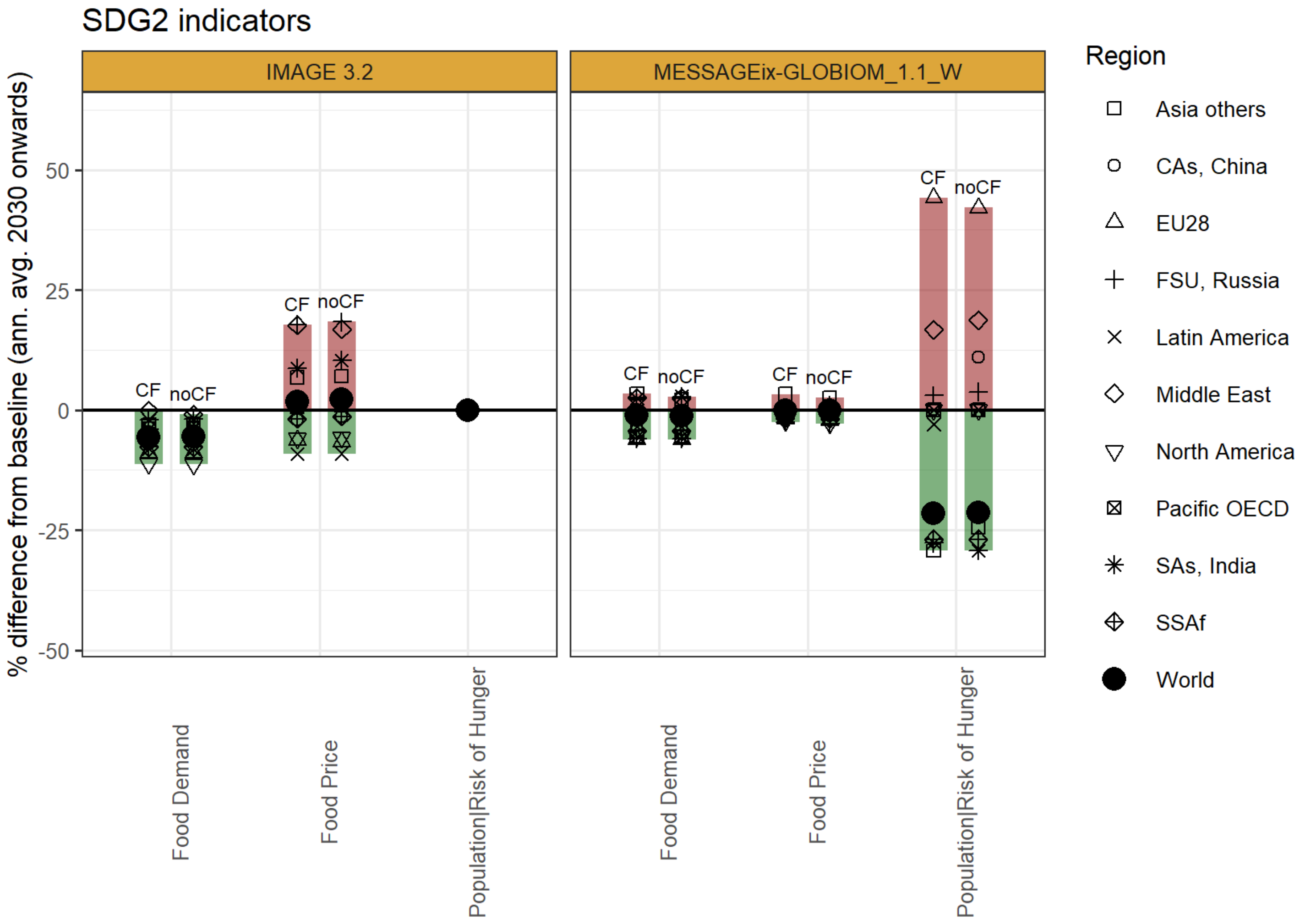
Results: SDG implications w and w/o climate feedbacks

What are the major system changes required to achieve SDG objectives in SSP2 RCP6.0 ?

- Healthy diet and food waste compensate the increase in calories intake on overall food demand
- Small and mostly negative food price changes, apart from central Asia
- Small changes with and w/o Climate Feedback (CF)

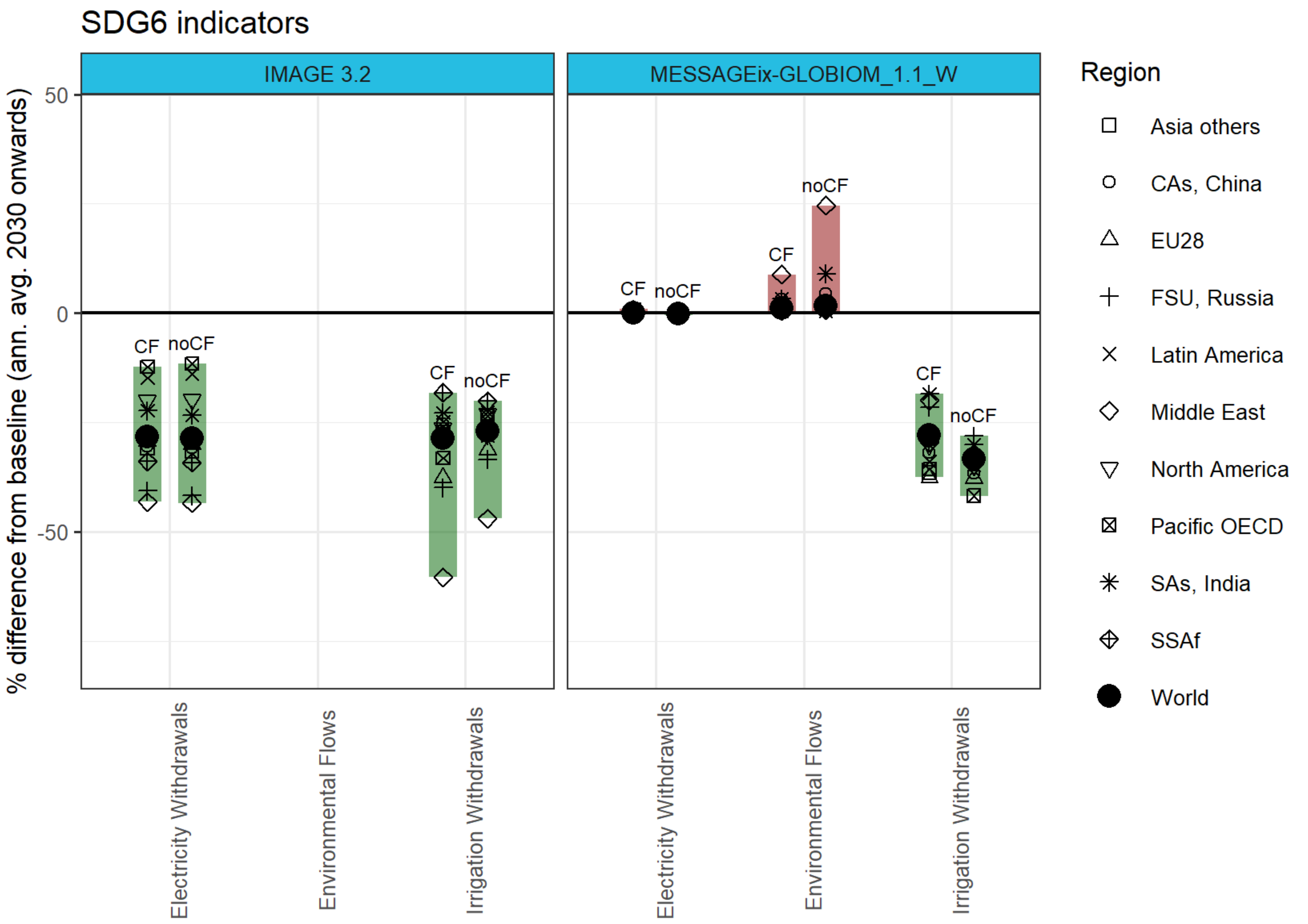
Note: short vs long term changes. the same results for before or after 2050 show similar effect of CF on SDG indicators. The SDG impacts themself are however higher on the long term.



Prelimary results, please don't cite

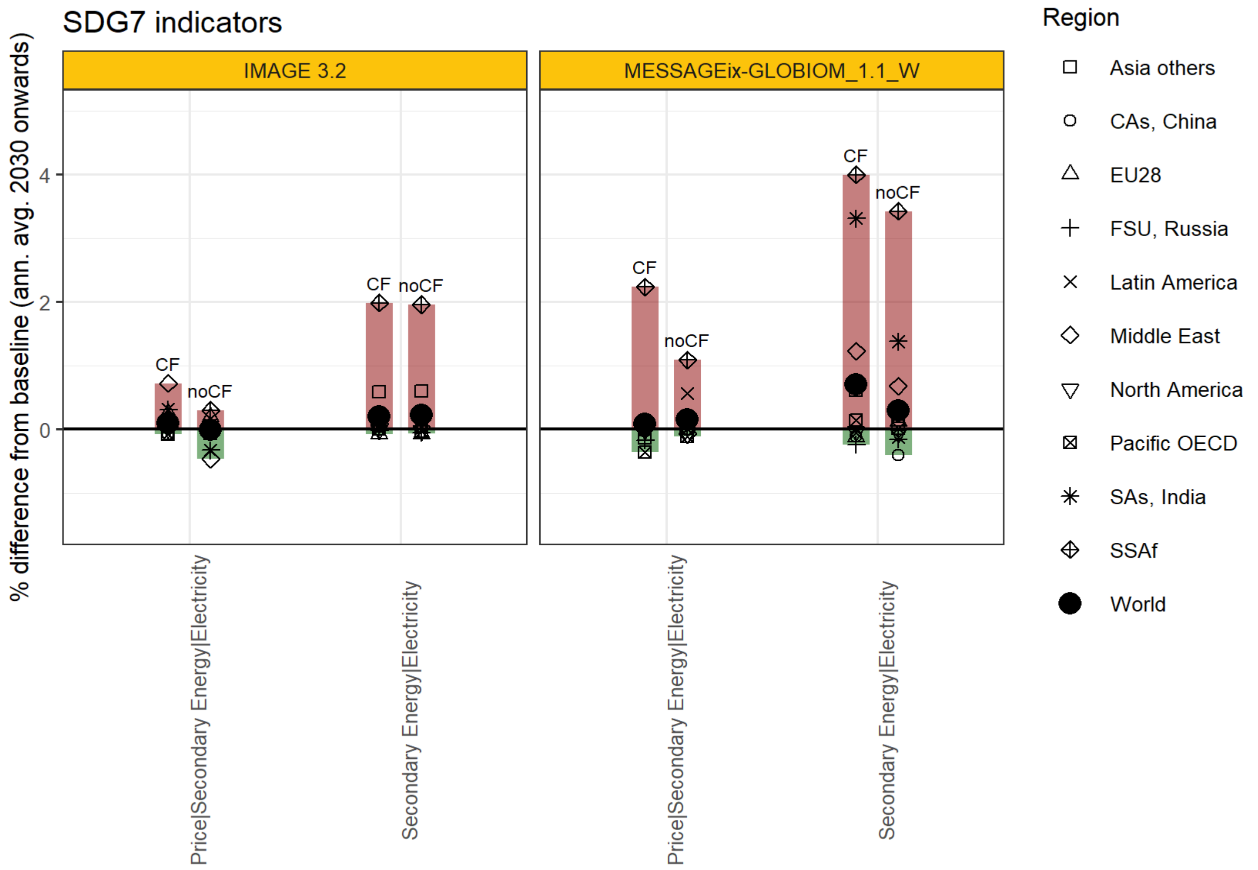
SDG implications w and w/o climate feedbacks

- Expected positive effects on all indicators
- Climate Feedback affect mostly **environmental flow** and **irrigation withdrawals**
- Some regions show high vulnerability to climate impacts and show high water stress e.g Middle East & South Asia
- Approx. 1900 million people provided with clean drinking water access globally



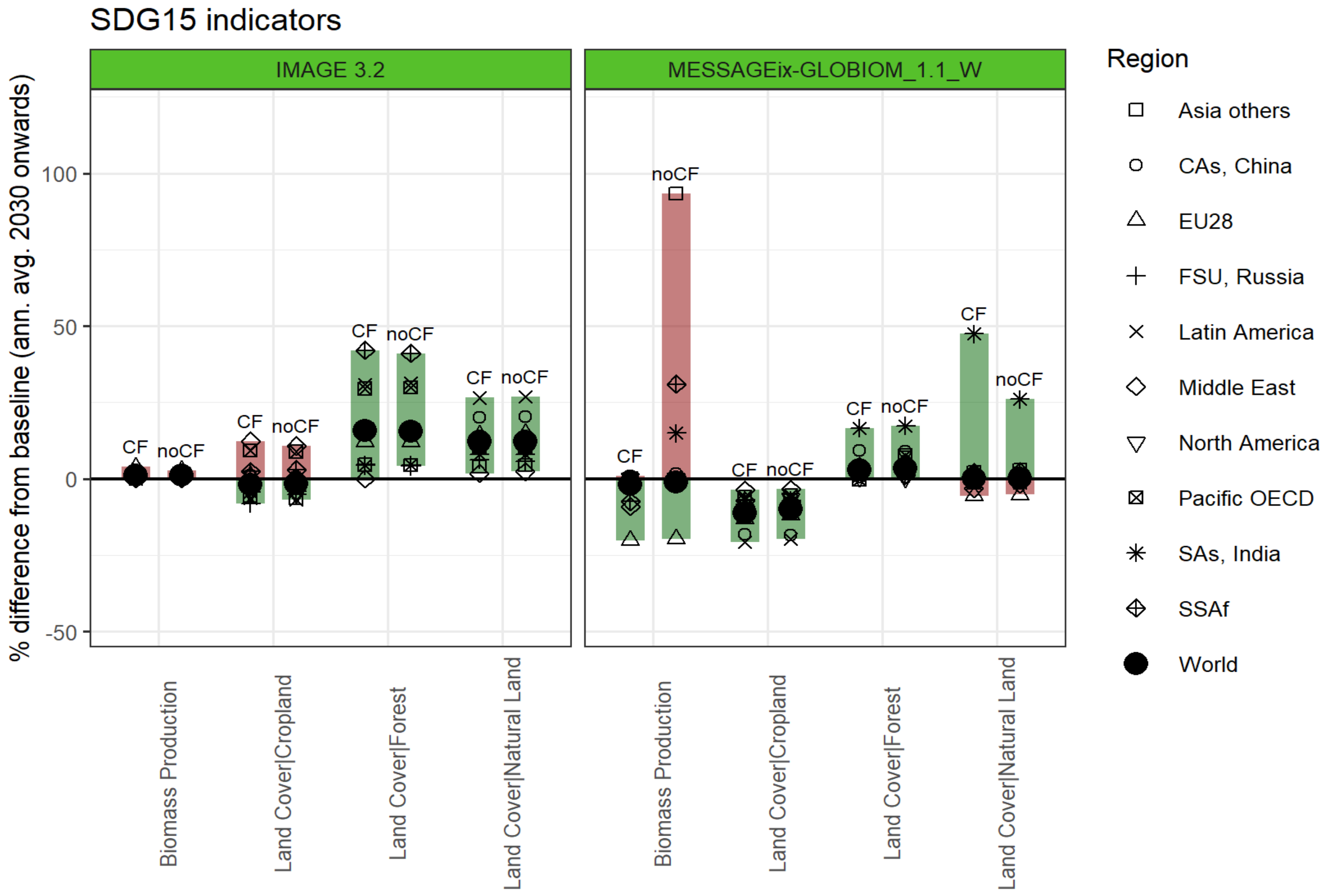
SDG implications w and w/o climate feedbacks

- Improving energy and water access, and AC demand **increases electricity production and prices**
- Variations lower than 3% and almost 0 globally
- Highest increases in **South Asia, Sub-Saharan Africa** and **Middle East**



SDG implications w and w/o climate feedbacks

- Great variations especially for Central Asia, South Asia and Sub-Saharan Africa
- Noticeable differences between IMAGE and MESSAGE-GLOBIOM, particularly in Biomass Production and Cropland



Upcoming work - Flexibility across scales

MESSAGEix-Nexus (Global)

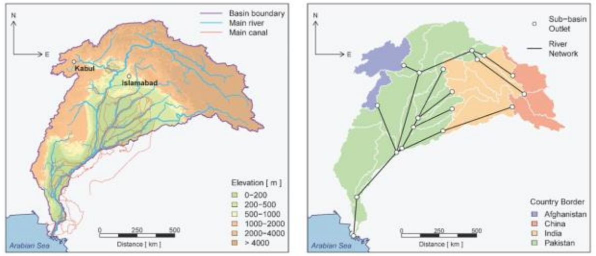
Downscale/Prototype
(existing method)

MESSAGEix-Country

Updated country scale model with water representation as in global model

Top-down approach to downscale energy & water components from national model

NEST Indus (Basin)



Improve existing model structure to be flexible to other regions in future

Bottom-up approach/sub-catchment level

MESSAGEix-Nexus (National/Basin)