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 is based on a bottom-up approach. However, if the national targets are not Paris-compatible in sum, the question arises whether national targets represent an adequate contribution to the necessary global efforts. An open and transparent discussion of this issue can contribute to NDCs that are Paris-compatible in sum.

[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 Report WGI (IPCC, 2021) and emissions data (EDGAR, 2022).

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

[2] Major change compared to the last version: Use of emission data published in September 2022 including emissions in 2021 according to (EDGAR, 2022).

Content

List of Tables

List of Figures

List of Digressions

Global CO2 budgets

CO2 accumulates in the atmosphere.[3] 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.

Warm-ing	Remaining carbon budgets			Scenario variation	Geophysical uncertainties			
Proba-bilities:	*50%*	*67%*	*83%*	Non-CO2 scenario variation	Non-CO2 forcing and response uncertainty	Historical temperature uncertainty	ZEC uncer-tainty	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[4]

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.*"

The need to take into account the socio-economic consequences of the pace of decarbonisation, the compliance probabilities and the further uncertainties in the remaining budget 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).[5]

If the Parties make transparent an underlying global CO2 budget and its distribution in their NDCs, or if they are more encouraged to do so, this can initiate a discourse that ultimately leads to converging benchmarks for the global framework data that contributes to Paris-compatible NDCs in sum.

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

[4] Tab. 1 based on Tables SPM.2 and 5.8 in the IPCC Sixth Assessment Report (cf. IPCC, 2021).

Regarding probabilities, the IPCC notes:

"*This likelihood is based on the uncertainty in transient climate response to cumulative CO2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the [left column]. Uncertainties related to historical warming (±550 GtCO2) and non-CO2 forcing and response (±220 GtCO2) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 GtCO2) and the climate response after net zero CO2 emissions are reached (±420 GtCO2) are separate*" (IPCC, 2021, p. 29 SPM).

For further scientific background information, please refer to the IPCC report.

In 2019, global emissions were around 41 GtCO2 (Global Carbon Project, 2021).

[5] See 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	11.8	8.3	32%	18%
United States	5.1	5.6	5.0	15.2	14%	4%
EU27	3.8	3.4	2.9	6.6	8%	6%
India	0.6	1.7	2.6	1.9	7%	18%
Russia	2.4	1.7	1.9	13.1	5%	2%
Japan	1.2	1.2	1.1	9.0	3%	2%
Sum	15.5	23.0	25.3		69%	50%
Nigeria	0.07	0.09	0.12	0.6	0.3%	2.6%
Global	22.7	34.2	38.0	4.9	100%	

Tab. 2: Baseline data of the six largest emitters plus Nigeria[6]

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[7]

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.[8]

[6] These are the CO2 emissions from fossil fuel use (except international shipping and aviation; ISA) and cement production (EDGAR, 2022). CO2 emissions from land-use change (LUC) are therefore not included here (see also Footnote 13).

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

[8] 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."

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.[9] 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).[10] 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:

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

where

E_{BY} or E^i_{BY}	global emissions or emissions of country *i* in the base year; here: *BY* = 2019
P_{BY} or P^i_{BY}	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 5). For reasons of simplification, a linear course of the **emission paths** (RM-6) is assumed below.[11]

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, 2022).

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

[10] 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.

[11] Due to the inclusion of actual emissions in the years 2020 and 2021, the emission paths only fall on a straight line from 2022 onwards (see Fig. 1).

Before calculating national budgets on this data basis, global budgets for LUC and ISA emissions must be deducted from the global budget (see exemplary calculations in Tab. 4).[12] The national budgets derived from this global CO2 budget thus include CO2 emissions from fossil fuel use (except ISA) and cement production.

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 there range from -230 Gt to +140 Gt for the period 2020 - 2100 (cf. Wolfsteiner & Wittmann, 2022d).[13] 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.[14]

Further a budget of 3% of the global budget is reserved for ISA, which corresponds roughly to its current share of global CO2 emissions.[15]

	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[16]

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.

Due to the budgetary nature of CO2, it would make sense to set separate targets for CO2 in the NDCs in addition to targets for all greenhouse gases.

[12] 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, with a wide range in accuracy, this could significantly distort the results.

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

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

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

[16] 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 CO2 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

According to the IPCC report, 400 GtCO2 from 2020 onwards correlates with a probability of 67% with compliance with the 1.5°C limit (see Tab. 1). Due to the historical responsibility of the "old" industrialised countries for past emissions, much can be said for dividing a 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 the target years 2030 and 2050. Using a global CO2 budget of 550 Gt leads 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	-100%	-100%	-100%	-100%	-100%	71	6	0.0	2030
United States	-100%	-100%	-100%	-100%	-100%	17	3	0.0	2026
EU27	-77%	-74%	-70%	-100%	-100%	22	8	0.0	2035
India	261%	24%	-16%	81%	-38%	69	27	0.0	2071
Russia	-100%	-100%	-100%	-100%	-100%	7	4	0.0	2026
Japan	-100%	-100%	-100%	-100%	-100%	6	6	0.0	2030
Nigeria	69%	38%	5%	68%	37%	10	84	0.0	-

Tab. 5: Reference values - B400 / P100 / NNE0 / LUC0[17]

[17] 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 emission 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 national CO2 budget for the period 2020 - 2100 results from applying the weighted distribution key to the global CO2 budget to be distributed here (see calculation logic Tab. 4).

The scope in years is obtained by dividing the national CO2 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 21). 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	53%	-60%	-68%	-100%	-100%	98	8	0.0	2034
United States	-100%	-100%	-100%	-100%	-100%	23	5	0.0	2028
EU27	-61%	-57%	-50%	-100%	-100%	31	10	0.0	2041
India	284%	32%	-10%	155%	-12%	95	37	0.0	2090
Russia	-100%	-100%	-100%	-100%	-100%	10	5	0.0	2029
Japan	-70%	-72%	-70%	-100%	-100%	9	8	0.0	2035
Nigeria	84%	50%	14%	114%	75%	14	116	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 figures 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	166%	-31%	-45%	-100%	-100%	135	11	0.0	2040
United States	-55%	-59%	-55%	-100%	-100%	48	10	0.0	2039
EU27	-55%	-50%	-41%	-100%	-100%	37	13	0.0	2045
India	257%	23%	-16%	69%	-42%	66	26	0.0	2068
Russia	-64%	-50%	-54%	-100%	-100%	19	10	0.0	2038
Japan	-48%	-51%	-47%	-100%	-100%	13	11	0.0	2042
Nigeria	61%	31%	0%	40%	14%	8	65	0.0	-

Tab. 7: Reference values - B550 / P50 / NNE0 / LUC0[18]

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 CO2 budget of 550 Gt and a population weighting of 50%. The figure also illustrates that if China does not reduce its emissions by 2030, it will create an ambition gap that others cannot easily fill.

[18] Tab. 18 in the appendix shows by way of example the 60 highest national CO2 budgets resulting from these framework data.

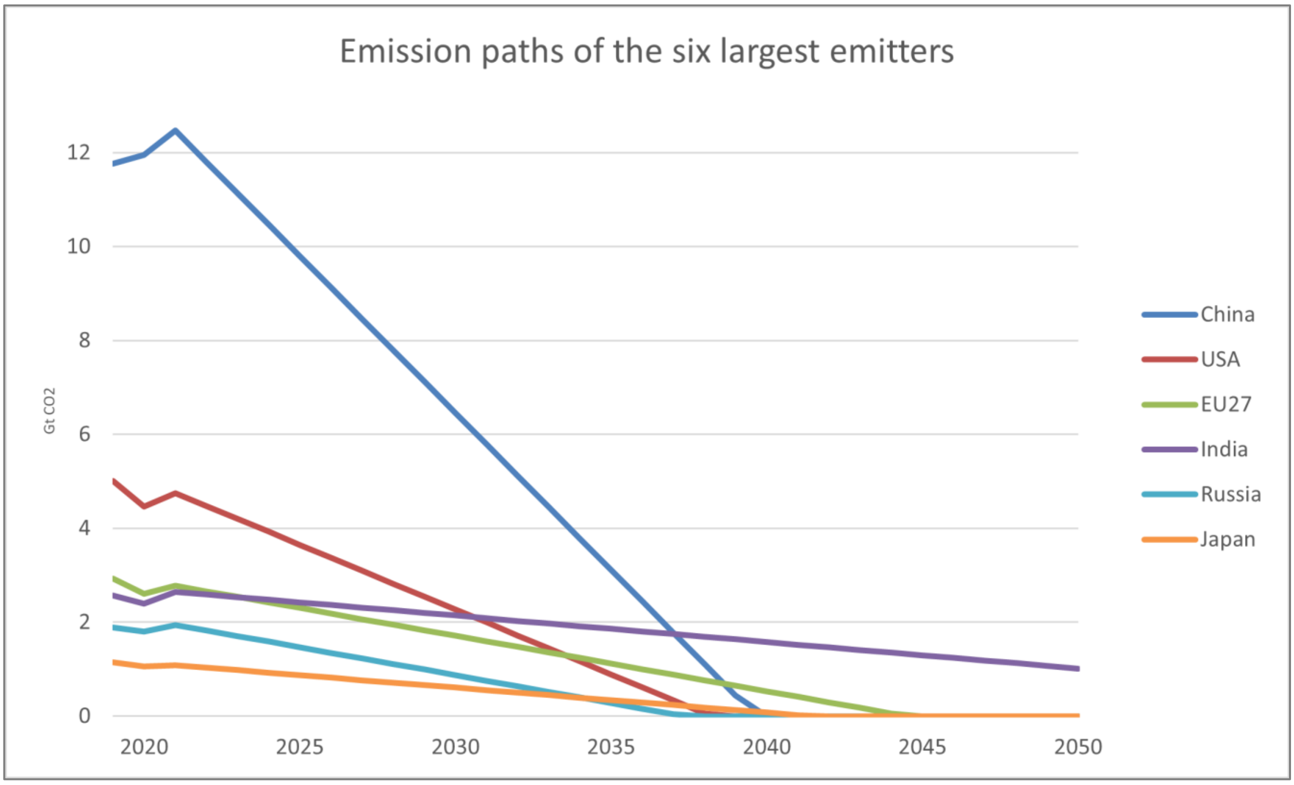

Fig. 1: Emission paths – B550 / P50 / NNE0 / LUC0[19]

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	211%	-19%	-36%	-100%	-100%	160	14	0.0	2044
United States	-41%	-46%	-40%	-100%	-100%	65	13	0.0	2046
EU27	-52%	-47%	-37%	-100%	-100%	41	14	0.0	2048
India	217%	9%	-26%	-61%	-87%	46	18	0.0	2053
Russia	-51%	-33%	-38%	-100%	-100%	25	13	0.0	2044
Japan	-40%	-43%	-39%	-100%	-100%	15	14	0.0	2047
Nigeria	41%	15%	-12%	-23%	-37%	4	30	0.0	2075

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:

[19] The kinks in 2020 are based on the consideration of actual emissions in the years 2020 and 2021 (see Footnote 11).

	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	**-52%**
Russia	-30%	1990	**-51%**
Japan	-46%	2013	**-47%**

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). According to Tab. 8 however, China would have to reduce its emissions by 36% 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.[20]

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	225%	-15%	-33%	-100%	-100%	171	15	0.0	2046
United States	-37%	-42%	-36%	-100%	-100%	73	15	0.0	2049
EU27	-51%	-45%	-36%	-100%	-100%	42	15	0.0	2049
India	184%	-2%	-33%	-100%	-100%	37	15	0.0	2047
Russia	-48%	-28%	-34%	-100%	-100%	27	15	0.0	2047
Japan	-38%	-40%	-36%	-100%	-100%	17	15	0.0	2049
Nigeria	8%	-12%	-33%	-100%	-100%	2	15	0.0	2046

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 leads to 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	209%	-19%	-36%	-100%	-100%	159	14	0.0	2044
United States	-47%	-51%	-46%	-100%	-100%	56	11	0.0	2042
EU27	-50%	-45%	-35%	-100%	-100%	43	15	0.0	2050
India	271%	28%	-13%	113%	-27%	78	30	0.0	2078
Russia	-56%	-39%	-44%	-100%	-100%	22	12	0.0	2041
Japan	-41%	-44%	-40%	-100%	-100%	15	13	0.0	2046
Nigeria	66%	35%	3%	57%	28%	9	77	0.0	-

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

[20] If actual emissions were not considered for the years 2020 and 2021 (see Footnote 11), 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	245%	-10%	-29%	-100%	-100%		189	16	0.0	2049
United States	-35%	-41%	-34%	-98%	-98%		77	15	0.0	2051
EU27	-48%	-42%	-32%	-94%	-93%		48	16	0.0	2053
India	237%	16%	-21%	6%	-64%		54	21	0.0	2060
Russia	-46%	-25%	-31%	-100%	-100%		29	16	0.0	2049
Japan	-35%	-38%	-33%	-95%	-95%		18	16	0.0	2052
Nigeria	46%	19%	-9%	-8%	-25%		4	35	0.0	2085

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.

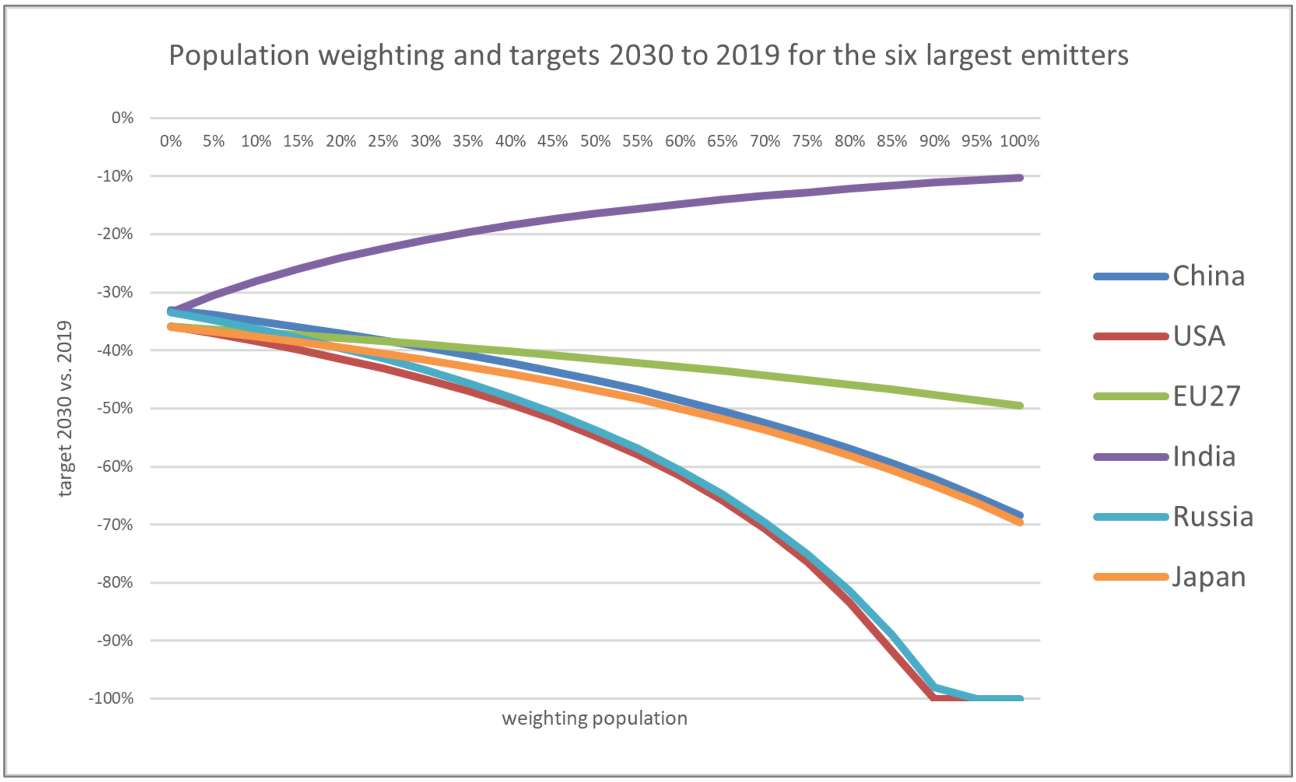

Fig. 2: Weighting population vs. targets 2030/2019 – B550 / NNE0 / LUC0

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.[21] The potential for net negative emissions are included

[21] 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.

in the model by a percentage of a country's emissions in 2019.[22] 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 temporary volume overshoot can lead to the overshooting of tipping points in the climate system.

(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. 9 chapter 5). 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.[23]

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	192%	-24%	-40%	-110%	-103%	135	11	13.7	2041
United States	-49%	-54%	-48%	-102%	-102%	48	10	6.0	2040
EU27	-53%	-47%	-38%	-102%	-102%	37	13	3.1	2046
India	259%	24%	-16%	76%	-39%	66	26	1.6	2069
Russia	-58%	-42%	-46%	-102%	-102%	19	10	2.3	2039
Japan	-44%	-46%	-43%	-102%	-102%	13	11	1.3	2043
Nigeria	61%	31%	0%	40%	14%	8	65	0.0	-

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

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

[22] This means that countries with high current emissions would have to realise or finance high net negative CO2 emissions. Since a budget for LUC is provided here at global level, negative CO2 emissions at national level refer to the non-LUC sector.

[23] 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	228%	-15%	-33%	-110%	-103%		160	14	12.8	2045
United States	-38%	-43%	-37%	-102%	-102%		65	13	5.2	2047
EU27	-50%	-44%	-35%	-101%	-101%		41	14	3.0	2049
India	223%	11%	-24%	-40%	-79%		46	18	2.3	2054
Russia	-48%	-29%	-34%	-102%	-102%		25	13	2.1	2045
Japan	-38%	-40%	-36%	-102%	-102%		15	14	1.2	2048
Nigeria	42%	16%	-12%	-21%	-36%		4	30	0.1	2075

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.[24] Despite these concerns, we add a LUC budget of -100 GtCO2 to a global CO2 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	172%	-29%	-44%	-110%	-103%		123	10	14.1	2040
United States	-53%	-57%	-52%	-102%	-102%		44	9	6.1	2039
EU27	-55%	-50%	-41%	-102%	-102%		33	11	3.3	2044
India	251%	21%	-18%	51%	-48%		60	24	1.8	2065
Russia	-62%	-47%	-51%	-102%	-102%		17	9	2.3	2038
Japan	-47%	-50%	-46%	-102%	-102%		12	10	1.3	2041
Nigeria	58%	29%	-2%	32%	7%		7	60	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.

[24] 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	210%	-19%	-36%	-110%	-103%		147	12	13.3	2043
United States	-41%	-46%	-40%	-102%	-102%		60	12	5.5	2045
EU27	-52%	-47%	-38%	-102%	-102%		37	13	3.1	2047
India	212%	8%	-27%	-75%	-91%		42	16	2.5	2051
Russia	-51%	-32%	-38%	-102%	-102%		23	12	2.1	2043
Japan	-40%	-43%	-39%	-102%	-102%		14	12	1.2	2046
Nigeria	39%	13%	-14%	-29%	-42%		3	27	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 need to be decided politically. For this, the following agenda emerges for each country:[25]

Political 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 a national CO2 budget on this base that ensure a fair and economically sensible distribution of a global CO2 budget.[26]
3. Align emission targets with a climate policy-sensible course of annual rates of change.[27]
4. Adjust the framework data and reduction targets regularly on the basis of new scientific findings and technical/real developments.

Despite the exemplary nature of the results shown here, they provide important indications of which scenarios/framework data lead to realistic national emissions targets that sum up to a 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.

[25] At present, a corresponding global agreement would not be realistic. Therefore, in the sense of the bottom-up approach of the Paris Ambition Mechanism, each country is to answer the points of the following agenda for itself. However, this can initiate a global discourse that contributes to Paris-compatible NDCs in sum.

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

[27] See Excursus 5: Regensburg Model Scenario Types.

The ESPM approach is open to the question of how a national CO2 budget is determined. The weighted distribution key used here for a global CO2 budget with the two components "emissions share" and "population share" represents a pragmatic approach that can map the current reality and equity.

With the scenario types offered in the ESPM (see Excursus 5), 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 in order to keep compliance with Paris climate targets 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 65.0), which can be downloaded from the platform zenodo (Wolfsteiner & Wittmann, 2022f).

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

The web app http://national-budgets.climate-calculator.info can be used to calculate Paris-compatible CO2 budgets for all countries in the world (corresponding detailed Excel tool: (Wolfsteiner & Wittmann, 2022e)).

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

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). (5) Cost efficiency can be seen as another approach.

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	13	28
United States	15	62
correlation coefficient	0.69	

Tab. 17: GDP per capita of the 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 CO2 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) and (Sargl, et al., 2022)], if per capita emissions are to converge at 0.5 t (cf. Wolfsteiner & Wittmann, 2022a).

Another approach is Integrated Assessment Models (IAMs), which can be used to identify globally cost-efficient national emission paths (cf. van Soest, et al., 2021); (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 politically 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 CO2 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 4.

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 CO2 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 otherwise 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 CO2 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 CO2 budget is given by

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

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). This tool can also be used to calculate national CO2 budgets for all countries in the world using an explicit population weighting.

Excursus 3: Allocation of a global CO2 budget

Emissions trading between countries: weighting population / global budget

The national CO2 budgets (see Tab. 18 in the Annex) resulting from the framework data in Tab. 11 and Tab. 12 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, especially if the NDCs are Paris-compatible in sum.

Excursus 4: Emissions trading between countries: weighting population / global 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 rates (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 the 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 scenario types RM-2 and RM-4.

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 5: Regensburg Model Scenario Types

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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	134.6	25.3%	11.77	11
India	66.0	12.4%	2.56	26
United States	47.8	9.0%	5.01	10
EU27	36.6	6.9%	2.92	13
Russia	18.6	3.5%	1.88	10
Indonesia	14.0	2.6%	0.65	22
Japan	12.7	2.4%	1.14	11
Brazil	10.8	2.0%	0.48	23
Pakistan	8.5	1.6%	0.20	42
Mexico	8.1	1.5%	0.48	17
Germany	7.9	1.5%	0.70	11
Nigeria	7.8	1.5%	0.12	65
Iran	7.7	1.5%	0.67	12
Bangladesh	6.6	1.2%	0.10	63
South Korea	6.5	1.2%	0.65	10
Turkey	5.9	1.1%	0.42	14
Vietnam	5.8	1.1%	0.33	17
Canada	5.7	1.1%	0.61	9
Egypt	5.4	1.0%	0.27	20
South Africa	5.4	1.0%	0.47	12
Saudi Arabia	5.4	1.0%	0.58	9
United Kingdom	5.0	0.9%	0.37	14
Philippines	4.8	0.9%	0.15	32
France and Monaco	4.6	0.9%	0.32	14
Italy, S. Mar. a. t. H. See	4.5	0.8%	0.33	13
Thailand	4.4	0.8%	0.28	16
Ethiopia	4.0	0.7%	0.02	200
Australia	3.8	0.7%	0.41	9
Poland	3.6	0.7%	0.31	11
Spain and Andorra	3.5	0.7%	0.26	14
Malaysia	3.1	0.6%	0.27	11
Dem. Rep. o. t. Congo	3.0	0.6%	0.00	898
Ukraine	3.0	0.6%	0.20	15
Argentina	2.9	0.5%	0.18	16
Taiwan	2.8	0.5%	0.28	10
Algeria	2.8	0.5%	0.18	16
Iraq	2.7	0.5%	0.18	15
Colombia	2.3	0.4%	0.08	28
Kazakhstan	2.3	0.4%	0.22	10
Tanzania	2.2	0.4%	0.01	164
Myanmar/Burma	2.2	0.4%	0.04	55
Sudan and South Sudan	2.0	0.4%	0.02	90
Uzbekistan	2.0	0.4%	0.12	17
Venezuela	2.0	0.4%	0.12	17
Kenya	2.0	0.4%	0.02	86
Morocco	1.8	0.3%	0.07	25
United Arab Emirates	1.8	0.3%	0.20	9
Netherlands	1.7	0.3%	0.16	11
Uganda	1.6	0.3%	0.01	229
Peru	1.6	0.3%	0.06	27
Afghanistan	1.3	0.3%	0.01	166
Chile	1.3	0.2%	0.09	14
North Korea	1.3	0.2%	0.06	22
Angola	1.3	0.2%	0.03	51
Romania	1.3	0.2%	0.08	16
Ghana	1.2	0.2%	0.02	57
Mozambique	1.1	0.2%	0.01	132
Nepal	1.1	0.2%	0.01	83
Belgium	1.1	0.2%	0.10	11
Yemen	1.1	0.2%	0.01	90
Czechia	1.1	0.2%	0.10	11
sum without EU	489		35	

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	159.1	25.3%	11.77	14
India	78.0	12.4%	2.56	30
United States	56.5	9.0%	5.01	11
EU27	43.2	6.9%	2.92	15
Russia	22.0	3.5%	1.88	12
Indonesia	16.6	2.6%	0.65	26
Japan	15.0	2.4%	1.14	13
Brazil	12.8	2.0%	0.48	27
Pakistan	10.1	1.6%	0.20	50
Mexico	9.5	1.5%	0.48	20
Germany	9.4	1.5%	0.70	13
Nigeria	9.2	1.5%	0.12	77
Iran	9.1	1.5%	0.67	14
Bangladesh	7.8	1.2%	0.10	74
South Korea	7.7	1.2%	0.65	12
Turkey	7.0	1.1%	0.42	17
Vietnam	6.8	1.1%	0.33	21
Canada	6.7	1.1%	0.61	11
Egypt	6.4	1.0%	0.27	24
South Africa	6.4	1.0%	0.47	14
Saudi Arabia	6.4	1.0%	0.58	11
United Kingdom	5.9	0.9%	0.37	16
Philippines	5.7	0.9%	0.15	38
France and Monaco	5.5	0.9%	0.32	17
Italy, S. Mar. a. t. H. See	5.3	0.8%	0.33	16
Thailand	5.2	0.8%	0.28	19
Ethiopia	4.7	0.7%	0.02	236
Australia	4.5	0.7%	0.41	11
Poland	4.2	0.7%	0.31	14
Spain and Andorra	4.1	0.7%	0.26	16
Malaysia	3.6	0.6%	0.27	14
Dem. Rep. o. t. Congo	3.6	0.6%	0.00	1,061
Ukraine	3.5	0.6%	0.20	18
Argentina	3.4	0.5%	0.18	19
Taiwan	3.4	0.5%	0.28	12
Algeria	3.3	0.5%	0.18	18
Iraq	3.2	0.5%	0.18	18
Colombia	2.8	0.4%	0.08	33
Kazakhstan	2.7	0.4%	0.22	12
Tanzania	2.6	0.4%	0.01	193
Myanmar/Burma	2.6	0.4%	0.04	66
Sudan and South Sudan	2.4	0.4%	0.02	106
Uzbekistan	2.4	0.4%	0.12	20
Venezuela	2.4	0.4%	0.12	20
Kenya	2.3	0.4%	0.02	101
Morocco	2.1	0.3%	0.07	29
United Arab Emirates	2.1	0.3%	0.20	11
Netherlands	2.1	0.3%	0.16	13
Uganda	1.9	0.3%	0.01	271
Peru	1.8	0.3%	0.06	32
Afghanistan	1.6	0.3%	0.01	197
Chile	1.6	0.2%	0.09	17
North Korea	1.6	0.2%	0.06	27
Angola	1.5	0.2%	0.03	60
Romania	1.5	0.2%	0.08	18
Ghana	1.4	0.2%	0.02	67
Mozambique	1.4	0.2%	0.01	156
Nepal	1.3	0.2%	0.01	98
Belgium	1.3	0.2%	0.10	13
Yemen	1.3	0.2%	0.01	107
Czechia	1.3	0.2%	0.10	13
sum without EU	578		35	

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	189.2	30.0%	11.77	16
United States	77.2	12.2%	5.01	15
India	54.2	8.6%	2.56	21
EU27	48.1	7.6%	2.92	16
Russia	29.2	4.6%	1.88	16
Japan	18.2	2.9%	1.14	16
Indonesia	12.8	2.0%	0.65	20
Germany	11.3	1.8%	0.70	16
Iran	10.8	1.7%	0.67	16
South Korea	10.1	1.6%	0.65	16
Brazil	9.6	1.5%	0.48	20
Canada	9.3	1.5%	0.61	15
Saudi Arabia	8.8	1.4%	0.58	15
Mexico	8.6	1.4%	0.48	18
South Africa	7.6	1.2%	0.47	16
Turkey	7.1	1.1%	0.42	17
Australia	6.2	1.0%	0.41	15
United Kingdom	6.2	1.0%	0.37	17
Vietnam	6.1	1.0%	0.33	18
Italy, S. Mar. a. t. H. See	5.6	0.9%	0.33	17
France and Monaco	5.5	0.9%	0.32	17
Pakistan	5.4	0.9%	0.20	27
Egypt	5.2	0.8%	0.27	19
Poland	5.0	0.8%	0.31	16
Thailand	5.0	0.8%	0.28	18
Taiwan	4.4	0.7%	0.28	16
Spain and Andorra	4.3	0.7%	0.26	17
Malaysia	4.3	0.7%	0.27	16
Nigeria	4.2	0.7%	0.12	35
Bangladesh	3.6	0.6%	0.10	34
Philippines	3.5	0.6%	0.15	23
Kazakhstan	3.5	0.6%	0.22	16
Ukraine	3.4	0.5%	0.20	17
Argentina	3.2	0.5%	0.18	18
Iraq	3.1	0.5%	0.18	17
Algeria	3.1	0.5%	0.18	18
United Arab Emirates	3.0	0.5%	0.20	15
Netherlands	2.5	0.4%	0.16	16
Uzbekistan	2.2	0.3%	0.12	18
Venezuela	2.1	0.3%	0.12	18
Colombia	1.8	0.3%	0.08	22
Ethiopia	1.6	0.3%	0.02	83
Czechia	1.6	0.3%	0.10	16
Belgium	1.6	0.3%	0.10	16
Chile	1.6	0.3%	0.09	17
Qatar	1.6	0.2%	0.11	15
Morocco	1.5	0.2%	0.07	21
Kuwait	1.5	0.2%	0.10	15
Romania	1.4	0.2%	0.08	18
Oman	1.3	0.2%	0.09	15
Peru	1.2	0.2%	0.06	22
Myanmar/Burma	1.2	0.2%	0.04	32
Turkmenistan	1.2	0.2%	0.08	16
North Korea	1.2	0.2%	0.06	20
Austria	1.1	0.2%	0.07	16
Dem. Rep. o. t. Congo	1.1	0.2%	0.00	330
Greece	1.1	0.2%	0.06	17
Israel a. Palest., State o.	1.0	0.2%	0.06	16
Belarus	1.0	0.2%	0.06	16
Sudan and South Sudan	1.0	0.2%	0.02	44
Kenya	1.0	0.2%	0.02	42
sum without EU	593		35	

Tab. 18: Exemplary national budgets with different global framework data[28]

[28] 59 countries plus the EU with the highest resulting national CO2 budgets.