Working paper

Calculation of Paris-compatible Emission Targets for the Six Largest Emitters with the ESPM[1]

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Abstract

What are realistic emissions targets for the world's six largest emitters that sum up to Paris-compatible emissions? To answer this question, this paper varies key global framework data on the available budget and the sharing mechanism to calculate top-down national emissions targets using the Extended Smooth Pathway Model (ESPM). The Paris Ambition Mechanism provides a combination of top-down and bottom-up approaches. For each country in the word the question arises to what extent their bottom-up targets fit with global needs. This might initiate a discourse on the global framework data that contributes to Paris-compatible NDCs in sum.

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[1] This paper is essentially an update of a publication in the "Zeitschrift für Umweltpolitik & Umweltrecht" (Sargl, et al., 2021) due to the publication of new data on the remaining budgets in the IPCC's AR6 WGI (IPCC, 2021) and new emission figures from EDGAR for all countries in the world (EDGAR, 2021).

See also analogous paper for Germany and the EU (Sargl, et al., 2022a).

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Global CO2 budgets

CO2 accumulates in the atmosphere.[2] If global warming is to keep within certain limits, the sum of CO2 emissions is therefore decisive. For the remaining global CO2 budgets, the IPCC published the figures in Tab. 1 in its Sixth Assessment Report 2021.

Warming	Remaining carbon budgets			Scenario variation	Geophysical uncertainties			
Probabilities:	*50%*	*67%*	*83%*	Non-CO2 scenario variation	Non-CO2 forcing and response uncertainty	Historical temperature uncertainty	ZEC uncertainty	Recent emissions uncertainty
[°C]	[GtCO2 from 2020 on]			[GtCO2]				
1.5	500	400	300	±220	±220	±550	±420	±20
1.6	650	550	400					
1.7	850	700	550					
1.8	1000	850	650					

Tab. 1: Remaining global CO2 budgets from 2020 onwards[3]

In the Summary for Policymakers, the IPCC states that (IPCC, 2021):

> "***D.1.1*** *(...) there is a near-linear relationship between cumulative anthropogenic CO2 emissions and the global warming they cause. Each 1000 GtCO2 of cumulative CO2 emissions is assessed to likely cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C. (...) This quantity is referred to as the transient climate response to cumulative CO2 emissions (TCRE). This relationship implies that reaching net zero anthropogenic CO2 emissions is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO2 emissions to within a carbon budget.*"

> "***D.1.2*** *(...) Remaining carbon budgets have been estimated for several global temperature limits and various levels of probability, based on the estimated value of TCRE and its uncertainty, estimates of historical warming, variations in projected warming from non-CO2 emissions, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO2 emissions reach net zero.*"

The need to assess socio-economic consequences in the speed of decarbonisation, the compliance probabilities and the bandwidths of variations and uncertainties in the budgets mentioned by the IPCC require a scientifically based political decision on the global CO2 budget to which nationally determined contributions (NDCs) should be oriented. In a landmark decision in 2021 the Federal Constitutional Court in Germany made this clear: Climate policy must be oriented towards remaining CO2 budgets (cf. BVerfG, 2021).[4]

If the Parties make the underlying global CO2 budget and its distribution transparent in their NDCs or if they are requested to do so, this could also initiate a discourse that ultimately leads to converging benchmarks for the global framework data.

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[2] The subscript of 2 in CO2 is generally omitted in this work for reasons of simplification.

[3] Tab. 1 based on Tables SPM.2 and 5.8 in the IPCC Sixth Assessment Report (cf. IPCC, 2021). The given probabilities indicate the percentage of the examined scenarios in which the temperature target is met (cf. MCC, 2020). For further scientific background information, please refer to the IPCC report. In 2019, global emissions were around 41 GtCO2 (Global Carbon Project, 2021).

[4] See also Excursus 1: German Federal Constitutional Court on CO2 budgets.

Current emission targets of the six largest emitters

Tab. 2 shows the baseline data for the six largest emitters in 2019. For comparison Nigeria is added as an example of a country with low per capita emissions and a low share of global emissions.

	emissions in Gt			per capita 2019 in t	share in global emissions 2019	share in global population 2019
	1990	2010	2019			
China	2.4	9.3	11.5	8	31%	18%
United States	5.1	6.0	5.0	15	14%	4%
EU27	3.8	3.7	2.9	7	8%	6%
India	0.6	1.2	2.6	2	7%	18%
Russia	2.4	1.7	1.8	12	5%	2%
Japan	1.2	1.3	1.1	9	3%	2%
sum	15.5	23.2	25.0		68%	50%
Nigeria	0.07	0.10	0.13	0.7	0.4%	2.6%
global	22.1	29.2	36.5	4.7	100%	

Tab. 2: Baseline data of the six largest emitters plus Nigeria[5]

Tab. 3 shows the current status of already submitted or announced NDC revisions of the six largest emitters, which together account for about 70% of global emissions (cf. Tab. 2):

country	target year 2030	reference year	long-term goals
United States	-50%	2005	climate neutrality by 2050
EU27	-55%	1990	
Japan	-46%	2013	
India	reduce emission intensity 45% in relation to the national product	2005	net zero 2070
Russia	at least -30%	1990	net zero 2060
China	turning point of CO2 emissions before 2030	-	CO2 neutrality before 2060

Tab. 3: Current emission targets of the six largest emitters[6]

The question arises, if these commitments are sufficient to meet the Paris climate targets, especially for the target year 2030. Due to the budgetary nature of CO2, the coming years are crucial to keeping the Paris climate targets within reach. Our way to answer to this question is to calculate national emission targets as reference values that arise top-down given different global framework data.

Before the UN Climate Change Conference in Glasgow (COP26), the UNFCCC Secretariat stated in its synthesis report that (UNFCCC, 2021):

> *"The total global GHG emission level in 2030, taking into account implementation of all the latest NDCs, is expected to be 15.9 per cent above the 2010 level. According to the SR1.5, to be consistent with global emission pathways with no or limited overshoot of the 1.5°C goal, global net anthropogenic CO2 emissions need to decline by about 45 per cent from the 2010 level by 2030, reaching net zero around 2050. For limiting global warming to below 2°C, CO2 emissions need to decrease by about 25 per cent from the 2010 level by 2030 and reach net zero around 2070."*

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[5] These are the CO2 emissions from fossil fuel use (except international shipping and aviation; ISA) and cement production (EDGAR, 2021). CO2 emissions from land-use change (LUC) are therefore not included here (see also Footnote 11).

[6] Source and further details at Climate Action Tracker (https://climateactiontracker.org; status as of 19/11/2021).

Calculation of national emission paths with the Extended Smooth Pathway Model

In order to calculate national emission targets for the six largest emitters based on global framework data, the Extended Smooth Pathway Model (ESPM) is used. The ESPM proceeds in two steps [cf. (Wiegand, et al., 2021) and (Sargl, et al., 2021):

(1) Determining national budgets

In order to derive national budgets from a global budget, an **allocation key** is needed.[7] The following exemplary national emissions targets use a weighted key that incorporates a country's share of global emissions and its share of the global population in 2019 (cf. Raupach, et al., 2014).[8] With this two-dimensional distribution key, the current emissions reflect the current reality and the population shares address the issue of climate justice. This leads to the following weighting formula:

$$B^i = \left(C * \frac{P_{BY}^i}{P_{BY}} + (1 - C) * \frac{E_{BY}^i}{E_{BY}} \right) * B$$

where

E_{BY} or E_{BY}^i	global emissions or emissions of country *i* in the base year; here: *BY* = 2019
P_{BY} or P_{BY}^i	global population or population of country *i* in the base year
B	global CO2 budget; here from 2020 onwards
B^i	national CO2 budget of the country *i*; here from 2020 onwards
C	weighting of population

(2) Derivation of national emission paths

Plausible emission paths are derived that adhere to the national budget. With the Regensburg Model Scenario Types, we offer the entire range of plausible possibilities (see Excursus 4). For reasons of simplification, a linear course of the **emission paths** (RM-6) is assumed below.[9]

The EU database EDGAR provides CO2 emissions excluding emissions from land-use change (**LUC**) and international shipping and aviation (**ISA**) for all countries in the world which are shown in Tab. 2 for the six largest emitters (cf. EDGAR, 2021).

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[7] On the general question about the distribution of a global budget, see Excursus 3.

[8] In some of our tools, it is also possible to specify national budgets that have been determined in a different way (see Chapter "Tools and further exemplary results "). For example, a base year other than 2019 can also be used.

[9] Due to the inclusion of actual emissions in 2020 and the consideration of a normalised value in 2020 when calculating emissions in 2021, the emission paths only fall on a straight line from 2022 onwards (see Fig. 1).

Before calculating national budgets on this data basis, budgets for LUC and ISA emissions must be deducted from the global budget (see exemplary calculations in Tab. 4).[10] The national budgets derived from this global CO2 budget thus include CO2 emissions from fossil fuel use (except ISA) and cement production.

The assumption about the global LUC budget has a significant impact on the concrete emission targets for countries. For the LUC budget, the illustrative model pathways P1 - P4 of the IPCC from its Special Report 2018 could be used as a reference. However, the cumulative LUC emissions range from -230 Gt to +140 Gt for the period 2020 - 2100 (cf. Wolfsteiner & Wittmann, 2022d).[11] In the following calculations of the reference values for the six largest emitters, a value of zero is used for the LUC budget (except in Tab. 15 and Tab. 16). This implies that annual net positive LUC emissions occurring until 2100 are completely compensated by annual net negative LUC emissions.[12]

Further a budget of 3% of the global budget is reserved for ISA, which corresponds roughly to its current share of global CO2 emissions.[13]

	Gt	Gt	Gt
LUC budget 2020 – 2100	-100	0	100
global CO2 budget 2020 - 2100	**550**	**550**	**550**
- LUC budget 2020 - 2100	-100	0	100
- ISA budget 2020 - 2100	17	17	17
= global CO2 budget 2020 - 2100 to be distributed	633	533	433

Tab. 4: Calculation scheme of the global budget to be distributed here[14]

Since the current commitments of the six largest emitters listed in Tab. 3 refer to all greenhouse gases, the reference values shown in the next chapter are only to a limited extend comparable with the official targets if greenhouse gas fractions are to be reduced at different rates.

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[10] If data were available at country level including LUC and ISA, this step would not be necessary (cf. Sargl, et al., 2022a). However, especially in the case of LUC emissions, there are still great uncertainties in determining the level of emissions. If estimates were used here, this could distort the results.

[11] Currently assumed to be +4 GtCO2 of LUC emissions annually (cf. Global Carbon Project, 2021).

[12] In the Excel tool used (Wolfsteiner & Wittmann, 2022f) other values can also be used for LUC emissions.

[13] In the Excel tool used (Wolfsteiner & Wittmann, 2022f) other values can also be used for ISA emissions.

[14] Example calculation of the second column: 550 - (-100) - 17 = 633.

Exemplary national emission targets for the six largest emitters

Exemplary national emission targets are calculated, with the following global framework data being varied:

(1) Global CO2 budget 2020 - 2100

(2) Weighting of the population in the determination of national budgets

(3) Inclusion of a national volume overshoot in the non-LUC sector

(4) Inclusion of a negative global LUC budget

Variation of the global budget and population weighting

As a baseline for the remaining global CO2 budget from 2020, 400 Gt are used, which according to the IPCC report correlate with the 1.5°C limit with a probability of 67% (see Tab. 1). Due to the historical responsibility of the "old" industrialised countries for past emissions, much can be said for dividing the remaining global CO2 budget among the countries according to their population size (weighting population: 100%). This would lead to the emission targets in Tab. 5 for 2030 and 2050. Using the alternative global budget of 550 Gt also mentioned in the IPCC report, lead to the results in Tab. 6.

global CO2 budget 2020 - 2100 in Gt	400	minimum annual emissions	0%
weighting population	100%	LUC budget 2020 - 2100 in Gt	0

reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	-49%	-87%	-89%	-100%	-100%	71	6	0.0	2032
United States	-100%	-100%	-100%	-100%	-100%	17	3	0.0	2026
EU27	-75%	-73%	-68%	-100%	-100%	22	8	0.0	2036
India	251%	20%	-18%	84%	-37%	69	27	0.0	2073
Russia	-100%	-100%	-100%	-100%	-100%	7	4	0.0	2028
Japan	-95%	-95%	-94%	-100%	-100%	6	6	0.0	2031
Nigeria	79%	48%	0%	71%	42%	10	76	0.0	-

Tab. 5: Reference values - B400 / P100 / NNE0 / LUC0[15]

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[15] Structure of the reference value tables: For the target years, the change in emissions in percent compared to the reference years is given for a linear emissions path. The percentage given for the minimum annual emissions is applied to the country's emissions in 2019. The result represents the possible minimum of the country's emissions until 2100. A temporary overshoot is possible if this minimum is negative (see Chapter "Inclusion of an overshoot and a negative LUC budget"). The budget for the period 2020 - 2100 results from applying the weighted distribution key to the global budget to be distributed here (see calculation logic Tab. 4). The scope in years is obtained by dividing the national budget by the country's emissions in 2019 (see Tab. 2). The year of emissions neutrality is the year in which positive emissions reach their minimum respectively emissions are zero (see also Footnote 19). If no year is specified, then emissions neutrality will not be achieved by 2100.

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			0%
weighting population				100%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	76%	-54%	-63%	-100%	-100%	98	9	0.0	2036
United States	-100%	-100%	-100%	-100%	-100%	23	5	0.0	2029
EU27	-62%	-57%	-50%	-100%	-100%	31	10	0.0	2042
India	274%	28%	-13%	153%	-13%	95	37	0.0	2092
Russia	-97%	-97%	-97%	-100%	-100%	10	6	0.0	2031
Japan	-69%	-70%	-68%	-100%	-100%	9	8	0.0	2035
Nigeria	94%	61%	9%	118%	81%	14	104	0.0	-

Tab. 6: Reference values - B550 / P100 / NNE0 / LUC0

The framework data used here obviously do not lead to realistic targets for the territorial emissions of the six largest emitters. This is particularly evident in the numbers for countries with high per capita emissions, such as the USA and Russia.

Weighting the factors *population* and *emissions* equally leads to the results in Tab. 7.

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			0%
weighting population				50%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	161%	-32%	-45%	-100%	-100%	133	12	0.0	2042
United States	-55%	-59%	-55%	-100%	-100%	48	10	0.0	2039
EU27	-56%	-50%	-42%	-100%	-100%	37	13	0.0	2046
India	247%	19%	-19%	73%	-41%	66	26	0.0	2070
Russia	-64%	-51%	-52%	-100%	-100%	18	10	0.0	2040
Japan	-48%	-51%	-47%	-100%	-100%	13	11	0.0	2043
Nigeria	70%	41%	-5%	44%	19%	8	59	0.0	-

Tab. 7: Reference values - B550 / P50 / NNE0 / LUC0[16]

Here it is still doubtful that China is able to reduce its emissions by 45% and the USA by 55% by 2030 compared to 2019. The results for India, Russia and Japan also do not seem very realistic.

Weighting the population with 50% instead of 100% would mean a higher ambition level for India, since among the six largest emitters, only India's per capita emissions in the base year 2019 are below the global average (see Tab. 2). For the other five, however, the requirements are reduced (cf. Fig. 2).

Fig. 1 shows the emission paths for the six largest emitters with a global budget of 550 Gt and a population weighting of 50%. The figure illustrates that if China does not reduce its emissions by 2030, it will create an ambition gap that others cannot easily fill.

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[16] Tab. 18 in the appendix shows by way of example the 60 highest national budgets resulting from these framework data.

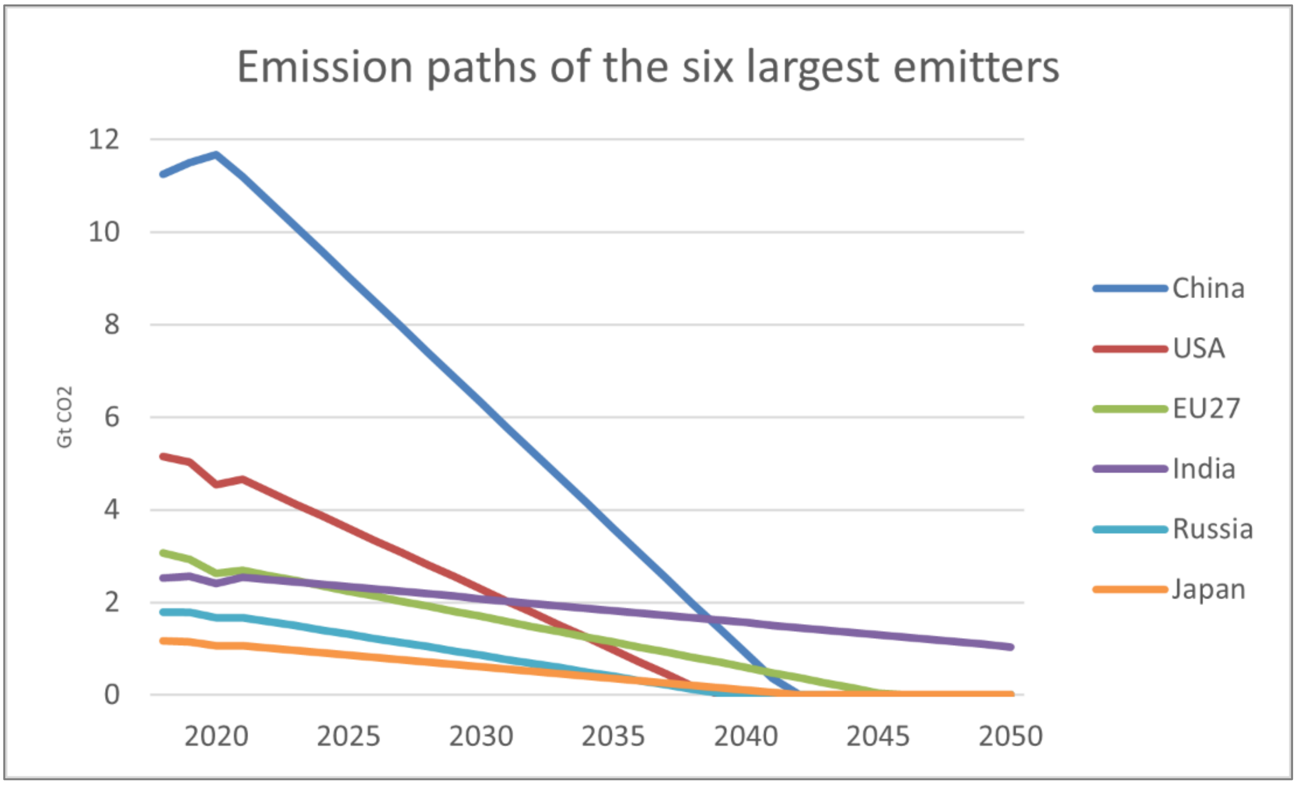

Fig. 1: Emission paths – B550 / P50 / NNE0 / LUC0

Weighting the population with only 15% would give the results in Tab. 8.

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			0%
weighting population				15%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	197%	-23%	-37%	-100%	-100%	157	14	0.0	2046
United States	-40%	-46%	-40%	-100%	-100%	66	13	0.0	2046
EU27	-53%	-47%	-38%	-100%	-100%	41	14	0.0	2049
India	208%	5%	-28%	-43%	-81%	46	18	0.0	2055
Russia	-55%	-38%	-39%	-100%	-100%	24	13	0.0	2046
Japan	-40%	-43%	-39%	-100%	-100%	15	14	0.0	2048
Nigeria	49%	23%	-17%	-19%	-33%	4	28	0.0	2074

Tab. 8: Reference values - B550 / P15 / NNE0 / LUC0

Using this framework data to calculate the reduction from individual reference years USA, EU, Russia and Japan (ranging from 1990 to 2013) and comparing it to the commitments of these countries give the following results:

	current targets (see Tab. 3)		framework data Tab. 8
country	target year 2030	individual reference year	change 2030 vs. individual reference year
United States	-50%	2005	**-49%**
EU27	-55%	1990	**-53%**
Russia	-30%	1990	**-55%**
Japan	-46%	2013	**-48%**

Tab. 9: Reference values - B550 / P15 / NNE0 / LUC0 - individual reference years

Disregarding the fact that the countries' targets generally refer to all greenhouse gases, the framework data used for Tab. 8 are a good representation of the current targets of the EU, USA and Japan for 2030 (but not for Russia).[17] According to Tab. 8 however, China would have to reduce its emissions by almost 40% by 2030 compared to 2019. Even India and Nigeria, would have to reduce their emissions significantly by 2030, despite far below-average per capita emissions in 2019 (see Tab. 2).

If the share of population is neglected ("grandfathering"), all six countries would have to reduce their emissions by around 35% by 2030 compared to 2019, as Tab. 10 shows.[18]

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			0%
weighting population				0%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	209%	-19%	-35%	-100%	-100%	168	15	0.0	2048
United States	-36%	-42%	-36%	-100%	-100%	73	15	0.0	2050
EU27	-51%	-46%	-37%	-100%	-100%	43	15	0.0	2050
India	179%	-5%	-35%	-100%	-100%	37	15	0.0	2048
Russia	-52%	-34%	-36%	-100%	-100%	26	15	0.0	2049
Japan	-38%	-41%	-36%	-100%	-100%	17	15	0.0	2050
Nigeria	17%	-3%	-35%	-100%	-100%	2	15	0.0	2048

Tab. 10: Reference values - B550 / P0 / NNE0 / LUC0

A further increase in the global budget to 650 Gt and a 50% weighting of the population give the results in Tab. 11 and a 15% weighting of the population in the results in Tab. 12.

global CO2 budget 2020 - 2100 in Gt				650		minimum annual emissions			0%
weighting population				50%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	196%	-23%	-37%	-100%	-100%	157	14	0.0	2046
United States	-47%	-51%	-46%	-100%	-100%	57	11	0.0	2043
EU27	-51%	-45%	-36%	-100%	-100%	43	15	0.0	2051
India	261%	23%	-16%	114%	-27%	78	30	0.0	2080
Russia	-58%	-42%	-44%	-100%	-100%	21	12	0.0	2044
Japan	-41%	-44%	-40%	-100%	-100%	15	13	0.0	2047
Nigeria	76%	46%	-2%	62%	34%	9	70	0.0	-

Tab. 11: Reference values - B650 / P50 / NNE0 / LUC0

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[17] Please note, that the current targets of the USA, EU and Japan can also be represented by a different combination of the framework data.

[18] If actual emissions were not considered for 2020 (see Footnote 9), grandfathering would result in the same reduction rate for emissions in 2030 compared to 2019 and the same year of emissions neutrality for all countries.

global CO2 budget 2020 - 2100 in Gt				650		minimum annual emissions			0%
weighting population				15%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	227%	-15%	-31%	-89%	-97%	186	16	0.0	2051
United States	-34%	-40%	-34%	-97%	-98%	78	15	0.0	2051
EU27	-48%	-42%	-33%	-92%	-91%	48	17	0.0	2054
India	228%	12%	-23%	16%	-60%	54	21	0.0	2061
Russia	-50%	-31%	-33%	-98%	-98%	28	16	0.0	2051
Japan	-35%	-38%	-33%	-94%	-94%	18	16	0.0	2053
Nigeria	54%	28%	-14%	-3%	-20%	4	33	0.0	2084

Tab. 12 : Reference values - B650 / P15 / NNE0 / LUC0

Fig. 2 shows the course of the reference values 2030 to 2019 depending on the weighting of the population with a global CO2 budget of 550 Gt.

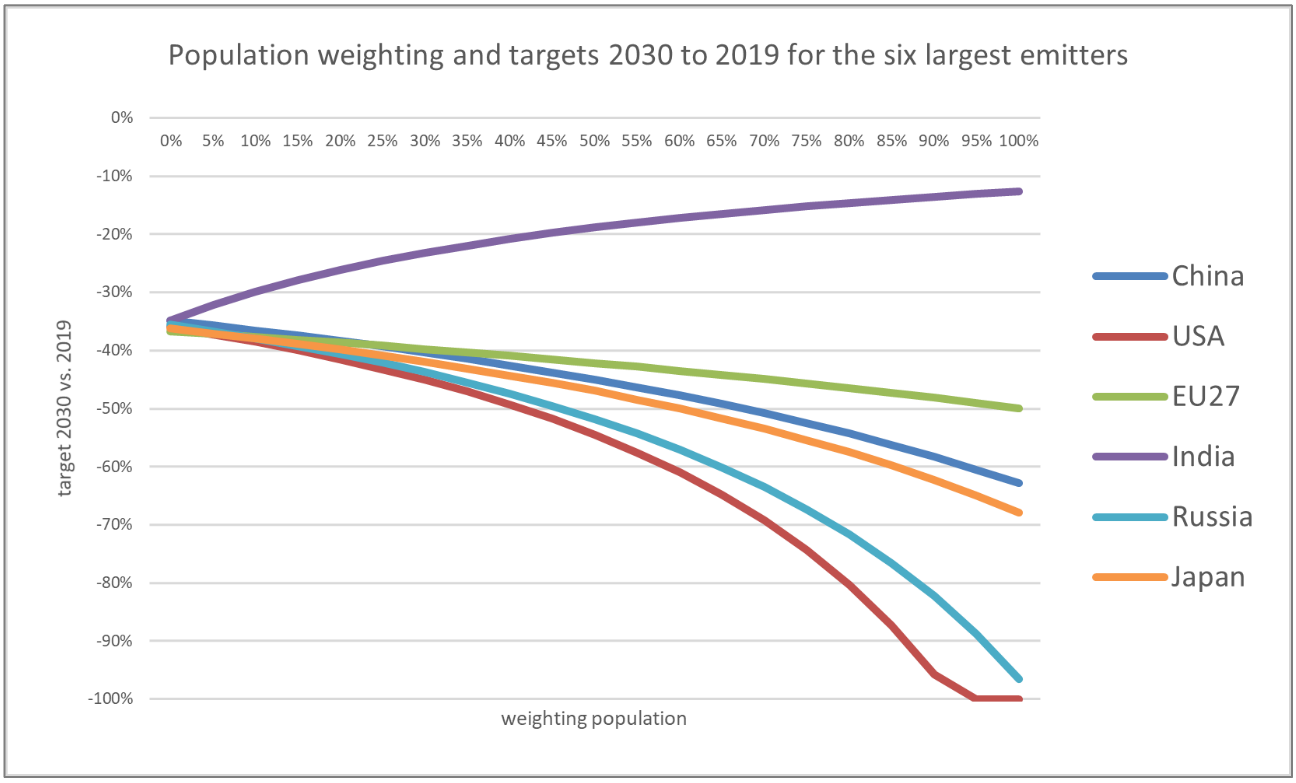

Fig. 2: Weighting population vs. targets 2030/2019 – B550 / NNE0 / LUC0

Inclusion of an overshoot and a negative LUC budget

A **volume overshoot** in the ESPM means a temporary exceeding of the previously defined CO2 budget. This overshoot ("temporary overshoot" column in the reference value tables) is offset by subsequent net negative emissions until 2100.[19] The potential net negative emissions are included in

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[19] In order to achieve climate neutrality, unavoidable methane and nitrous oxide emissions from agriculture, for example, must be offset by negative CO2 emissions. These must be provided in addition to the net negative CO2 emissions assumed here.

the model by a percentage of a country's emissions in 2019.[20] The result represents the potential minimum emissions by 2100. With a negative minimum value, the lower this value, the higher the overshoot.

The following main aspects need to be considered:

(1) At present, the potential of negative emissions is very uncertain technically, economically and in terms of their durability (cf. SRU, 2020).

(2) Even if a budget is met that corresponds to the targeted limitation of global warming, a volume overshoot can lead to the overshooting of tipping points in the climate system (cf. PIK, 2018) lead.

(3) According to recent findings, “the century-scale climate–carbon cycle response to a CO2 removal from the atmosphere is not always equal and opposite to the response to a CO2 emission” (IPCC, 2021, p. 5-9). This potential asymmetry is not taken into account here.

Combining a potential of net negative emissions of -2%, a global CO2 budget of 550 Gt and a weighting of population with 50% give the results of Tab. 13.[21]

global CO2 budget 2020 - 2100 in Gt	550	minimum annual emissions	-2%
weighting population	50%	LUC budget 2020 - 2100 in Gt	0

reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	181%	-27%	-41%	-109%	-102%	133	12	13.0	2043
United States	-49%	-53%	-49%	-102%	-102%	48	10	5.9	2041
EU27	-53%	-48%	-39%	-102%	-102%	37	13	3.1	2047
India	249%	19%	-18%	79%	-39%	66	26	1.5	2071
Russia	-60%	-45%	-46%	-101%	-102%	18	10	2.1	2041
Japan	-44%	-47%	-43%	-102%	-102%	13	11	1.3	2044
Nigeria	70%	41%	-5%	44%	19%	8	59	0.0	-

Tab. 13: Reference values - B550 / P50 / NNE2 / LUC0

Reducing the weighting the population to 15% leads to the results in Tab. 14.

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[20] This means that countries with high current emissions would have to realise or finance high net negative emissions. Since a budget for LUC is provided here at global level, negative emissions at national level refer to the non-LUC sector.

[21] The illustrative model paths P1 - P4 of the IPCC from its Special Report 2018 could be used as a reference. However, the corresponding values show a wide range from -55% to +2% (cf. Wolfsteiner & Wittmann, 2022d).

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			-2%
weighting population				15%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	211%	-19%	-35%	-109%	-102%	157	14	12.0	2047
United States	-38%	-43%	-37%	-102%	-102%	66	13	5.2	2048
EU27	-51%	-45%	-36%	-99%	-99%	41	14	2.9	2050
India	214%	7%	-27%	-25%	-74%	46	18	2.3	2056
Russia	-53%	-35%	-36%	-101%	-102%	24	13	1.9	2047
Japan	-38%	-41%	-36%	-102%	-102%	15	14	1.2	2049
Nigeria	49%	24%	-16%	-17%	-31%	4	28	0.1	2074

Tab. 14: Reference values - B550 / P15 / NNE2 / LUC0

The temporary overshoot resulting from this potential of net negative emissions would roughly correspond to the current annual emissions of the major emitters (cf. Tab. 2 with Tab. 13 and Tab. 14).

The inclusion of a **negative LUC budget** would increase the global CO2 budget to be distributed (see calculation logic in Tab. 4). However, it is not clear who would be responsible that this negative LUC budget is actually realised. Moreover, there are major doubts about the permanence of negative LUC emissions.[22] Despite these concerns, we add a LUC budget of -100 Gt to a global budget of 400 Gt and a 50% weighting of the population and get the results in Tab. 15.

global CO2 budget 2020 - 2100 in Gt				400		minimum annual emissions			-2%
weighting population				50%		LUC budget 2020 - 2100 in Gt			-100
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	164%	-31%	-44%	-109%	-102%	122	11	13.3	2042
United States	-53%	-57%	-52%	-102%	-102%	44	9	6.1	2039
EU27	-55%	-50%	-42%	-102%	-102%	34	11	3.2	2045
India	242%	17%	-20%	57%	-46%	60	24	1.7	2066
Russia	-63%	-49%	-50%	-101%	-102%	16	9	2.1	2040
Japan	-47%	-50%	-46%	-102%	-102%	12	10	1.3	2042
Nigeria	67%	38%	-7%	36%	12%	7	54	0.0	-

Tab. 15: Reference values - B400 / P50 / NNE2 / LUC100

A reduced weighting of the population with 15% would lead to the results in Tab. 16.

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[22] For example, a reforested forest can also be destroyed again by climate change.

global CO2 budget 2020 - 2100 in Gt				400		minimum annual emissions			-2%
weighting population				15%		LUC budget 2020 - 2100 in Gt			-100
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	196%	-23%	-38%	-109%	-102%	144	13	12.6	2045
United States	-40%	-46%	-40%	-102%	-102%	60	12	5.5	2045
EU27	-53%	-47%	-38%	-102%	-102%	38	13	3.1	2048
India	204%	4%	-29%	-56%	-85%	42	16	2.4	2053
Russia	-55%	-38%	-39%	-101%	-102%	22	12	1.9	2045
Japan	-40%	-43%	-39%	-102%	-102%	14	12	1.2	2046
Nigeria	46%	21%	-18%	-26%	-39%	3	26	0.1	2070

Tab. 16: Reference values - B400 / P15 / NNE2 / LUC100

Conclusions

The emission targets for the world's six largest emitters presented here are only examples, as important framework data like the global budget need to be discussed in more detail and decided politically. For this discourse and ultimate political decision, the following agenda emerges:

Agenda:

1. Concretise global framework data based on the state of scientific knowledge, especially with regard to the global CO2 budget and the scope of negative emissions.
2. Derive national CO2 budgets on this base that ensure a fair and economically sensible distribution of a global CO2 budget.[23]
3. Align emission targets with a climate policy-sensible course of annual rates of change.[24]
4. Adjust the framework data and reduction targets regularly on the basis of new scientific findings and technical/real developments.

However, the exemplary results shown here give important indications which scenarios / framework data lead to realistic national emission targets that sum up to Paris-compatible global emissions budget.

If the global CO2 budget is oriented towards the 1.5°C limit, it is very unlikely that the six largest emitters (except India) will be able to achieve their share of CO2 reductions if the weighting of population is 50% or more. We see a trade-off between realistic emission pathways for the six largest emitters in accordance with the 1.5°C limit and climate justice emerging: With a high weighting of the population a significantly higher global CO2 budget, extensive negative LUC emissions or volume overshoots would be necessary to achieve realistic emission targets. Realistic emission targets strictly in accordance with the 1.5°C limit are only feasible with a lower weighting of population. A consequence might be to compensate the developing and emerging countries by supporting them in building a fossil-free economy.

The calculations also demonstrate that an orientation towards the 1.5°C limit cannot be achieved without a substantial contribution already by 2030 from the world’s largest emitter by far. This is a major requirement for China, especially since its share of historical emissions is still relatively small.

The ESPM approach is open to the question of how a national budget is determined. The weighted distribution key used here to determine exemplary reference values for a global CO2 budget with the

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[23] See Excursus 3: Allocation of a global CO2 budget.

[24] See Excursus 4: Regensburg Model Scenario Types.

two allocation keys "emission share" and "population share" represents a pragmatic approach reflecting current reality and equity.

With the scenario types offered in the ESPM (see Excursus 4), national paths can be derived that adhere to a predefined budget and take socio-economic factors into account.

The ESPM is a helpful tool for making comprehensible science-based policy decisions and for presenting meaningful reference values in the Paris Ambition Mechanism.

At the UN Climate Change Conference in Glasgow 2021 (COP26), the following decisions were taken concerning the Paris Ambition Mechanism (CMA.3/-Decision, 2021):

„*29. Recalls Article 3 and Article 4, paragraphs 3, 4, 5 and 11, of the Paris Agreement and requests Parties to revisit and strengthen the 2030 targets in their nationally determined contributions as necessary to align with the Paris Agreement temperature goal by the end of 2022, taking into account different national circumstances;*

30. Also requests the secretariat to annually update the synthesis report on nationally determined contributions under the Paris Agreement, referred to in decision 1/CMA.2, paragraph 10, to be made available to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at each of its sessions;“.

The annual revision of the NDCs now foreseen is a major step forward towards the necessary reductions in global emissions already by 2030 to keep compliance with the 1.5°C limit within reach.

Tools and further exemplary results

For the calculation of the exemplary results in this paper we have used the Excel tool "ESPM" (version 64.0), which can be downloaded from http://save-the-climate.info or from the platform zenodo (Wolfsteiner & Wittmann, 2022f). In addition, we offer a universally applicable Excel tool to derive emission paths with the RM Scenario Types for a given national budget (Wolfsteiner & Wittmann, 2022c).

At https://climate-calculator.info we provide an overview of the web applications we offer.

At http://espm.save-the-climate.info, further exemplary results are shown for the six largest emitters with different framework data and scenario types.

Our tool for calculating implicit weighting of population can also be downloaded on zenodo (Wolfsteiner & Wittmann, 2022e). This tool can also be used to calculate national budgets for all countries in the world using an explicit population weighting.

Digressions

German Federal Constitutional Court on CO2 budgets

Excerpt from the main considerations of the Federal Constitutional Court (BVerfG, 2021):

“The constitutionally relevant temperature threshold of well below 2°C and preferably 1.5°C can in principle be converted into a global CO2 residual budget, which can then be distributed among the states. The Intergovernmental Panel on Climate Change (IPCC) has named concrete global CO2 residual budgets for various temperature thresholds and various probabilities of occurrence on the basis of a quality-assurance procedure, disclosing the remaining uncertainty. On this basis, the German Advisory Council on the Environment [(cf. SRU, 2020), note by the authors] has also determined a concrete national residual budget for Germany from 2020 that would be compatible with the Paris target. Due to the uncertainties and evaluations contained therein, the budget size determined cannot currently provide a numerically accurate measure for constitutional court review. The legislature still has room for manoeuvre. However, it may not fill this space at its political discretion. If there is scientific uncertainty about environmentally relevant causal relationships, Article 20a of the Basic Law imposes a special duty of care on the legislature. According to this, already reliable indications of the possibility of serious or irreversible impairments must be taken into account. At present, a violation of this duty of care cannot be established. It follows that estimates by the IPCC on the size of the remaining global CO2 residual budget must be taken into account, even though they contain uncertainties. The emission levels regulated in Article 4 para. 1 sentence 3 KSG [Climate Protection Act, note by the authors] in conjunction with Annex 2 would largely exhaust the residual budget determined by the German Advisory Council on the Environment on the basis of the IPCC estimates until the year 2030. However, compared to the uncertainties currently included in the calculation of the residual budget, the degree of shortfall did not form a sufficient basis for a constitutional court challenge.”

Excursus 1: German Federal Constitutional Court on CO2 budgets

German Federal Constitutional Court on freedom opportunities for future generations

Excerpt from the guiding principles of the decision of the Federal Constitutional Court (BVerfG, 2021):

“Under certain conditions, the Basic Law obliges the safeguarding of freedom protected by fundamental rights over time and the proportionate distribution of opportunities for freedom over the generations. In terms of subjective law, fundamental rights, as an intertemporal safeguard of freedom, protect against a unilateral shifting of the greenhouse gas reduction burden imposed by Article 20a GG [Basic Law, note by the authors] to the future. The objective-law protection mandate of Article 20a of the Basic Law also includes the necessity to treat the natural foundations of life with such care and to leave them to posterity in such a condition that future generations could not continue to preserve them only at the price of radical abstinence of their own. The protection of future freedom also requires that the transition to climate neutrality be initiated in good time. In concrete terms, this requires the early formulation of transparent targets for further greenhouse gas reductions that provide orientation for the necessary development and implementation processes and give them a sufficient degree of development pressure and planning certainty.”

Excursus 2: German Federal Constitutional Court on freedom opportunities for future generations

Allocation of a global CO2 budget

The global community has set itself the following framework: “*Acknowledging that the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions*” (United Nations Climate Change Framework Convention of 1992).

Four basic allocation approaches can be distinguished: (1) grandfathering, (2) equality, (3) responsibility and (4) capability (cf. Du Ponte, et al., 2017, p. 40). Cost efficiency can be seen as another approach (5).

In addition to the allocation keys "current emissions share" (1) and "current population share" (2) used here, other criteria may therefore be taken into account such as historical emissions (3) or GDP per capita (4). Including historical emissions highlights the responsibility of the "old" industrialised countries for the decarbonisation process, but results in unrealistic territorial emission targets. However, historical emissions could play a significant role, especially in compensating for Loss and Damage. The idea behind "capability" is that wealthier countries should set themselves more ambitious goals. However, the GDP per capita criterion cannot be integrated into a distribution key for a global budget straightforward, as it does not contain any information about the size of a country. Since there is a correlation between emissions per capita and GDP per capita for the six largest emitters (cf. Tab. 17), the GDP per capita criterion is already indirectly mapped via the weighting of the population. However, the correlation coefficient of 0.7 is clearly below 1, so that this mapping is not perfect.

In principle, it might make more sense to use criteria based on economic performance for direct financial issues such as contributions to Climate Finance.

per capita	emissions in t	GDP in TUSD
India	2	7
EU27	7	45
China	8	16
Japan	9	41
Russia	12	28
United States	15	62
correlation coefficient	0.72	

Tab. 17: GDP per capita six largest emitters

Instead of allocating a global budget, a global path can be allocated by using a convergence model [also a combination of the approaches (1) and (2)]. Using a convergence model implies an implicit weighting of the population that is the same for all countries. This implicit weighting essentially depends on the course of the global path chosen [cf. (Wittmann, 2022) and (Sargl, et al., 2022b)]. With a global budget of 550 Gt from 2020 on and a linear emissions path, this implicit weighting of the population is around 12% in the Regensburg Model (cf. Sargl, et al., 2017), if per capita emissions are to converge at 0.5 t (cf. Wolfsteiner & Wittmann, 2022a).

Another approach are Integrated Assessment Models (IAMs), which can be used to identify globally cost-effective national emission paths (cf. van Soest, et al., 2021); approach (5). But the results of IAMs are based on many assumptions. The results are therefore a "black box" for policy makers. For the ESPM approach, on the other hand, only a few framework data need to be specified and equity aspects can be explicitly considered. In convergence models and IAMs, the national budgets and thus the distribution of a global CO2 budget result indirectly.

A distinction can be made whether the allocation of a global budget refers to the actual territorial emissions of a country or to tradable emission rights. If allocation is based on emission rights, the scope for climate justice can be considered even greater (Rajamani, et al., 2021). However, it is important to keep in mind that the resulting potential financial flows in a subsequent emissions trading should be realistic. The potential to generate certificates with different weightings of the population is discussed in Excursus 5. If the allocation is based on territorial emissions, it would have to be examined whether it makes sense for countries with low per capita emissions today to build up an economy that is more fossil fuel-based and has to decarbonise again soon afterwards.

In principle, the distribution of a global budget should take into account that it must also be sustainable for countries with currently high per capita emissions. There are two aspects to consider: (1) National emission targets must also be politically enforceable at the national level. (2) National emission targets should also be economically viable in the sense that the global economy is not unduly affected. This would also have a considerable negative impact on countries with low economic power. An ethical justification for this aspect can be found in Rawls' "Theory of Justice".

States indirectly point out with their NDC which national budget they are claiming for themselves in the future. The implicit weighting of the population is a helpful measure for assessing this claim (cf. Sargl, et al., 2022b). If this national budget can be estimated or, at best, is even directly specified, the implicit weighting of the population depending of the global budget is given by

$$\mathrm{C} = \frac{B^{i} - B * E^{i}_{BY} / E_{BY}}{B * (P^{i}_{BY} / P_{BY} - E^{i}_{BY} / E_{BY})}$$

after transforming the above weighting formula. We offer a tool with a database of all countries in the world, which can be used to calculate this implicit weighting (Wolfsteiner & Wittmann, 2022e).

Excursus 3: Allocation of a global CO2 budget

Regensburg Model Scenario Types

From an overall perspective of climate policy, scenarios with a nonlinear emissions path may be useful. Additional scenario types also offer the possibility of taking country-specific features into account.

The Regensburg Model Scenario Types RM 1 - 5 are based on the course of the annual reduction rates. Four basic types can be distinguished with regard to the increase in annual reduction rates with a monotonous course:

(1) Constant: constant annual reduction rate (RM-1)
(2) Linear: linear increase (RM-3)
(3) Concave: initially under-proportional increase (RM-2, RM-4)
(4) Convex: initially over-proportional increase (RM-5)

In addition, the scenario type RM-6 uses linear emission paths. Accordingly, the annual reduction rates for RM-6 have a concave course and the annual reduction amount is constant.

With our **web application** http://espm.climate-calculator.info the different scenario types can be graphically traced. For a comprehensive mathematical description, we refer to (Wolfsteiner & Wittmann, 2022b).

The following questions should be considered, when assessing a scenario type:

(1) Which reduction rates are realistic and when?
(2) Do initially slowly increasing reduction rates (RM-2/4 and RM-6) imply an unjustifiable duty for future, as they imply higher reduction rates later?
(3) Do high later reduction rates make sense, if they provide a longer lead time for the necessary investments and the investments could then rather be made within the framework of normal investment cycles? However, this requires a very credible climate policy backed by effective instruments.
(4) Do initially rapidly increasing reduction rates (RM-3 and RM-5) convey a more credible climate protection policy that creates planning security for public and private investments in a fossil-free future?

The German Advisory Council on the Environment (SRU) recommends to refrain from linear emission paths (RM-6): "*A slow start, hoping for steep emission reductions in later years, jeopardises compliance with the budget and climate targets*" (SRU, 2020, p. 56). This argument would also apply to the RM-2/4 scenario types.

The decision of the German Federal Constitutional Court on the Climate Protection Act also implicitly poses the question of what annual reduction rates we must accept today so that the freedom of future generations is not unduly restricted (see Excursus 2: German Federal Constitutional Court on freedom opportunities for future generations).

To avoid very high annual reduction rates in later years, the scenario types RM-3 and RM-5 are suitable.

Nevertheless, linear emission paths are used here for the comparison of emission targets for the six largest emitters for reasons of simplification, as the differences between the scenario types are not the focus of this work. If the scenario types RM-3 or RM-5 were applied, the emission targets for 2030 would be more ambitious for all countries examined.

Excursus 4: Regensburg Model Scenario Types

Emissions trading between countries: weighting population / global budget

The national budgets resulting from the framework data in Tab. 11 and Tab. 12 (see Tab. 18 in the Annex) show for example: The lower the weighting of the population, the smaller the scope for newly industrialising and developing countries to generate certificates within the framework Article 6 (2) of the Paris Agreement. The stated scopes of the national budgets can serve as a measure of this leeway. A higher the weighting of the population, would result in a higher demand for certificates of the industrialised countries plus China. Emissions trading therefore does not solve the fundamental problem of a tight global CO2 budget.

For a further development of the Cooperative Mechanisms under Article 6 of the Paris Agreement with regard to a global remaining CO2 budget, it would make sense that the NDCs must state the CO2 budget that a country will claim for itself through the NDC in the future. Such explicit national CO2 budgets could also facilitate emissions trading between countries. The Paris Ambition Mechanism could then be used to achieve compliance with an overall Paris-compatible global CO2 budget.

Excursus 5: Emissions trading between countries: weighting population / global budget

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Appendix: Exemplary national budgets with different global framework data

global budget 2020 - 2100 in Gt		550	LUC budget	0
weighting population		50%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	133.0	25.0%	11.504	12
India	66.0	12.4%	2.564	26
United States	48.1	9.0%	5.036	10
EU27	36.7	6.9%	2.933	13
Russia	17.9	3.4%	1.778	10
Indonesia	14.0	2.6%	0.645	22
Japan	12.7	2.4%	1.139	11
Brazil	10.8	2.0%	0.477	23
Pakistan	8.7	1.6%	0.218	40
Mexico	8.1	1.5%	0.488	17
Germany	8.0	1.5%	0.702	11
Nigeria	7.9	1.5%	0.133	59
Iran	7.9	1.5%	0.686	11
Bangladesh	6.6	1.2%	0.110	60
South Korea	6.6	1.2%	0.663	10
Turkey	5.9	1.1%	0.414	14
Vietnam	5.8	1.1%	0.328	18
Canada	5.6	1.1%	0.595	9
Egypt	5.6	1.0%	0.282	20
Saudi Arabia	5.5	1.0%	0.593	9
South Africa	5.4	1.0%	0.468	12
United Kingdom	4.9	0.9%	0.359	14
Philippines	4.8	0.9%	0.150	32
France and Monaco	4.6	0.9%	0.320	14
Italy, S. Mar. a. t. H. See	4.5	0.8%	0.333	13
Thailand	4.4	0.8%	0.269	16
Ethiopia	3.9	0.7%	0.019	207
Australia	3.9	0.7%	0.414	9
Poland	3.6	0.7%	0.313	11
Spain and Andorra	3.5	0.7%	0.256	14
Malaysia	3.1	0.6%	0.265	12
Dem. Rep. o. t. Congo	3.0	0.6%	0.003	870
Ukraine	3.0	0.6%	0.197	15
Argentina	2.9	0.6%	0.189	16
Iraq	2.9	0.5%	0.206	14
Taiwan	2.9	0.5%	0.284	10
Algeria	2.8	0.5%	0.177	16
Kazakhstan	2.6	0.5%	0.274	10
Colombia	2.4	0.5%	0.093	26
Tanzania	2.2	0.4%	0.013	172
Myanmar/Burma	2.2	0.4%	0.038	57
Sudan and South Sudan	2.1	0.4%	0.024	89
Kenya	1.9	0.4%	0.019	102
Venezuela	1.9	0.4%	0.109	18
United Arab Emirates	1.9	0.4%	0.213	9
Uzbekistan	1.8	0.3%	0.091	20
Morocco	1.8	0.3%	0.072	25
Netherlands	1.7	0.3%	0.158	11
Uganda	1.6	0.3%	0.006	262
Peru	1.5	0.3%	0.055	28
Afghanistan	1.4	0.3%	0.012	114
Chile	1.3	0.2%	0.091	14
Angola	1.3	0.2%	0.024	52
Romania	1.3	0.2%	0.081	16
Ghana	1.2	0.2%	0.018	66
Mozambique	1.2	0.2%	0.011	104
Nepal	1.2	0.2%	0.018	65
Czechia	1.1	0.2%	0.105	11
North Korea	1.1	0.2%	0.032	35
Belgium	1.1	0.2%	0.099	11
Yemen	1.1	0.2%	0.011	103
sum without EU	488		34	

global budget 2020 - 2100 in Gt		650	LUC budget	0
weighting population		50%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	157.3	25.0%	11.504	14
India	78.0	12.4%	2.564	30
United States	56.9	9.0%	5.036	11
EU27	43.4	6.9%	2.933	15
Russia	21.2	3.4%	1.778	12
Indonesia	16.6	2.6%	0.645	26
Japan	15.0	2.4%	1.139	13
Brazil	12.8	2.0%	0.477	27
Pakistan	10.2	1.6%	0.218	47
Mexico	9.6	1.5%	0.488	20
Germany	9.4	1.5%	0.702	13
Nigeria	9.4	1.5%	0.133	70
Iran	9.3	1.5%	0.686	14
Bangladesh	7.8	1.2%	0.110	71
South Korea	7.8	1.2%	0.663	12
Turkey	7.0	1.1%	0.414	17
Vietnam	6.8	1.1%	0.328	21
Canada	6.7	1.1%	0.595	11
Egypt	6.6	1.0%	0.282	23
Saudi Arabia	6.5	1.0%	0.593	11
South Africa	6.4	1.0%	0.468	14
United Kingdom	5.8	0.9%	0.359	16
Philippines	5.7	0.9%	0.150	38
France and Monaco	5.4	0.9%	0.320	17
Italy, S. Mar. a. t. H. See	5.3	0.8%	0.333	16
Thailand	5.2	0.8%	0.269	19
Ethiopia	4.7	0.7%	0.019	244
Australia	4.6	0.7%	0.414	11
Poland	4.3	0.7%	0.313	14
Spain and Andorra	4.1	0.7%	0.256	16
Malaysia	3.6	0.6%	0.265	14
Dem. Rep. o. t. Congo	3.6	0.6%	0.003	1,028
Ukraine	3.5	0.6%	0.197	18
Argentina	3.5	0.6%	0.189	18
Iraq	3.4	0.5%	0.206	17
Taiwan	3.4	0.5%	0.284	12
Algeria	3.3	0.5%	0.177	18
Kazakhstan	3.1	0.5%	0.274	11
Colombia	2.8	0.5%	0.093	31
Tanzania	2.6	0.4%	0.013	204
Myanmar/Burma	2.5	0.4%	0.038	67
Sudan and South Sudan	2.5	0.4%	0.024	105
Kenya	2.3	0.4%	0.019	121
Venezuela	2.3	0.4%	0.109	21
United Arab Emirates	2.2	0.4%	0.213	10
Uzbekistan	2.1	0.3%	0.091	23
Morocco	2.1	0.3%	0.072	29
Netherlands	2.1	0.3%	0.158	13
Uganda	1.9	0.3%	0.006	310
Peru	1.8	0.3%	0.055	33
Afghanistan	1.6	0.3%	0.012	135
Chile	1.5	0.2%	0.091	17
Angola	1.5	0.2%	0.024	62
Romania	1.5	0.2%	0.081	18
Ghana	1.4	0.2%	0.018	78
Mozambique	1.4	0.2%	0.011	123
Nepal	1.4	0.2%	0.018	76
Czechia	1.3	0.2%	0.105	13
North Korea	1.3	0.2%	0.032	41
Belgium	1.3	0.2%	0.099	13
Yemen	1.3	0.2%	0.011	122
sum without EU	577		34	

global budget 2020 - 2100 in Gt		650	LUC budget	0
weighting population		15%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	186.1	29.5%	11.504	16
United States	77.9	12.4%	5.036	15
India	54.4	8.6%	2.564	21
EU27	48.4	7.7%	2.933	17
Russia	27.8	4.4%	1.778	16
Japan	18.3	2.9%	1.139	16
Indonesia	12.8	2.0%	0.645	20
Germany	11.3	1.8%	0.702	16
Iran	11.1	1.8%	0.686	16
South Korea	10.4	1.6%	0.663	16
Brazil	9.6	1.5%	0.477	20
Canada	9.2	1.5%	0.595	15
Saudi Arabia	9.1	1.4%	0.593	15
Mexico	8.8	1.4%	0.488	18
South Africa	7.6	1.2%	0.468	16
Turkey	7.1	1.1%	0.414	17
Australia	6.4	1.0%	0.414	15
United Kingdom	6.1	1.0%	0.359	17
Vietnam	6.0	1.0%	0.328	18
Pakistan	5.7	0.9%	0.218	26
Italy, S. Mar. a. t. H. See	5.6	0.9%	0.333	17
France and Monaco	5.5	0.9%	0.320	17
Egypt	5.4	0.9%	0.282	19
Poland	5.1	0.8%	0.313	16
Thailand	4.8	0.8%	0.269	18
Taiwan	4.5	0.7%	0.284	16
Nigeria	4.4	0.7%	0.133	33
Spain and Andorra	4.3	0.7%	0.256	17
Malaysia	4.3	0.7%	0.265	16
Kazakhstan	4.2	0.7%	0.274	15
Bangladesh	3.7	0.6%	0.110	33
Philippines	3.5	0.6%	0.150	23
Iraq	3.5	0.6%	0.206	17
Ukraine	3.4	0.5%	0.197	17
Argentina	3.3	0.5%	0.189	18
United Arab Emirates	3.2	0.5%	0.213	15
Algeria	3.1	0.5%	0.177	18
Netherlands	2.5	0.4%	0.158	16
Venezuela	2.0	0.3%	0.109	18
Colombia	2.0	0.3%	0.093	21
Uzbekistan	1.7	0.3%	0.091	19
Czechia	1.7	0.3%	0.105	16
Ethiopia	1.6	0.3%	0.019	85
Qatar	1.6	0.3%	0.109	15
Belgium	1.6	0.3%	0.099	16
Chile	1.6	0.2%	0.091	17
Morocco	1.5	0.2%	0.072	21
Kuwait	1.5	0.2%	0.098	15
Serbia and Montenegro	1.4	0.2%	0.090	16
Romania	1.4	0.2%	0.081	18
Oman	1.3	0.2%	0.087	15
Turkmenistan	1.3	0.2%	0.081	16
Myanmar/Burma	1.2	0.2%	0.038	32
Peru	1.2	0.2%	0.055	22
Greece	1.2	0.2%	0.073	17
Austria	1.1	0.2%	0.071	16
Israel a. Palest., State o.	1.1	0.2%	0.070	16
Dem. Rep. o. t. Congo	1.1	0.2%	0.003	321
Belarus	1.0	0.2%	0.063	17
Sudan and South Sudan	1.0	0.2%	0.024	44
Tanzania	0.9	0.1%	0.013	73
sum without EU	592		35	

Tab. 18: Exemplary national budgets with different global framework data[25]

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[25] 59 countries plus the EU with the highest resulting budgets.