Supplementary Information

Uncompensated claims to fair emission space risk putting Paris Agreement goals out of reach

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Region definitions applied in this paper

In this paper, we have used the R10-level scenario information published by the IPCC. In Table S1 below, we provide a brief overview of the regional definitions, using the information published along with the AR6 scenario database (Byers *et al.*, 2022). We also group the scenarios according to the composite regions which are used to present the information in this paper.

Table S1: Regional definitions. We also indicate the composite region definitions applied for Figure 1, Figure 2, and Figure 3 in the main text.

Region name	Region definition
Composite region from this paper: Developed Region [DR]	
R10NORTH_AM	North America; primarily the United States of America and Canada
R10EUROPE	Eastern and Western Europe (i.e., the EU28)
R10PAC_OECD	Pacific OECD
R10REF_ECON	Reforming Economies of Eastern Europe and the Former Soviet Union; primarily Russia
Composite region from this paper: Other Developing Region [ODR]	
R10CHINA+	Countries of centrally-planned Asia; primarily China
R10REST_ASIA	Other countries of Asia, except R10INDIA+
R10MIDDLE_EAST	Countries of the Middle East; Iran, Iraq, Israel, Saudi Arabia, Qatar, etc.
R10LATIN_AM	Countries of Latin America and the Caribbean
Individual regions assessed	
R10INDIA+	Countries of South Asia; primarily India
R10AFRICA	Countries of Sub-Saharan Africa

Applying the equal cumulative per capita emissions scheme from 1850-2019

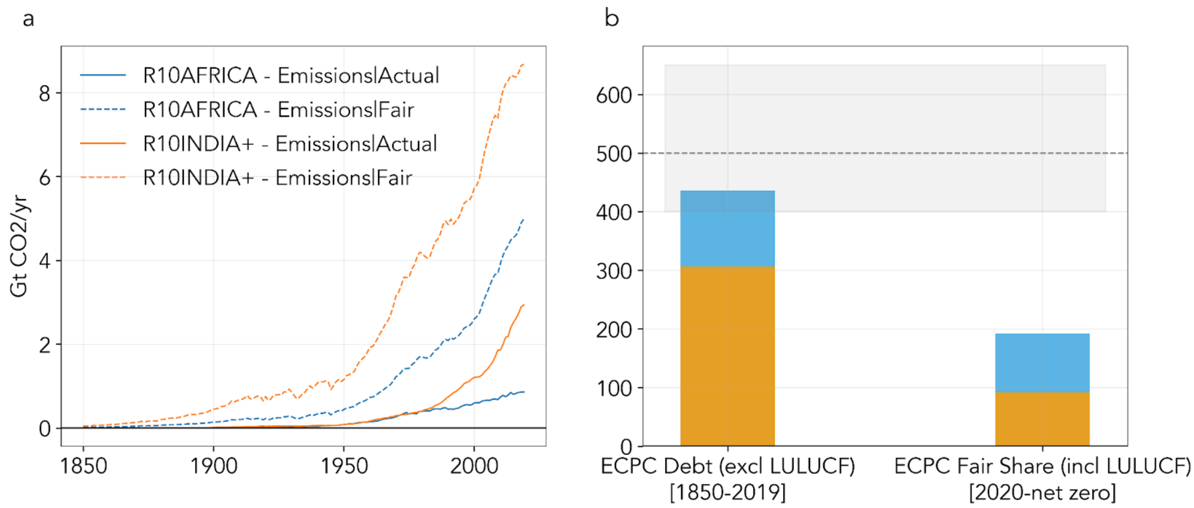

Figure S1: Comparing the equal cumulative per capita approach applied from 1850. (a) Emission pathways (actual versus the equal per capita counter factual), (b) Cumulative emission allowances in proportion to the debt.

Here, we calculate the moral claim for R10INDIA+ and R10AFRICA starting from the year 1850. Given data limitations for CO_2 land use, land use change, and forestry emissions (LULUCF), we restrict our analysis to total CO_2 emissions excluding land use, land use change, and forestry. We draw the emissions from the PRIMAP-Hist dataset, and the population estimates from a composite dataset published by Our World in Data (Gütschow, Günther and Pflüger, 2021; Our World in Data, 2022). We compare this cumulative emission allowance (i.e., moral claim between 1850-2019) and the moral claim to the remaining carbon budget (Figure S1b). This figure accompanies the analysis presented in the section “Focusing on the remaining carbon budget” in the main text.

Regional scenarios selected to construct global synthetic scenarios

In Table S2, we indicate the specific regional scenarios from the AR6 scenario database used to construct the synthetic emission scenarios (per modelling framework). The labels ‘min’ and ‘max’ in each cell indicates the scenarios with the minimum and maximum CO_2 emissions until regional net zero CO_2 emissions. Please note that we do not use the ‘max’ scenarios for developed regions.

Table S2: Regional scenarios per modelling framework underlying synthetic scenarios

	GCAM 5.3	IMAGE 3.2	MESSAGEix-GLOBIOM_1.1	REMIND 2.1	REMIND-MAgPIE 2.1-4.2	WITCH 5.0
R10CHINA+	'min':'R_MAC_30_n0', 'max':'R_MAC_75_n8'	'min':'SSP1_SPA1_19I_RE_LB', 'max':'SSP1_SPA1_26I_LIRE'	'min':'EN_NPi2020_500', 'max':'EN_NPi2020_1200'	'min':'CEMICS_GDPgrowth_1p5', 'max':'LeastTotalCost_CBA_brkSR15_SSP2_P50'	'min':'EN_NPi2020_400', 'max':'EN_INDCi2030_1200'	'min':'EN_NPi2020_450', 'max': 'EN_INDCi2030_1000f'
R10EUROPE	'min': 'R_MAC_30_n0' 'max': 'R_MAC_75_n8'	'min':'SSP1_SPA1_19I_LIRE_LB', 'max':'SSP2_SPA2_26I_D'	'min':'EN_NPi2020_450', 'max':'EN_NPi2020_1200_COV'	'min': 'R2p1_SSP1-PkBudg900', 'max':'LeastTotalCost_LTC_brkSR15_SSP5_P50'	'min':'NGFS2_Net-Zero 2050 - IPD-median', 'max':'EN_NPi2020_1200'	'min': 'EN_NPi2020_450', 'max': 'EN_INDCi2030_1000f_NDCp'
R10LATIN_AM	'min':'R_MAC_30_n0', 'max': 'NGFS2_Below 2°C'	'min':'SSP1_SPA1_19I_LIRE_LB', 'max': 'SSP2_SPA2_26I_D'	'min':'EN_NPi2020_450', 'max': 'EN_INDCi2030_1200_COV_NDCp'	'min': 'R2p1_SSP5-PkBudg900', 'max':'LeastTotalCost_CBA_brkSR15_SSP2_P50'	'min': 'EN_NPi2020_400', 'max': 'EN_INDCi2030_1000_NDCp'	'min':'EN_NPi2020_450', 'max':'EN_INDCi2030_1000f_NDCp'
R10MIDDLE_EAST	'min': 'R_MAC_35_n8', 'max': 'R_MAC_65_n0'	'min':'SSP1_SPA1_19I_RE_LB', 'max':'SSP1_SPA1_26I_LIRE'	'min': 'NGFS2_Delayed Transition', 'max': 'EN_NPi2020_1200'	'min': 'R2p1_SSP5-PkBudg900', 'max': 'LeastTotalCost_CBA_brkSR15_SSP2_P50'	'min':'EN_NPi2020_400', 'max':'EN_NPi2020_1200'	'min': 'CO_Bridge', 'max': 'EN_NPi2020_1000f'
R10NORTH_AM	'min':'R_MAC_30_n0', 'max':'R_MAC_75_n8'	'min': 'SSP2_SPA1_19I_LIRE_LB', 'max':'SSP1_SPA1_26I_D'	'min':'EN_NPi2020_450', 'max':'EN_NPi2020_1200_COV'	'min': 'R2p1_SSP1-PkBudg900', 'max':'CEMICS_GDPgrowth_2C'	'min':'EN_NPi2020_400', 'max':'EN_NPi2020_1200f'	'min':'EN_NPi2020_450', 'max':'EN_INDCi2030_1000f'
R10PAC_OECD	'min':'R_MAC_35_n8', 'max':'R_MAC_65_n0'	'min':'SSP1_SPA1_19I_LIRE_LB', 'max':'SSP1_SPA1_26I_RE'	'min': 'EN_NPi2020_450', 'max':'EN_NPi2020_1200_COV'	'min': 'R2p1_SSP1-PkBudg900', 'max':'CEMICS_GDPgrowth_2C'	'min': 'EN_NPi2020_400', 'max': 'EN_INDCi2030_1200'	'min':'EN_NPi2020_450', 'max':'EN_INDCi2030_1000f_NDCp'
R10REF_ECON	'min':'R_MAC_30_n0', 'max': 'NGFS2_Below 2°C'	'min':'SSP1_SPA1_19I_LIRE_LB', 'max':'SSP2_SPA2_26I_D'	'min':'EN_NPi2020_450', 'max':'EN_NPi2020_1200'	'min':'CEMICS_Linear_1p5', 'max':'LeastTotalCost_CBA_brkSR15_SSP2_P50'	'min':'EN_NPi2020_400', 'max':'EN_INDCi2030_1200'	'min':'EN_NPi2020_450', 'max':'EN_INDCi2030_1000f_NDCp'
R10REST_ASIA	'min': 'R_MAC_35_n8', 'max': 'R_MAC_65_n0'	'min':'SSP1_SPA1_19I_LIRE_LB', 'max':'SSP1_SPA1_26I_LIRE'	'min':'EN_NPi2020_450', 'max':'EN_NPi2020_1200'	'min':'CEMICS_GDPgrowth_1p5', 'max':'LeastTotalCost_CBA_brkSR15_SSP2_P50'	'min':'EN_NPi2020_400', 'max':'EN_NPi2020_1200f'	'min':'EN_NPi2020_450', 'max':'CO_Bridge'

Other developing region emissions at global net zero CO_2

In Table S3, we show the regional emission profiles (for the developing regions) in the year of global net zero CO_2, relative to 2015 emission levels.

Table S3: Regional emissions at global net zero CO_2 (relative to 2015 emissions) [%]

	R10LATIN_AM_normalised		R10CHINA+_normalised		R10MIDDLE_EAST_normalised		R10REST_ASIA_normalised	
stat_type	**max**	**min**	**max**	**min**	**max**	**min**	**max**	**min**
model								
GCAM 5.3	-7	-33	-3	-16	25	3	8	-38
IMAGE 3.2	-65	-133	7	-4	58	1	13	-4
MESSAGEix-GLOBIOM_1.1	-42	-86	3	-1	49	1	13	1
REMIND 2.1	-16	-75	-1	-13	47	20	31	-14
REMIND-MAgPIE 2.1-4.2	-3	-5	-1	-4	28	15	19	-2
WITCH 5.0	-59	-161	18	10	71	-7	10	-15

Criteria to assess Paris Agreement consistency of scenarios

Here, we describe the criteria used to assess the Paris Agreement consistency of the synthetic emission scenarios (Table S4), based on the criteria proposed by Schleussner et al.,(2022).

Table S4: Criteria to assess Paris Agreement consistency of scenarios

Criterion	Specification
Crit I: "pursuing efforts to limit warming to 1.5°C"	• Pathways should not ever have a greater than 67% chance of exceeding 1.5°C • Pathways should bring warming to 1.5°C in 2100 with at least a 50% chance in case of overshoot
Crit II: hold warming to "well below 2°C"	• Pathways should keep warming below 2°C with at least a 90% chance throughout the century

Methane emissions compared for the ecpc_minc1_maxc3 case

Figure S2 accompanies the assessment presented in the section “Formal assessment of the warming outcomes of the scenarios” in the main text. Here, Scenario 1 refers to the ecpc_minc1_maxc3 case.

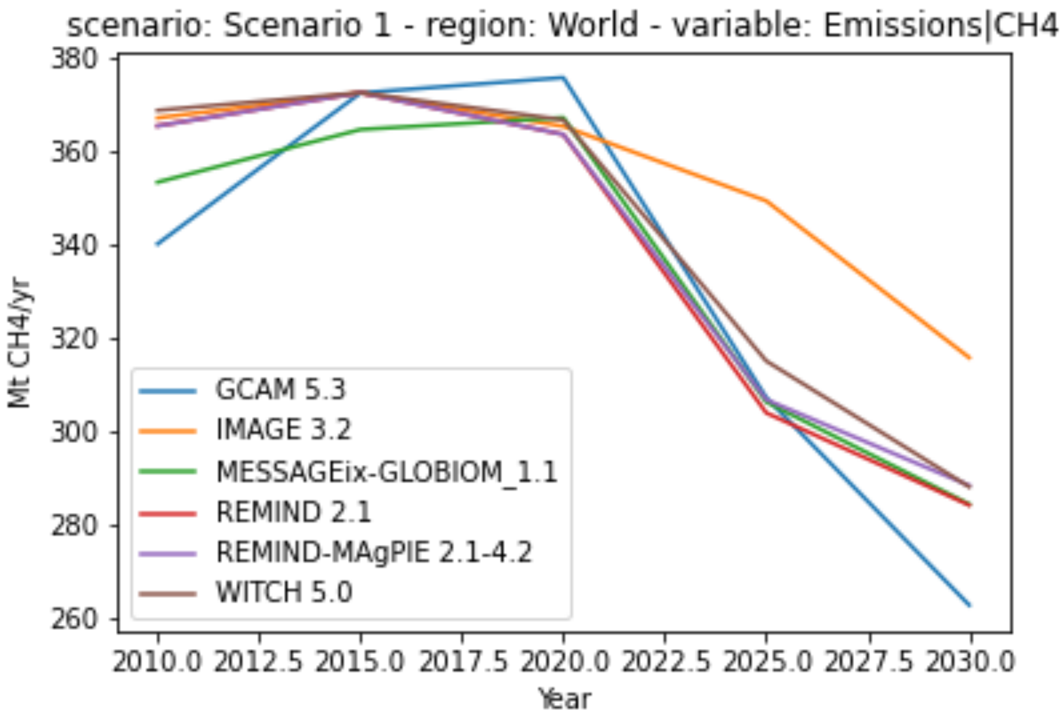

Figure S2: Comparison of infilled CH_4 emissions across the “ecpc_minc1_maxc3” scenarios.

References

Byers, E. *et al.* (2022) ‘AR6 Scenarios Database’. Zenodo. Available at: https://doi.org/10.5281/zenodo.5886912.

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