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

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Integration of climate impacts in policy analysis

Different approaches:

1. Top-down economic assessments of climate impacts, e.g. damage functions, SCC
2. Sectoral implementation of biophysical impacts: eg, crop yields and food production, power plant capacity and cooling potential, health-related mortality
3. **Multi-sectoral approach assessing economic implications and feedbacks across sectors:** water, energy, land policy analysis with Integrated Assessment Model (MESSAGEix-GLOBIOM).

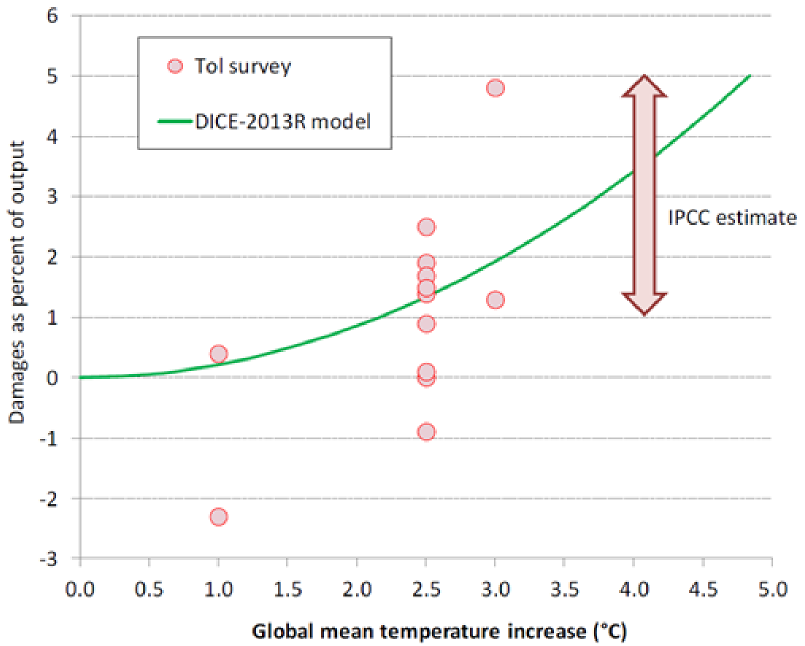

Figure 2. Estimates of the Impact of Climate Change on the Global Economy This figure shows a compilation of studies of the aggregate impacts or damages of global warming for each level of temperature increase (dots are from Tol 2009). The solid line is the estimate from the DICE-2013R model. The arrow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

Multiple sectors and multiple policy objectives

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.)*

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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-SDG-noCF	6.0	2 ZERO HUNGER; 6 CLEAN WATER AND SANITATION; 7 AFFORDABLE AND CLEAN ENERGY; 15 LIFE ON LAND	Frozen to 2020
SSP2-SDG-CF	6.0	2 ZERO HUNGER; 6 CLEAN WATER AND SANITATION; 7 AFFORDABLE AND CLEAN ENERGY; 15 LIFE ON LAND	
SSP2-26-SDG-CF	2.6	2 ZERO HUNGER; 6 CLEAN WATER AND SANITATION; 7 AFFORDABLE AND CLEAN ENERGY; 15 LIFE ON LAND	
SSP2-26-CF	2.6 13 CLIMATE ACTION	No additional effort	
SSP2-26-noCF	2.6 13 CLIMATE ACTION	No additional effort	Frozen to 2020

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

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Climate Feedback: hydrology, runoff, groundwater

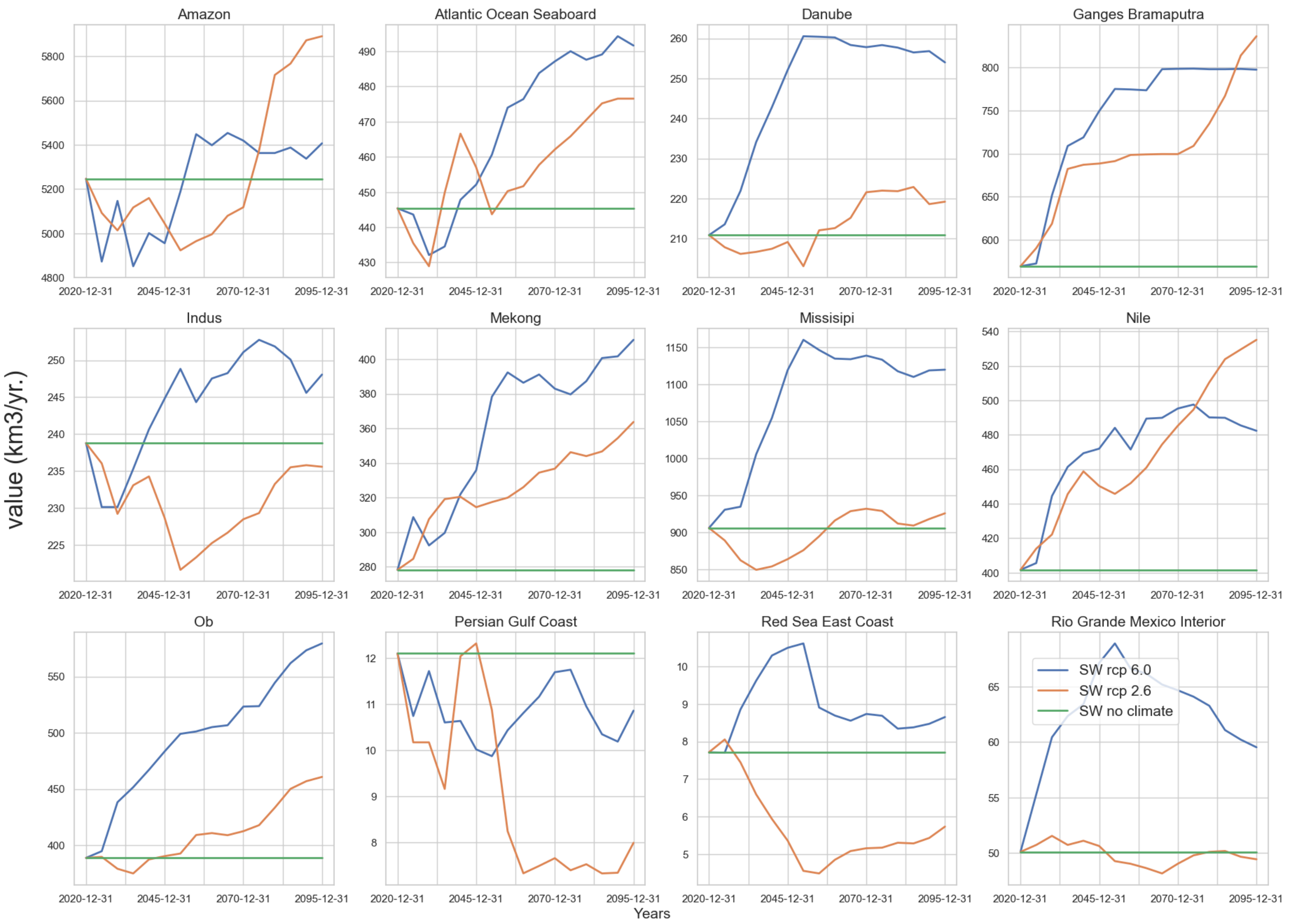
Large hydrological uncertainties with pronounced **regional differences**

Unconventional adaptation options:
- water recycling/treatment,
- Desalination
- deep groundwater (depletion)

Impacts on **SDG 6** (water access) & **SDG 2** (sustainable food production)

Limitation:
Irrigation considers seasonality, all other sectors employ simplified approach through q90 values for runoff to test system resilience.

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



Climate Feedback: Crop yields

Some regions will gain yield, other will have yield losses.

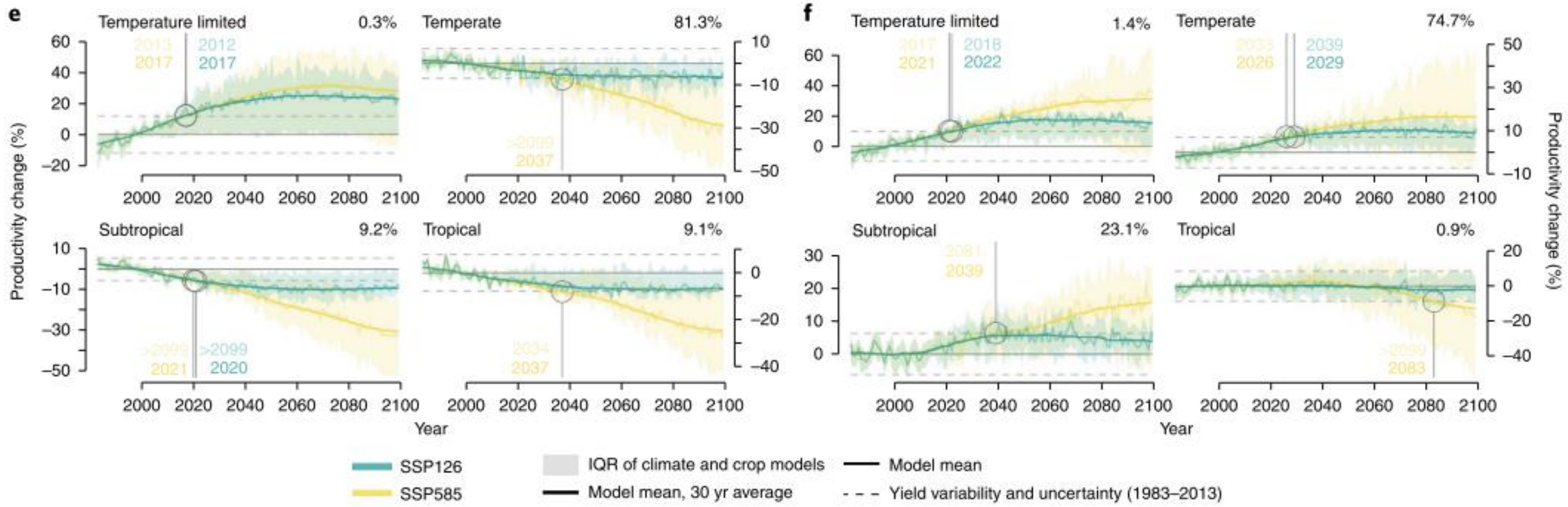
EPIC crop model (ISIMIP, LPJmL input) → MESSAGEix-GLOBIOM

Adaptation options include crop shift, irrigation vs rainfed

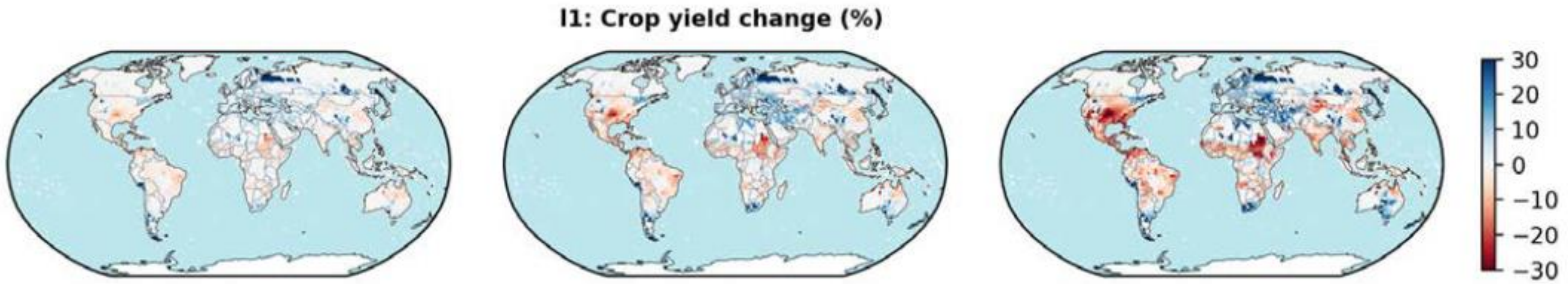
Responses to meet SDG 2 (diet), 15 crop choices and SDG6 (env flow)

Maize

Wheat



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*



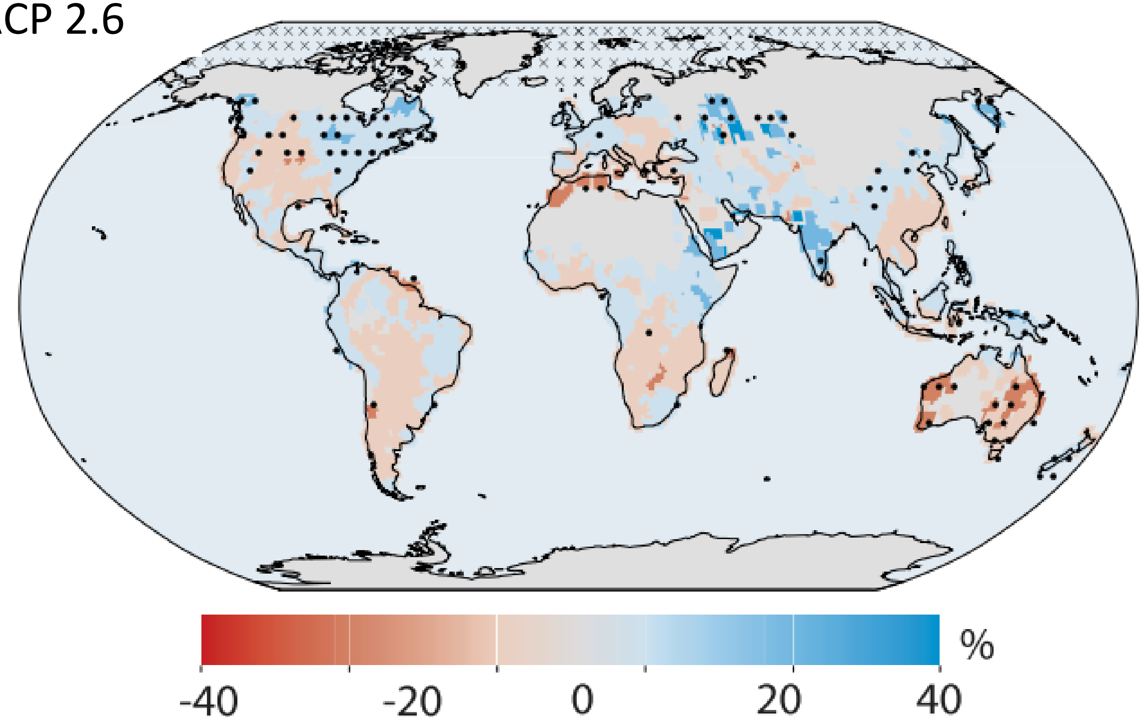
Crop yields change 1.5, 2.0 and 3.0°C GMT change (left to right), from Byers et al. 2018, *ERL*

Climate Feedback: Hydropower potential

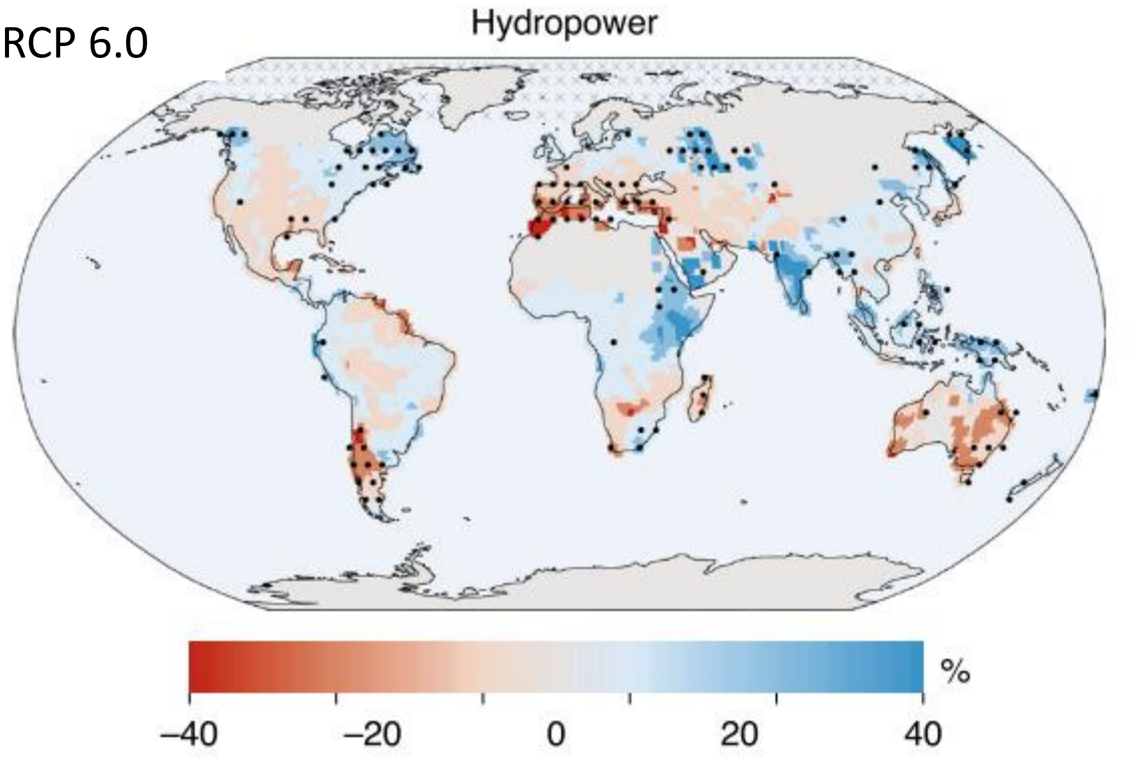
Some regions benefit, some regions show declining potential

Adaptation→ expand hydro switch to other energy sources
SDG→ Both benefits and trade-off with SDG 7 and SDG 13

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***

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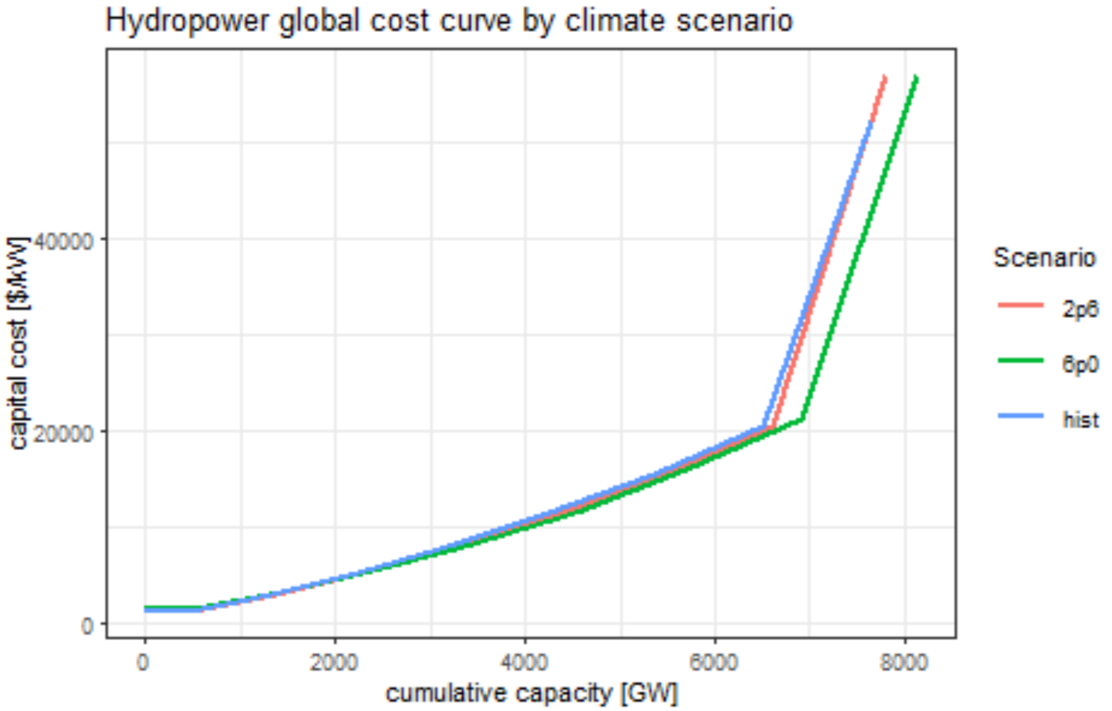

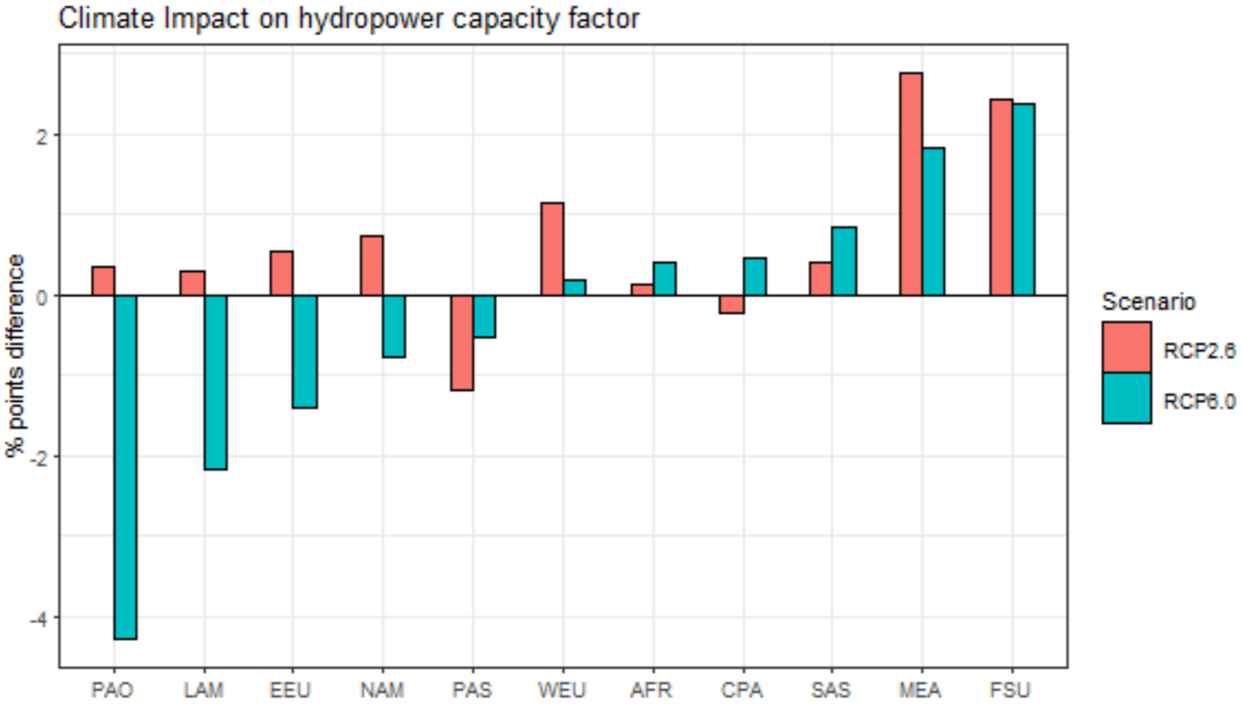

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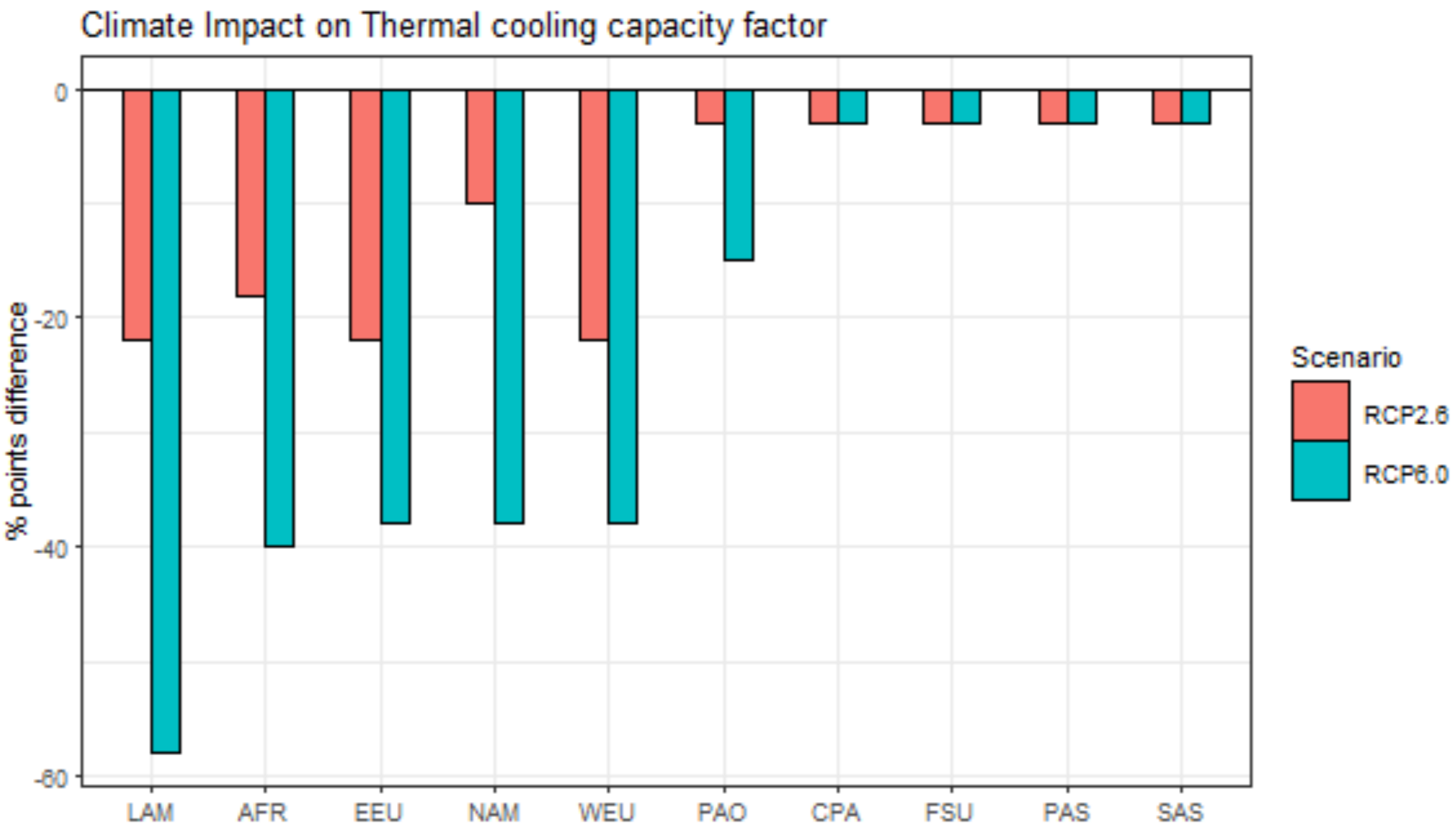
Climate Feedback: Thermal power plant cooling

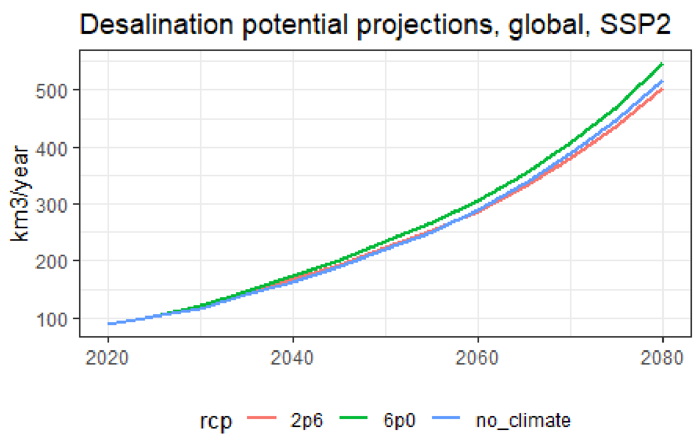
Cooling capacity factor reductions from van Vliet et al. (2021) water availability and thermal pollution

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

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



Climate Feedback: Desalination potential



Desalination potential depends on governance capacity and water stress

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

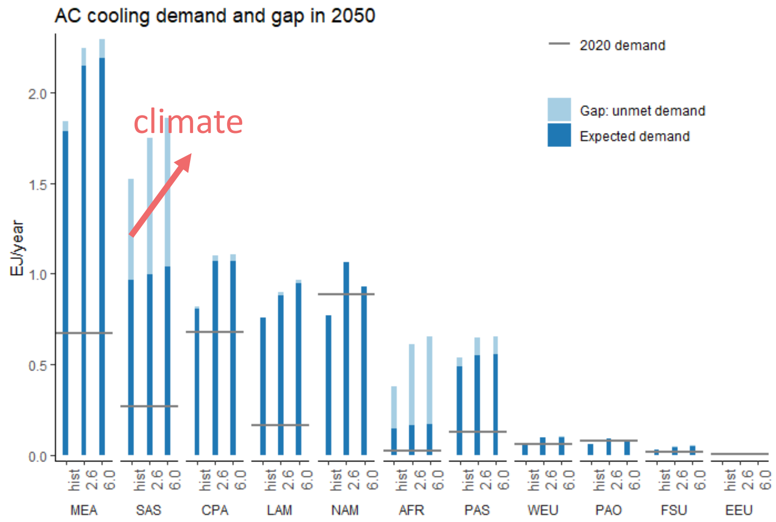
SDG→ Small variations across climate, impacts on SDG 6 costs

Adaptation→ Desalination itself, other water sources

Climate Feedback: 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

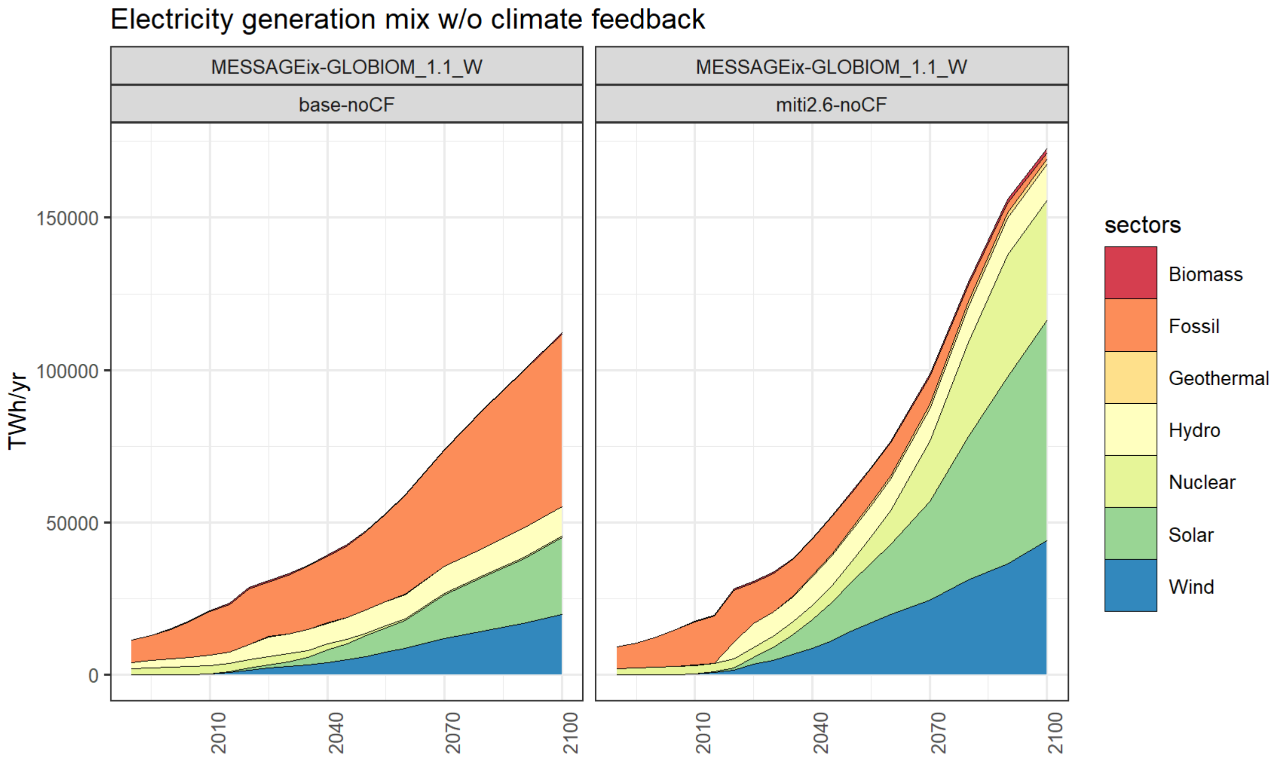
SDG→ interactions with SDG 7, energy access, higher energy requirements for RCP 6.0

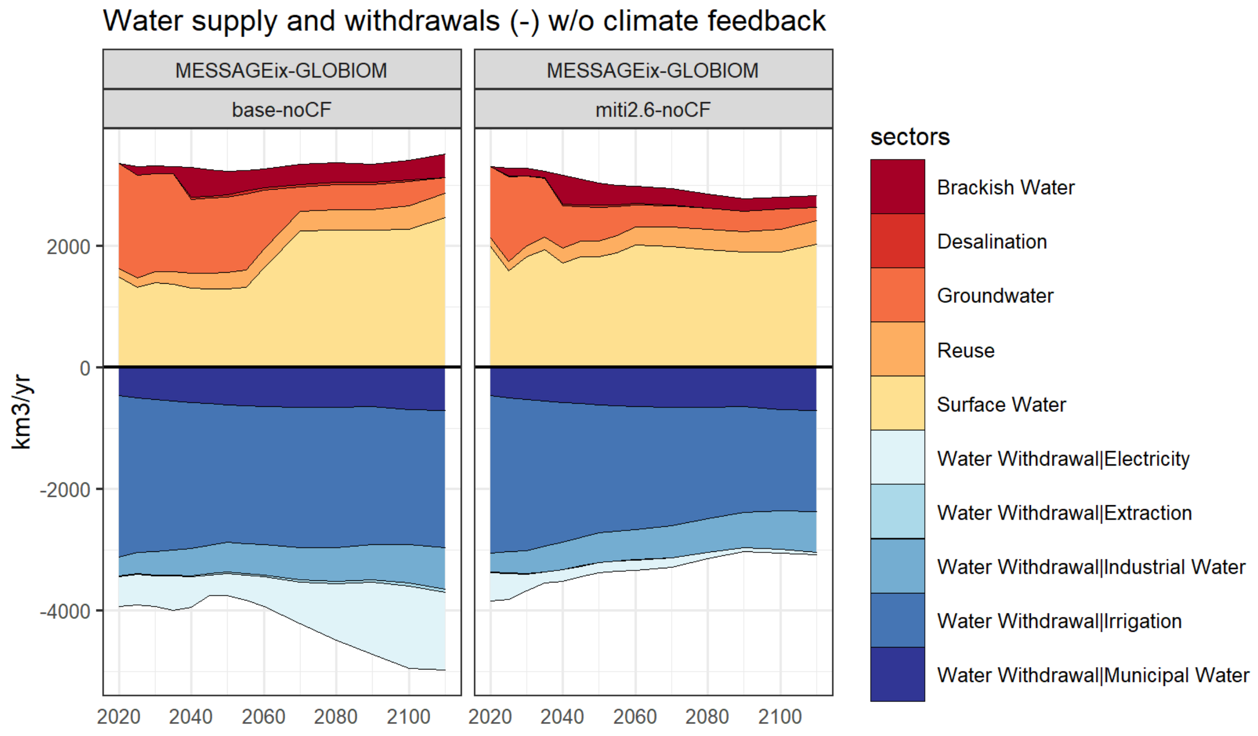


SSP2 projections from Mastrucci et al. 2021, Climatic Change

Electricity generation mix and water supply (all sectors)

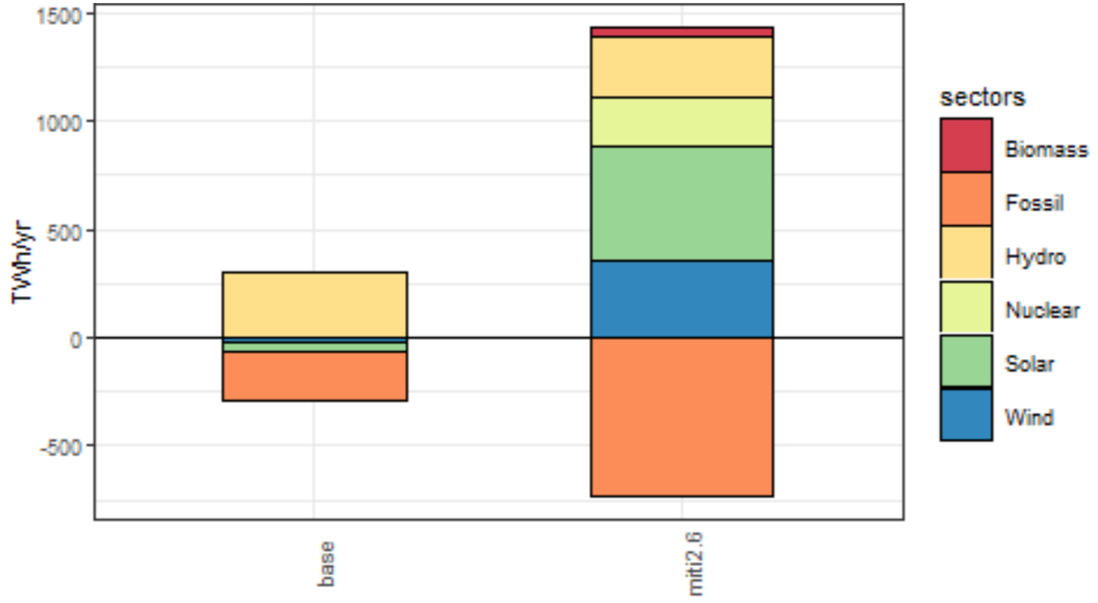
No climate change impacts or feedbacks



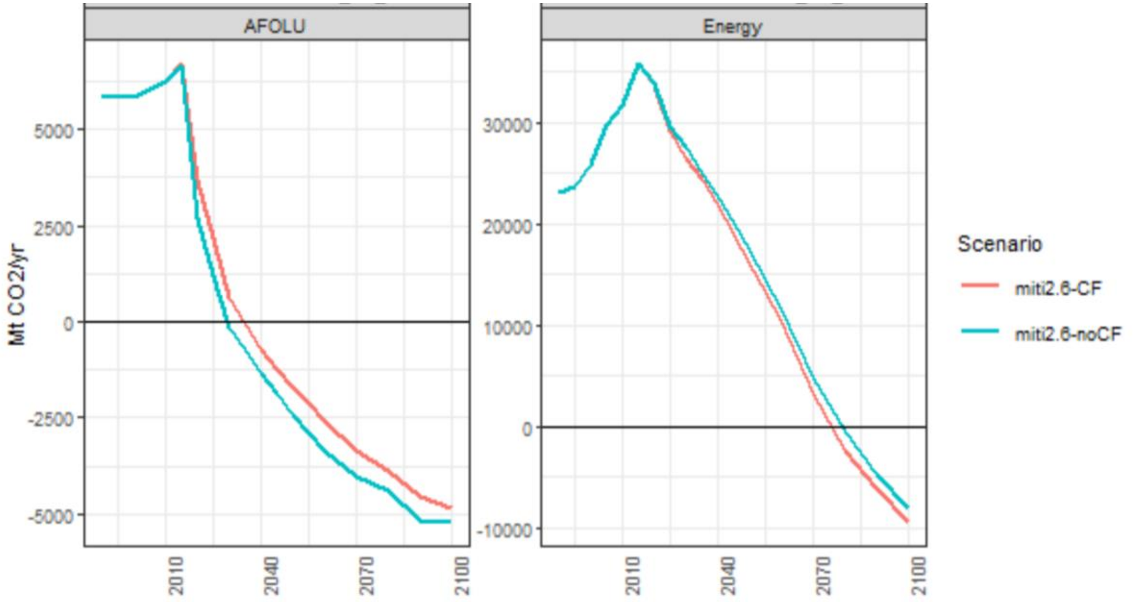


Climate Feedbacks: Electricity mix and CO_2 emissios

Change in electricity generation due to climate feedbacks



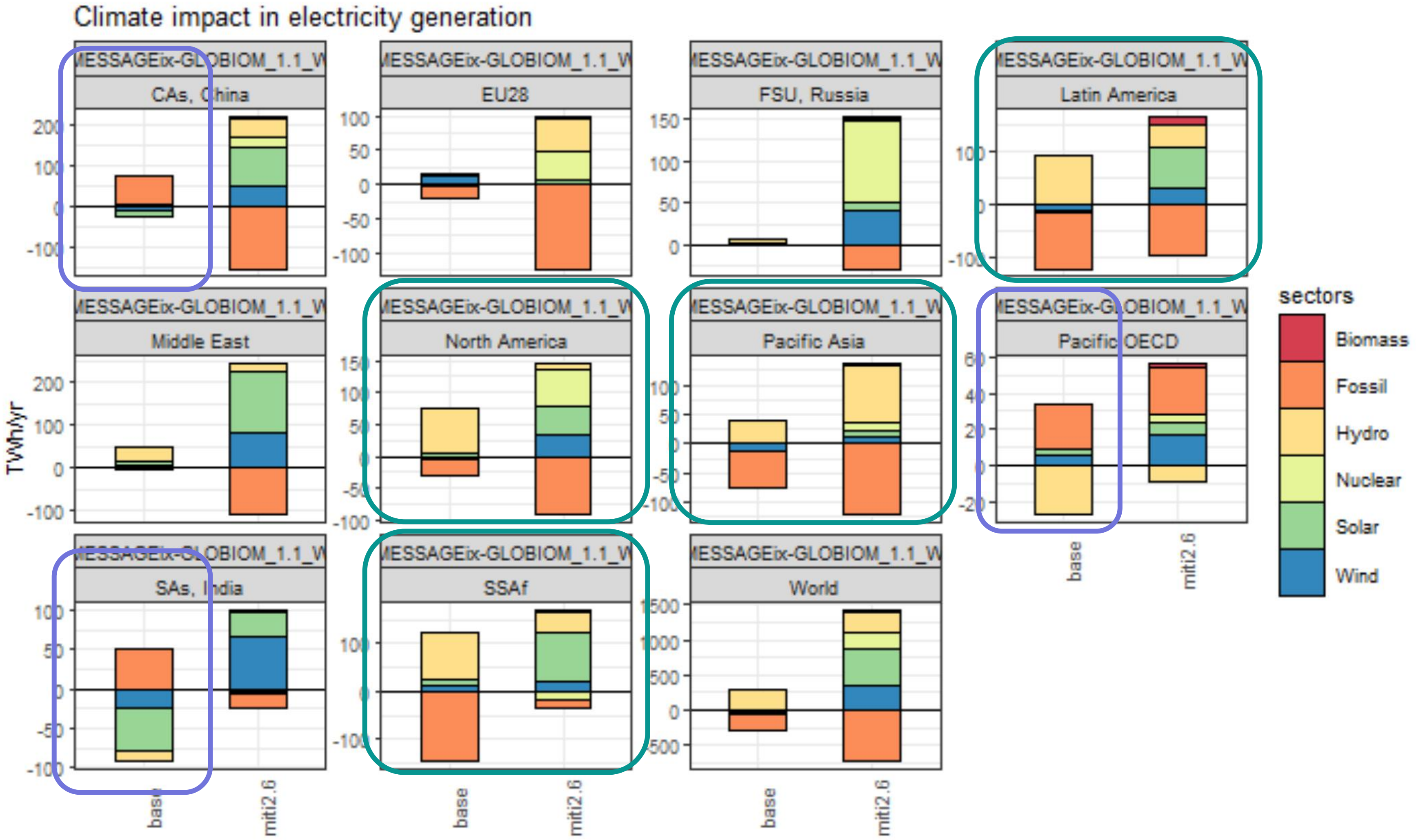
CO_2 emissions with and without climate feedbacks



Climate feedbacks:

- Acceleration of the phase-out of fossil fuels in power generation
- Slightly higher CO_2 prices (8%)
- Little impact though on overall CO_2 emissions

Climate Feedback results: Electricity generation mix



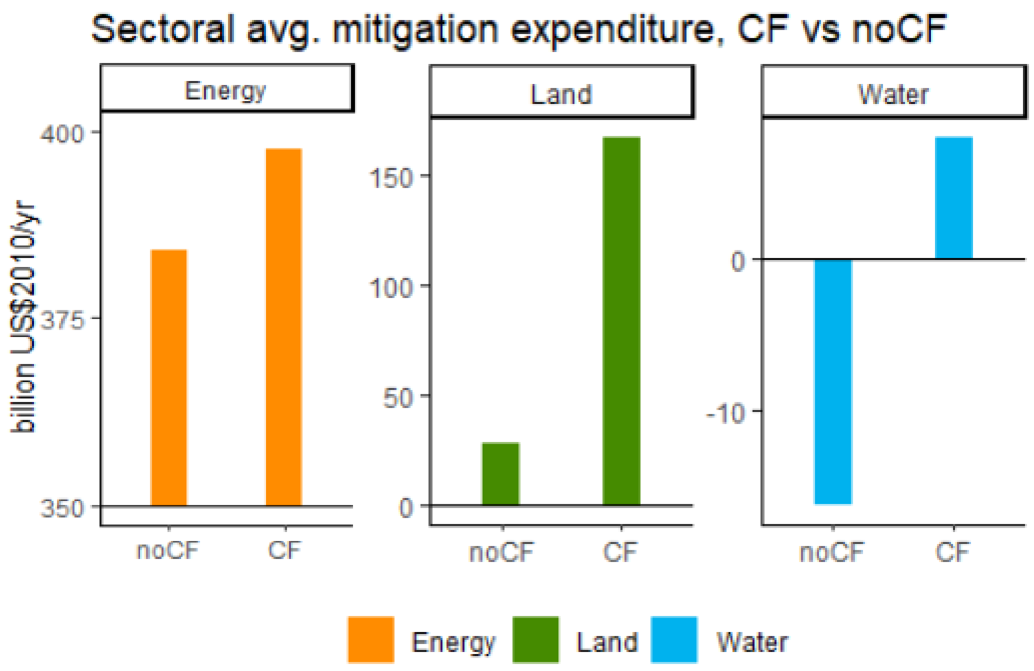
RCP 6.0

Low impacts on thermal cooling and on hydro

Strong impact on thermal cooling and/or hydro increase

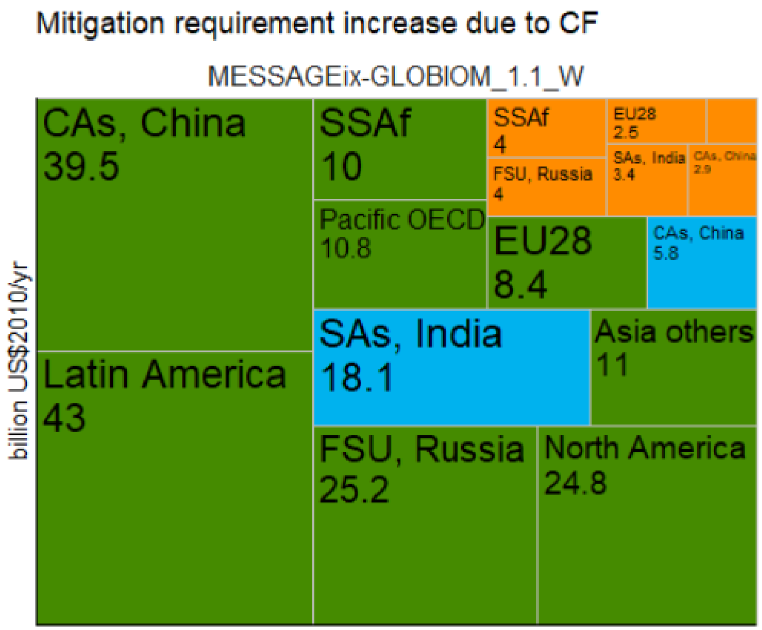
Mitigation investments w or w/o climate impacts

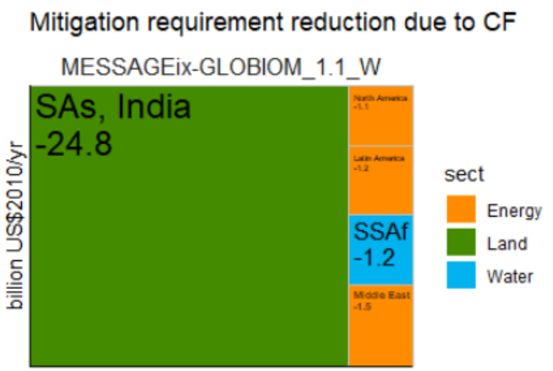
Global average mitigation requirements would increase from 396 to 572 billion$/year: **+ 44%** When including climate feedbacks



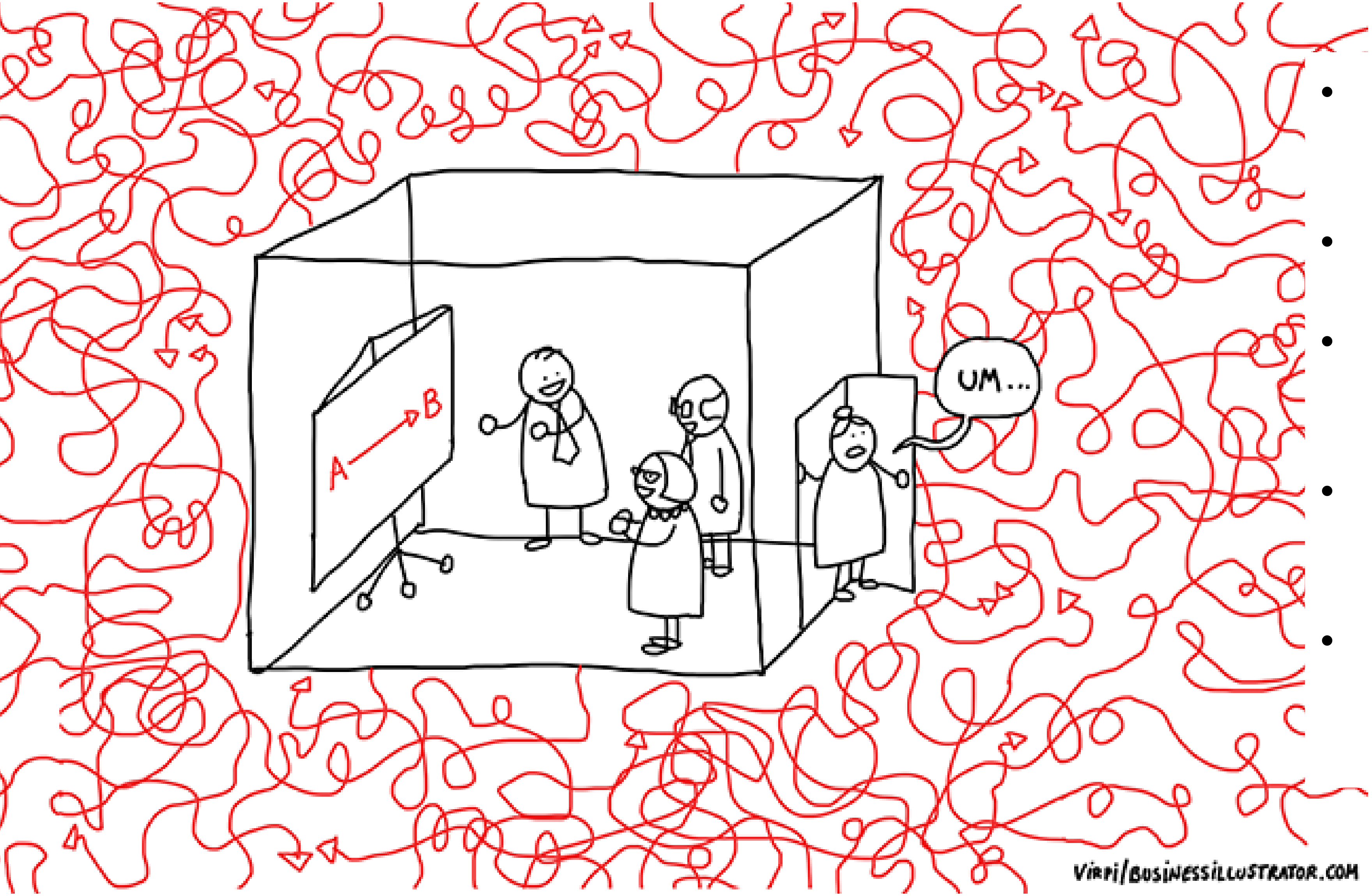
Most regions, and sectors show slightly increased in mitigation required investments when adding CF:

- China, India, SSA energy
- Lam, FSU, SSA, Pacific OECD, North America, Asia other, China land
- China, India water





Final considerations



- A first (baby)step towards better integration of complex biophysical impacts
- Further analysis of complexity of some responses
- Better representation of extremes and temporal granularity
- More model sensitivity to understand hydrological uncertainties and responses
- Translation to macroeconomic impacts still outstanding

Thank you!

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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