Development of a very low emission scenario for climate change research in line with the Paris Agreement long-term goal

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General context

The 2015 Paris Agreement calls for nations to pursue efforts to limit global-mean temperature rise to 1.5°C. While researchers have extensively explored transition pathways limiting warming below 2°C, the same cannot be said for 1.5°C. Here we present **new community scenarios** that limit end-of-century radiative forcing to 1.9 Wm^{-2}. **Median year-2100 warming in these scenarios is limited to less than 1.5°C, although this level is temporarily exceeded in earlier years.** Scenarios presented here are an extension of efforts to provide scenarios for the integrated assessment of climate-change-related challenges: **the SSP scenario matrix framework**. This framework provides a basis of internally consistent socioeconomic assumptions that represent development along five distinct storylines:

- SSP1: development under a green-growth paradigm
- SSP2: middle-of-the-road development along historical patterns
- SSP3: regionally heterogeneous development
- SSP4: development breeding geographical & social inequalities
- SSP5: development path dominated by high energy demand supplied by extensive fossil-fuel use.

Six integrated assessment modelling (IAM) teams, using five Shared Socioeconomic Pathways (SSPs) participated:

- AIM (NIES – Japan)
- GCAM (PNNL – USA)
- IMAGE (PBL – The Netherlands)
- MESSAGE-GLOBIOM (IIASA – International/Austria)
- REMIND-MAgPIE (PIK – Germany)
- WITCH-GLOBIOM (FEEM – Italy)

Each team attempted to model scenarios that limit end-of-century RF to 1.9 Wm^{-2} under various SSPs (see Figure on the right).

This study provides detailed emissions and land-use developments of a very stringent climate mitigation future for analysis in the Scenario Model Intercomparison Project (ScenarioMIP) of the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6), which will provide the bulk of the climate model information for the Sixth Assessment Report (AR6) of the IPCC.

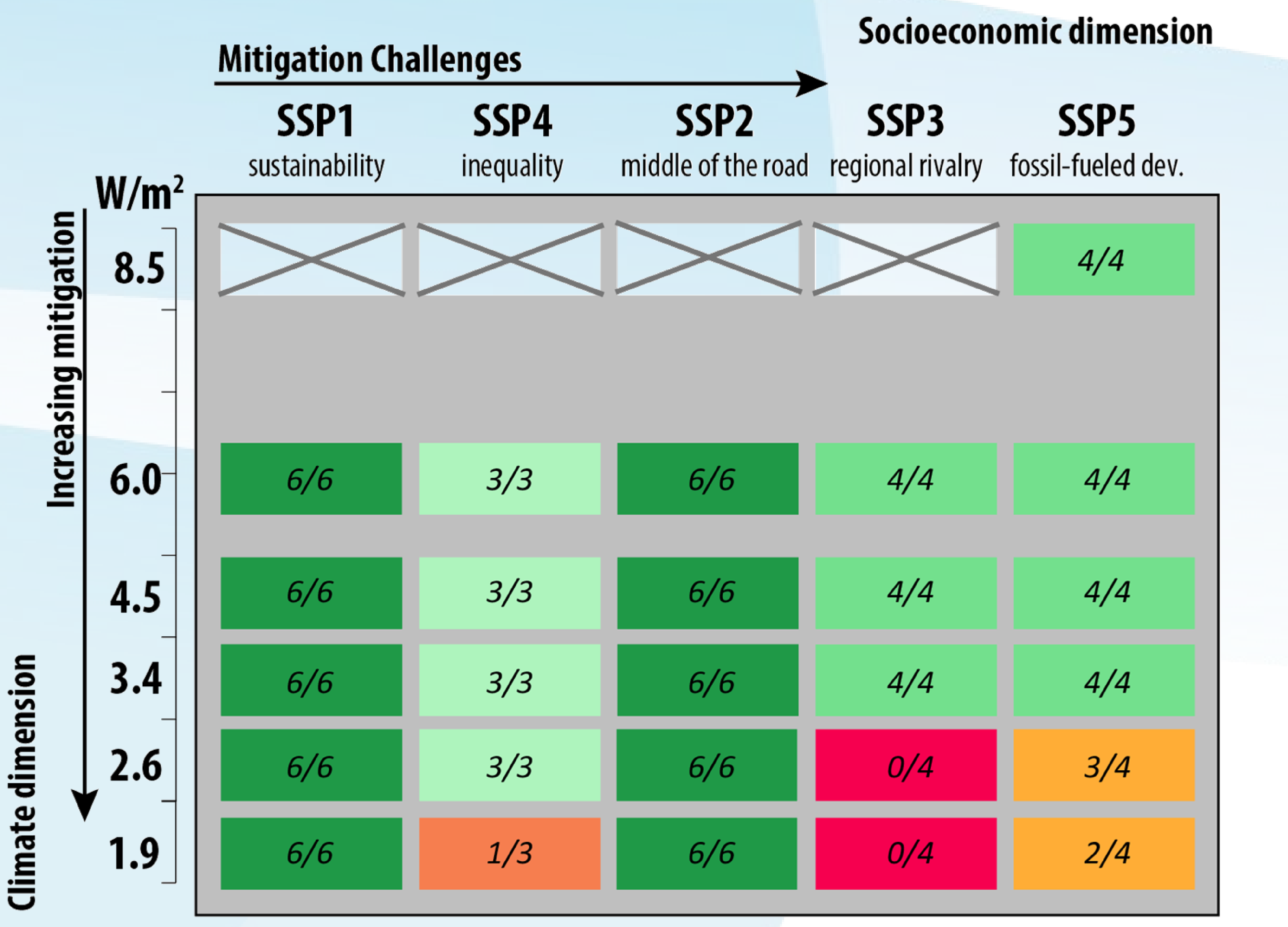

Figure – Overview of successful scenario runs in SSP matrix framework. Values show the number of successful runs over the number of participating modelling frameworks.

Emission pathways & climate characteristics

Timing of net zero emissions & carbon budgets

- net zero greenhouse gas (GHG) emissions around 2050-2075
- timing inversely correlated with 2030 emissions, e.g. for example, scenarios with GHG emissions higher than 40 GtCO$_2$-eq yr^{-1} reach net zero GHG emissions before 2060.
- net zero CO$_2$ emissions reached earlier
- phase-out of industry and energy-related CO$_2$ generation at a rate of 0.3-7.1%yr^{-1} (median: 3.3%yr^{-1}), combined with upscaling of carbon capture and storage (CCS) and CO$_2$ removal (CDR).
- cumulative CO$_2$ emissions over the 2016-2100 period range from -250 to 450 GtCO$_2$ (SSP2 median: 300 GtCO$_2$, rounded to the nearest 25 GtCO$_2$). End-of-century non-CO$_2$ RF strongly influences the variation across this range (see Figure).

Likelihood of warming depends on near-term emission evolution in 1.9 Wm^{-2} scenarios

- warming kept below 2°C with more than 66% probability
- peak median (50%) temperature between 1.5°C to 1.8°C
- warming kept below 1.5°C with ca. 66% probability by 2100
- higher 2030 emissions come with temperature penalty, e.g. the probability of limiting peak warming below 1.5°C is roughly halved and peak temperature about 0.2°C higher if emissions are at the high (>45 GtCO$_2$-eq yr^{-1}) instead of the low (<30 GtCO$_2$-eq yr^{-1}) end of the available range in 2030.

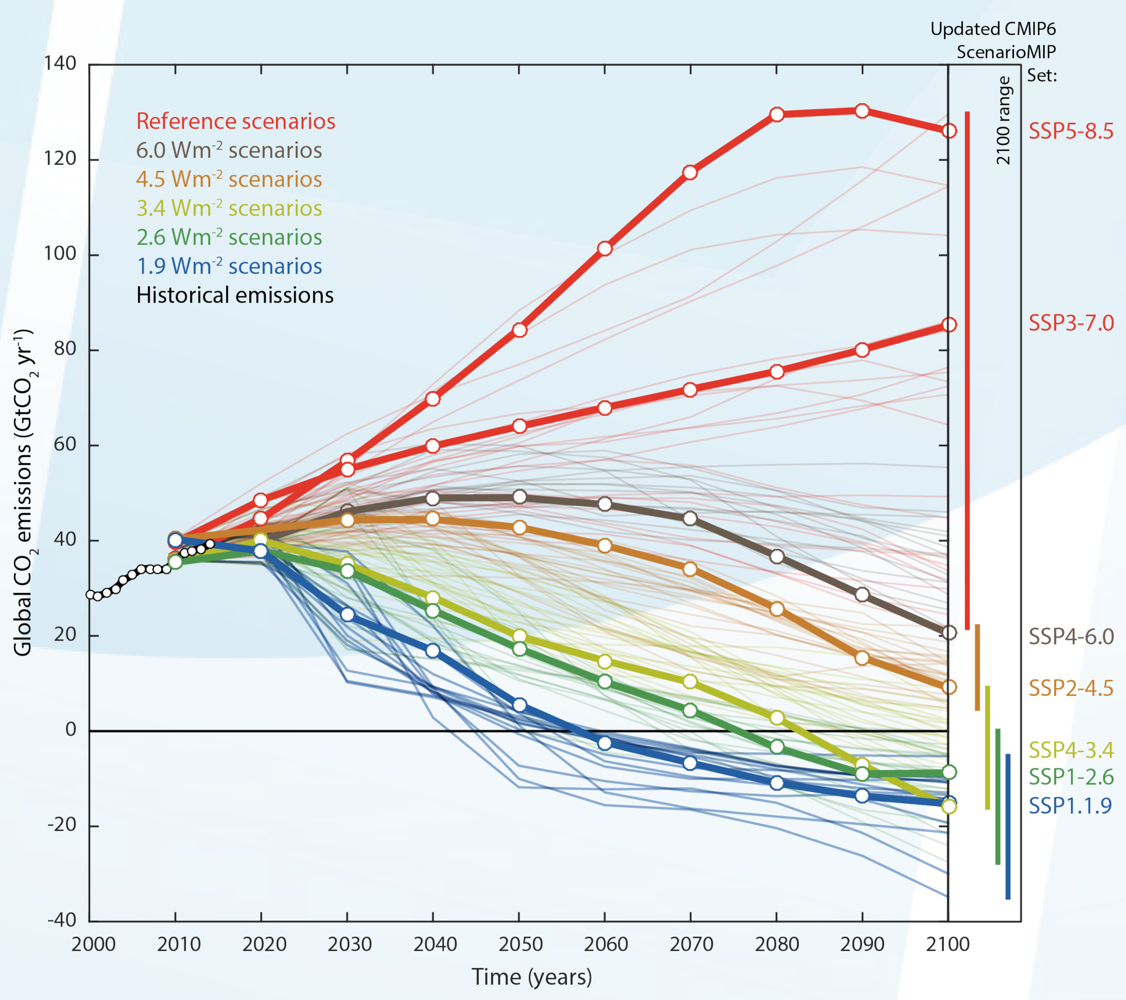

Figure – Global CO$_2$ emissions of current SSP scenarios with the subset selected for CMIP6 ScenarioMIP highlighted. Historical emission are from the Global Carbon Project.

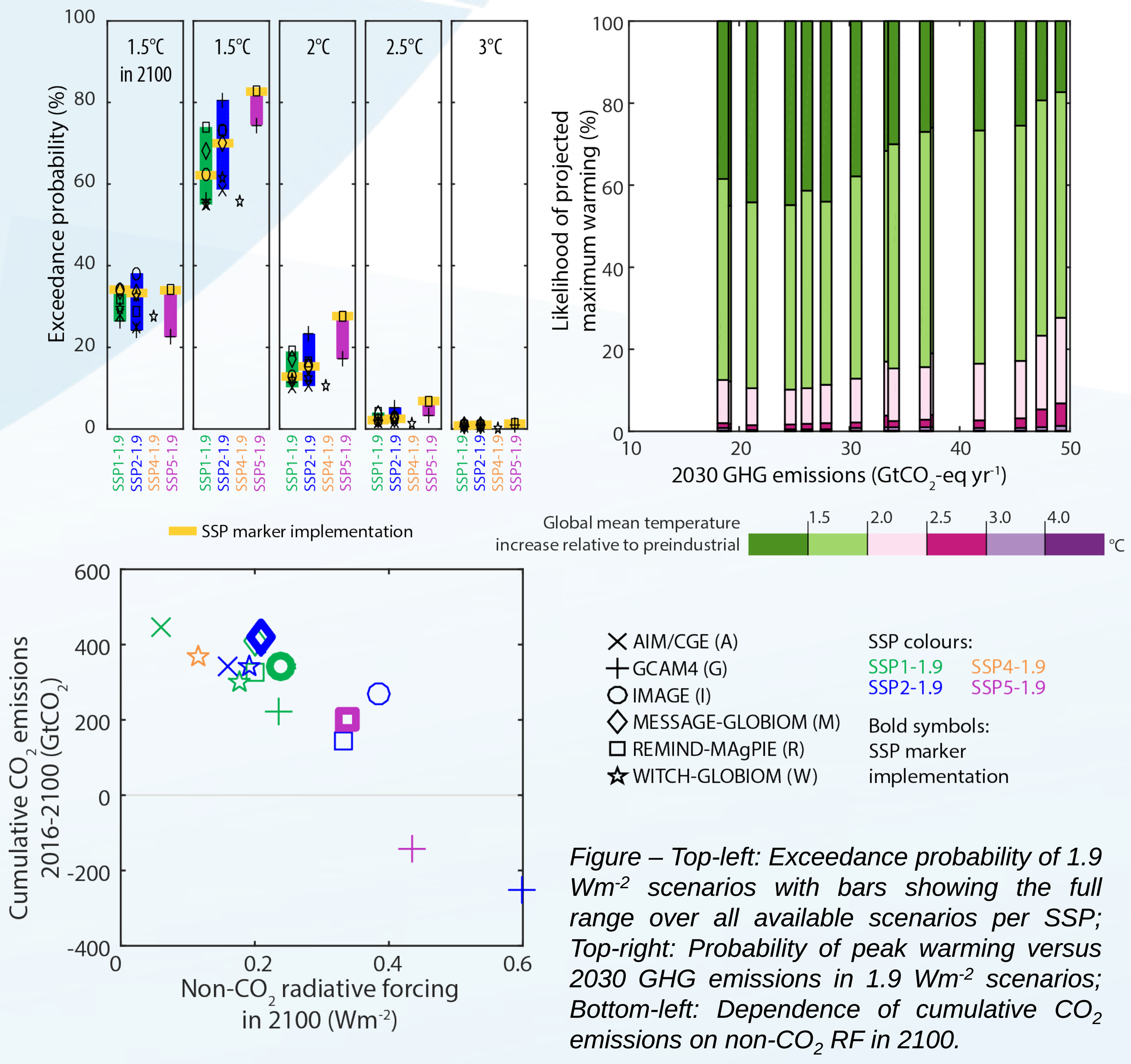

Figure – Top-left: Exceedance probability of 1.9 Wm^{-2} scenarios with bars showing the full range over all available scenarios per SSP; Top-right: Probability of peak warming versus 2030 GHG emissions in 1.9 Wm^{-2} scenarios; Bottom-left: Dependence of cumulative CO$_2$ emissions on non-CO$_2$ RF in 2100.

Transformation characteristics

Differential mitigation efforts

Moving from 2°C to 1.5°C implies stronger near-term action until 2030 and 2040, a stronger decarbonisation pace in the first half of the century and stronger emissions reductions in end-use sectors.

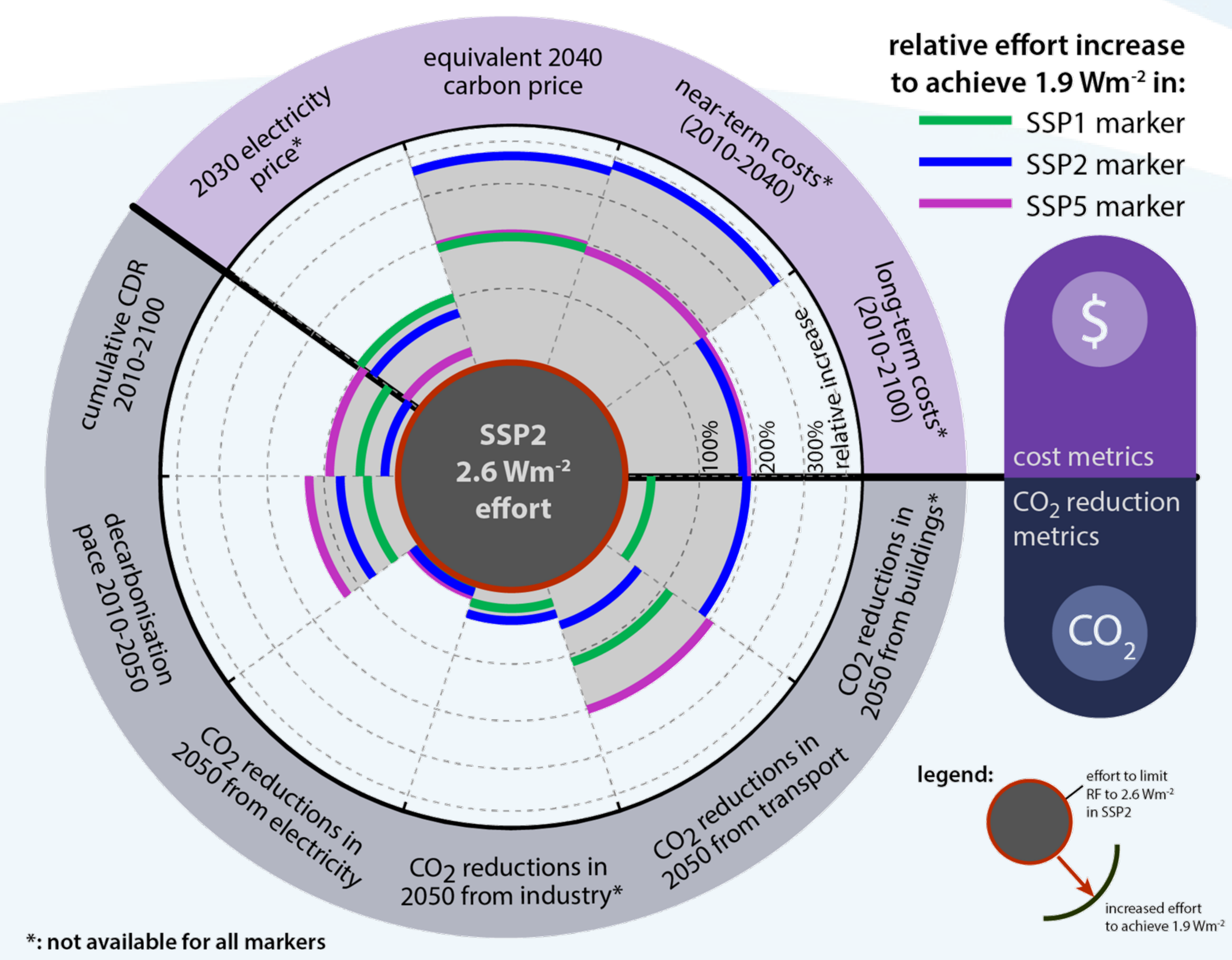

Figure – Differential mitigation characteristics when moving from a 2.6 Wm^{-2} to a 1.9 Wm^{-2} scenario. Indicators are: long-term mitigation costs (2010–2100 aggr. consumption losses rel. to baseline disc. at 5%); short-term mitigation costs (2010–2040 aggr. disc. at 5%); 2040 global equiv. carbon price level; electricity price in 2030; cum. CDR between 2010 and 2100 incl. BECCS and CO$_2$ removal by land use and land-use change; decarbonisation pace (av. linear 2010–2050 rate of reductions in energy-related CO$_2$ emissions); reductions in CO$_2$ emissions from electricity from baseline in 2050; reductions in CO$_2$ emissions from industry from baseline in 2050; reductions in CO$_2$ emission from transport from baseline in 2050; and reductions in CO$_2$ emissions from buildings from baseline in 2050.

Differential mitigation challenges

Not all 1.5°C scenarios are created equal. Mitigation challenges differ considerably depending on the overall socioeconomic development.

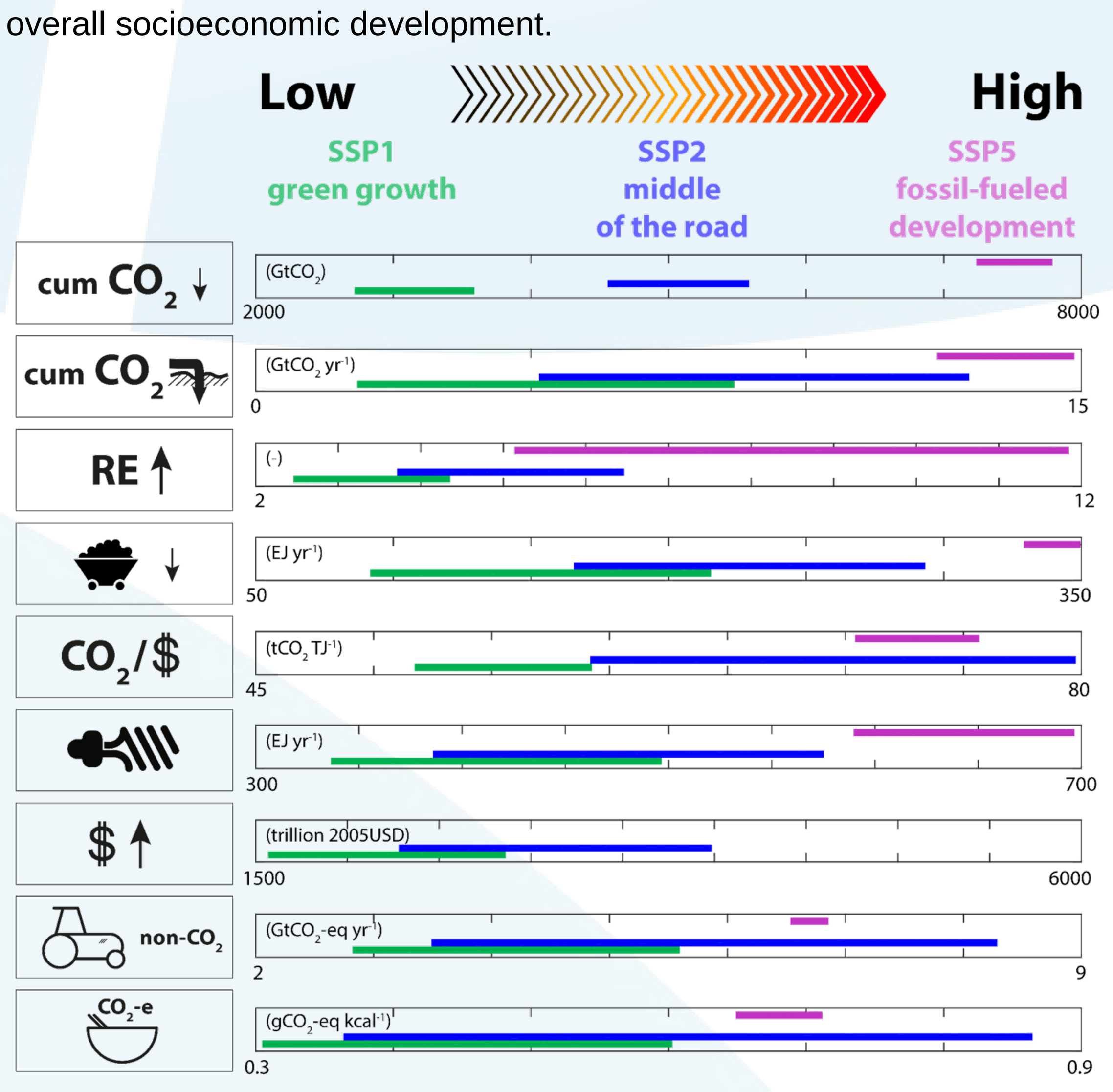

Figure – Variation in mitigation challenges in 1.9 Wm^{-2} scenarios. Ranges show the minimum-maximum range across models per SSP. Panels show various dimensions of climate change mitigation challenges: (i) cumulative CO$_2$ mitigation from baseline in 2020-2100 period; (ii) average CO$_2$ storage from BECCS over 2020-2100 period; (iii) upscaling of low-carbon primary energy share in 2050 rel. to baseline; (iv) reduction in coal primary energy in 2050 rel. to baseline; (v) reduction in carbon intensity of primary energy in 2050 rel. to baseline; (vi) average final energy demand over 2020-2100 period; (vii) average annual energy system investment over 2020-2100 period; (viii) emission intensity of food production in 2050; (ix) non-CO$_2$ emissions from agriculture in 2050.

References

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SSP storylines: O'Neill, B. et al. (2017). "The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century." Global Environmental Change 42: 169-180