Working paper

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

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Abstract

What are achievable 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 they represent an adequate contribution to the necessary global efforts. An open and transparent discussion of this issue can contribute to NDCs that, in sum, are once compatible with the Paris Agreement.

[1] This paper is also 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 global budgets in the Sixth Assessment Report of the IPCC (IPCC, 2021) and emissions data (EDGAR, 2023).

See also our corresponding paper for Germany and the EU (Sargl, et al., 2024a).

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Global CO2 budgets and their relevance for national targets

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:

<table>
<tr><th>Warm-
ing</th><th colspan="3">Remaining
carbon budgets</th><th>Scenario
variation</th><th colspan="4">Geophysical uncertainties</th></tr>
<tr><td>Proba-
bilities:</td><td>50%</td><td>67%</td><td>83%</td><td>Non-CO2
scenario
variation</td><td>Non-CO2 forcing
and response
uncertainty</td><td>Historical
temperature
uncertainty</td><td>ZEC
uncer-
tainty</td><td>Recent
emissions
uncertainty</td></tr>
<tr><td>[°C]</td><td colspan="3">[GtCO2 from 2020 on]</td><td colspan="5">[GtCO2]</td></tr>
<tr><td>1.5</td><td>500</td><td>400</td><td>300</td><td rowspan="4">±220</td><td rowspan="4">±220</td><td rowspan="4">±550</td><td rowspan="4">±420</td><td rowspan="4">±20</td></tr>
<tr><td>1.6</td><td>650</td><td>550</td><td>400</td></tr>
<tr><td>1.7</td><td>850</td><td>700</td><td>550</td></tr>
<tr><td>1.8</td><td>1000</td><td>850</td><td>650</td></tr>
</table>

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

The need to take into account the socio-economic consequences of the pace of decarbonisation, the likelihood of compliance and other uncertainties requires a science-based but ultimately policy decision on the global carbon budget against which nationally determined contributions (NDCs) are set.

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] This results from the physically given budget property of CO2.

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.

[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). Here, only the budgets up to a global warming of 1.8°C are shown, as a minimum target of well below the 2°C limit was agreed in the Paris Agreement.

In the Summary for Policymakers, the IPCC states that (IPCC, 2021, p. 28 SPM):

"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."

Regarding probabilities, the IPCC notes (IPCC, 2021, p. 29 SPM):

"*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.*"

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

For 2019, global total emissions are estimated at 40.9 GtCO2 (GCP, 2023). See also our web app on linear global emission paths that adhere to a predetermined CO2 budget: http://global-paths.climate-calculator.info.

[4] 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	9.1	11.8	8.3	32%	18%
United States	5.0	5.5	5.0	15.1	14%	4%
EU27	3.8	3.4	2.9	6.5	8%	6%
India	0.6	1.7	2.5	1.9	7%	18%
Russia	2.4	1.7	1.9	13.0	5%	2%
Japan	1.2	1.2	1.1	8.9	3%	2%
Sum	15.3	22.7	25.2		69%	50%
Nigeria	0.07	0.09	0.12	0.6	0.3%	3%
Global	21.9	32.7	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 NDCs of the six largest emitters, which together account for about 70% of global emissions (cf. Tab. 2):[6]

country	target year 2030	reference year	long-term goals
United States	-50% to -52%	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.

[5] These are the CO2 emissions from fossil fuel use (except international shipping and aviation; ISA) and cement production (EDGAR, 2023). CO2 emissions from land-use change (LUC) are therefore not included here (see also Chapter “Data basis used”).

[6] Remark: The countries (excluding the EU) that account for less than 2% of global CO2 emissions are together responsible for around 40% of global emissions. This means that even countries with a small share of global emissions cannot escape responsibility.

[7] Source and further details at Climate Action Tracker (https://climateactiontracker.org; status as of 08/11/2022). See also Tab. 5 for better comparability of the targets.

Calculation of national emission paths with the Extended Smooth Pathway Model

The Extended Smooth Pathway Model

In order to calculate national emission targets 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 of national budgets**

In order to derive national budgets from a global budget, an allocation key is needed. In determining the following exemplary national emissions targets, a weighted distribution key was used that takes into account a country's share of global emissions and its share of the world's 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:

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

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 or B^i	global CO2 budget or national CO2 budget of the country i; here from 2020 on
C	weighting of population

There are many possible approaches to allocating a global budget to countries. In our view, this distribution key represents the most important factors and makes it possible in particular to identify feasible national targets. Other criteria seem to us to make more sense in other contexts (see Excursus 3: Allocation of a global CO2 budget). A two-dimensional distribution key also has the advantage that only one factor has to be determined.

(2) **Derivation of national emission paths**

Plausible emission paths are derived that adhere to the national budget. With the Regensburg Model Scenario Types RM 1 - 6, we offer the entire range of plausible possibilities (see

[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.

Excursus 5).[9] For reasons of simplification, a linear course of the emission paths (RM-6) is used in the following.[10]

Data basis used

The EU database EDGAR provides CO2 emissions excluding CO2 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 plus Nigeria (cf. EDGAR, 2023).

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).[11] 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 paths 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, 2023b).[12] In the following calculations of the reference values for the six largest emitters plus Nigeria, a value of zero is used for the LUC budget (except in Tab. 16 and in Tab. 17). This implies that annual net positive LUC emissions occurring until 2100 are completely compensated by annual net negative LUC emissions.[13]

Further a budget of 3% of the global budget is reserved for ISA, which corresponds roughly to its current share of global CO2 emissions.[14]

	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[15]

[9] Fig. 3 uses China as an example to illustrate the differences in the RM Scenario Types. The following web app also shows the differences between the scenario types: http://paths.climate-calculator.info.

[10] Due to the inclusion of actual emissions in the years 2020 - 2022, the emission paths only fall on a straight line from 2023 onwards (see Fig. 1).

[11] If country level data including LUC and ISA are available, this step is not necessary (cf. Sargl, et al., 2024a). 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.

[12] Global LUC emissions are estimated at +4.6 GtCO2 in 2019 (GCP, 2023).

[13] In the Excel tool used (Wolfsteiner & Wittmann, 2024b), other values for LUC emissions can also be taken.

[14] Global ISA emissions are estimated at 1.3 GtCO2 in 2019 (EDGAR, 2023). In the Excel tool used (Wolfsteiner & Wittmann, 2024b), other values for ISA emissions can also be taken.

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

Since current NDCs, according to Tab. 3, refer to all greenhouse gases or, in the case of China, likely to all CO2 emissions, the reference values shown in the next chapter are only to a limited extend comparable 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.

Leaving aside the fact that the NDCs may refer to different greenhouse gas fractions, the targets there for some countries can be converted into the change in CO2 emissions in 2030 compared to 2019 considered here, which allows for better comparability (see Tab. 5).

country	target year 2030	reference year	change 2030 vs. 2019
	see Tab. 3		
United States	-50%	2005	**-41%**
EU27	-55%	1990	**-41%**
Russia	-30%	1990	**-12%**
Japan	-46%	2013	**-37%**

Tab. 5: Conversion of emission targets to the change in 2030 compared to 2019

Exemplary national emission targets for the six largest emitters plus Nigeria[16]

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 corresponds 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. 6. Using a global CO2 budget of 550 Gt leads to the results in Tab. 7.

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		2040					
reference year:	1990	2019	1990	2019				
China	-100%	-100%	-100%	-100%	71	6	0.0	2029
United States	-100%	-100%	-100%	-100%	17	3	0.0	2025
EU27	-80%	-74%	-100%	-100%	22	8	0.0	2034
India	271%	-12%	175%	-35%	69	27	0.0	2069
Russia	-100%	-100%	-100%	-100%	7	4	0.0	2025
Japan	-100%	-100%	-100%	-100%	6	6	0.0	2029
Nigeria	66%	0%	66%	0%	10	82	0.0	-

Tab. 6: Reference values - B400 / P100 / NNE0 / LUC0[17]

[16] The results can also be reproduced with our web app (with minor deviations due to a different mathematical approach): http://national-budgets.climate-calculator.info. The results here were determined with the Excel tool: (Wolfsteiner & Wittmann, 2024b).

[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 first year with negative emissions or emissions are zero (see also Footnote 22). 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		2040					
reference year:	1990	2019	1990	2019				
China	28%	-74%	-100%	-100%	98	8	0.0	2033
United States	-100%	-100%	-100%	-100%	23	5	0.0	2027
EU27	-61%	-49%	-100%	-100%	31	11	0.0	2039
India	294%	-7%	225%	-23%	95	37	0.0	2088
Russia	-100%	-100%	-100%	-100%	10	5	0.0	2028
Japan	-73%	-72%	-100%	-100%	9	8	0.0	2034
Nigeria	79%	8%	96%	18%	14	113	0.0	-

Tab. 7: 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. 8.

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		2040					
reference year:	1990	2019	1990	2019				
China	170%	-45%	-100%	-100%	135	11	0.0	2039
United States	-55%	-55%	-100%	-100%	48	10	0.0	2037
EU27	-54%	-40%	-89%	-86%	37	13	0.0	2044
India	267%	-13%	166%	-37%	66	26	0.0	2067
Russia	-63%	-54%	-100%	-100%	19	10	0.0	2037
Japan	-48%	-46%	-98%	-98%	13	11	0.0	2041
Nigeria	58%	-5%	49%	-10%	8	64	0.0	-

Tab. 8: 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 (see also 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. 20 in the appendix shows by way of example the 60 highest national CO2 budgets resulting from these framework data.

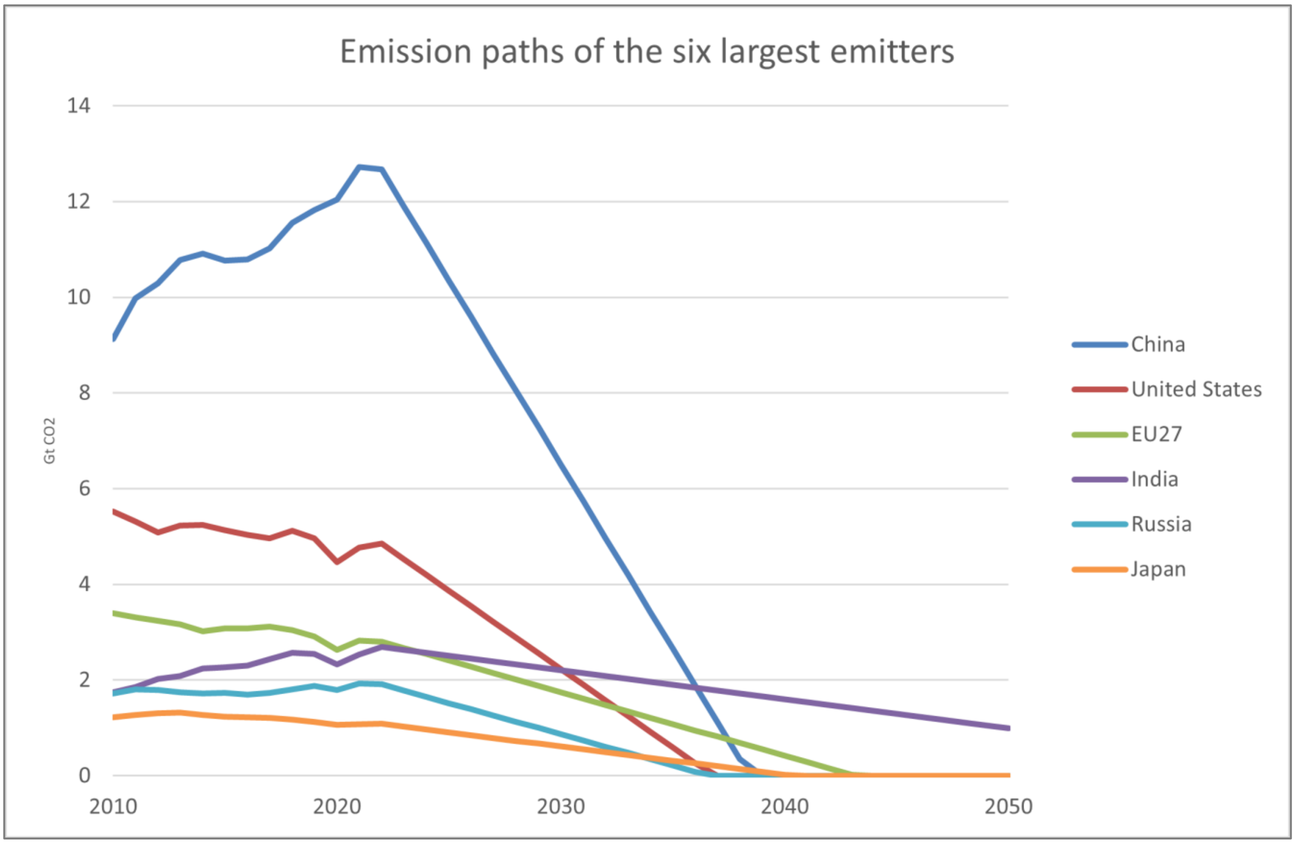

Fig. 1: Linear emission paths (RM-6-abs) – B550 / P50 / NNE0 / LUC0[19]

Weighting the population with only 15% would give the results in Tab. 9.[20]

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		2040						
reference year:	1990	2019	1990	2019					
China	222%	-35%	-34%	-87%		161	14	0.0	2043
United States	-38%	-38%	-82%	-82%		65	13	0.0	2044
EU27	-51%	-36%	-81%	-76%		41	14	0.0	2047
India	226%	-23%	73%	-59%		46	18	0.0	2052
Russia	-50%	-37%	-88%	-85%		25	13	0.0	2044
Japan	-39%	-37%	-79%	-78%		15	14	0.0	2046
Nigeria	41%	-15%	10%	-34%		4	29	0.0	2076

Tab. 9: 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] Actual emissions 2010 - 2022 (see also Footnote 10).

[20] 15% correspond to the implicit weighting of the population in the convergence approach Regensburg Model (cf. Excursus 3: Allocation of a global CO2 budget).

	current targets (see Tab. 3)		framework data Tab. 9
country	target year 2030	individual reference year	change 2030 vs. individual reference year
United States	-50%	2005	**-48%**
EU27	-55%	1990	**-51%**
Russia	-30%	1990	**-50%**
Japan	-46%	2013	**-46%**

Tab. 10: 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. 9 are a good representation of the current targets of the EU, USA and Japan for 2030 (but not for Russia). According to Tab. 9 however, China would have to reduce its emissions by 35% 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 countries would have to reduce their emissions by rounded 33% by 2030 compared to 2019, as Tab. 11 shows.[21]

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		2040					
reference year:	1990	2019	1990	2019				
China	238%	-31%	2%	-79%	173	15	0.0	2045
United States	-34%	-33%	-73%	-72%	73	15	0.0	2048
EU27	-49%	-34%	-79%	-72%	42	15	0.0	2048
India	192%	-31%	-3%	-77%	37	15	0.0	2045
Russia	-46%	-32%	-80%	-75%	27	15	0.0	2046
Japan	-36%	-34%	-73%	-72%	16	15	0.0	2048
Nigeria	11%	-33%	-57%	-74%	2	15	0.0	2047

Tab. 11: 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. 12 and a 15% weighting of the population leads to the results in Tab. 13.

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		2040					
reference year:	1990	2019	1990	2019				
China	219%	-35%	-39%	-88%	160	14	0.0	2043
United States	-45%	-45%	-98%	-98%	56	11	0.0	2041
EU27	-49%	-33%	-77%	-71%	43	15	0.0	2048
India	281%	-10%	197%	-30%	78	31	0.0	2076
Russia	-55%	-43%	-99%	-99%	22	12	0.0	2041
Japan	-40%	-38%	-81%	-81%	15	13	0.0	2045
Nigeria	63%	-2%	60%	-4%	9	75	0.0	-

Tab. 12: Reference values - B650 / P50 / NNE0 / LUC0

[21] If actual emissions were not considered for the years 2020 - 2022 (see Footnote 10), 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		2040					
reference year:	1990	2019	1990	2019				
China	259%	-27%	50%	-69%	191	16	0.0	2048
United States	-32%	-31%	-68%	-68%	77	15	0.0	2049
EU27	-46%	-30%	-71%	-63%	48	17	0.0	2052
India	247%	-18%	121%	-48%	54	21	0.0	2058
Russia	-44%	-30%	-76%	-69%	29	16	0.0	2048
Japan	-33%	-31%	-66%	-65%	18	16	0.0	2051
Nigeria	45%	-13%	19%	-28%	4	35	0.0	2087

Tab. 13 : 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.

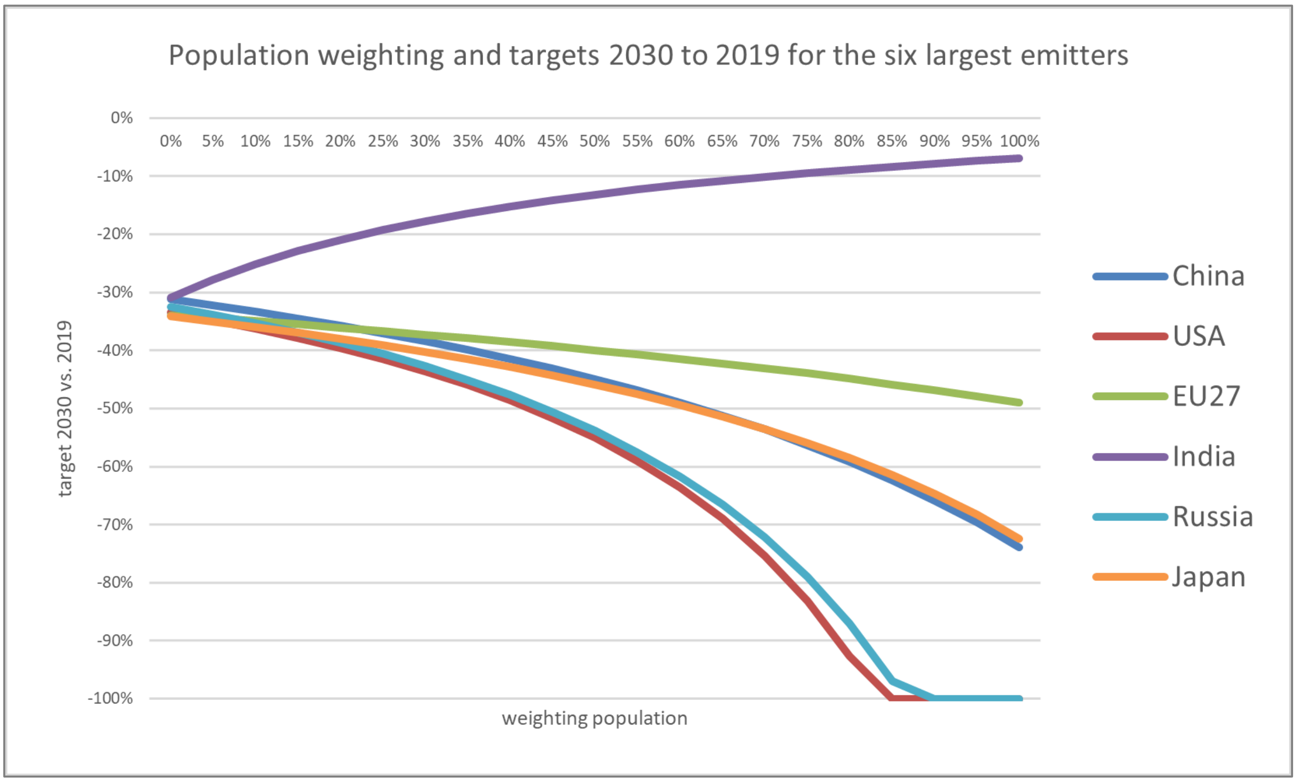

Fig. 2: Weighting population vs. targets 2030/2019 – B550 / NNE0 / LUC0

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.[22] The potential for net negative emissions is included

[22] 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.[23] The result represents the potential minimum emissions by 2100. If this value is negative, then a volume overshoot is possible. Thereby, the lower this negative 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. 14.[24]

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		2040					
reference year:	1990	2019	1990	2019				
China	201%	-39%	-81%	-96%	135	11	14.2	2041
United States	-48%	-47%	-102%	-102%	48	10	6.1	2040
EU27	-51%	-36%	-83%	-78%	37	13	3.2	2046
India	270%	-13%	171%	-36%	66	26	1.7	2068
Russia	-57%	-46%	-102%	-102%	19	10	2.3	2040
Japan	-43%	-41%	-88%	-87%	13	11	1.3	2043
Nigeria	58%	-5%	49%	-10%	8	64	0.0	-

Tab. 14: Reference values - B550 / P50 / NNE2 / LUC0

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

[23] 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.

[24] 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, 2023b).

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		2040					
reference year:	1990	2019	1990	2019				
China	240%	-31%	8%	-78%	161	14	13.2	2045
United States	-35%	-35%	-75%	-75%	65	13	5.4	2047
EU27	-49%	-33%	-77%	-70%	41	14	3.0	2049
India	233%	-21%	89%	-55%	46	18	2.4	2054
Russia	-47%	-33%	-82%	-77%	25	13	2.1	2046
Japan	-36%	-34%	-73%	-72%	15	14	1.2	2048
Nigeria	41%	-15%	11%	-33%	4	29	0.1	2077

Tab. 15: Reference values - B550 / P15 / NNE2 / LUC0[25]

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. 14 and Tab. 15).

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.[26] 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. 16.

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		2040					
reference year:	1990	2019	1990	2019				
China	178%	-43%	-110%	-102%	124	10	14.5	2039
United States	-52%	-52%	-102%	-102%	44	9	6.2	2038
EU27	-54%	-40%	-89%	-85%	33	12	3.3	2044
India	262%	-14%	154%	-40%	60	24	1.9	2064
Russia	-61%	-51%	-102%	-102%	17	9	2.4	2038
Japan	-47%	-45%	-96%	-96%	12	10	1.3	2041
Nigeria	55%	-6%	43%	-13%	7	58	0.0	-

Tab. 16: Reference values - B400 / P50 / NNE2 / LUC100

A reduced weighting of the population with 15% would lead to the results in Tab. 17.

[25] Tab. 19 uses this framework data to show the results for different RM Scenario Types using China as an example.

[26] 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		2040					
reference year:	1990	2019	1990	2019				
China	222%	-35%	-34%	-87%	148	13	13.7	2043
United States	-38%	-38%	-82%	-82%	60	12	5.6	2045
EU27	-51%	-36%	-82%	-76%	37	13	3.2	2046
India	222%	-24%	64%	-61%	42	16	2.5	2051
Russia	-50%	-37%	-88%	-85%	23	12	2.1	2044
Japan	-39%	-37%	-79%	-78%	14	12	1.2	2046
Nigeria	39%	-16%	6%	-36%	3	27	0.1	2073

Tab. 17: Reference values - B400 / P15 / NNE2 / LUC100

Conclusions

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

- 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" in a base year represents a pragmatic approach that can map the two important factors “current reality” and “equity” (see Excursus 3).
- 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 scenario types ultimately enable a transparent political decision on emission paths.

The emission targets for the world's six major emitters presented here are only examples, as important framework data need to be decided politically. For this, the following political agenda emerges for each country:[27]

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 net negative emissions.
2. Derive a national CO2 budget on this base that ensure a fair and economically sensible distribution of a global CO2 budget.[28]
3. Align emission targets with a climate policy-sensible course of annual rates of change.[29]
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 emission targets that sum up to a Paris-compatible global emissions budget.

An important finding is that there is a trade-off between realisable national emission paths for major emitters in line with the 1.5°C limit and climate justice.

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[27] 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. In addition, the major emitters need to find a binding negotiation format (see below).

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

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

The following is now crucial:

- We have to face the difficult task of identifying achievable national targets that are consistent with the Paris Agreement and adequately address climate justice. In doing so, concessions will be necessary, both in terms of orientation towards the 1.5°C limit and in terms of the per capita distribution of a remaining global CO2 budget.
- Major emitters should find a negotiating format to agree on Paris-compatible and binding targets. The UN climate conferences are not the appropriate format for such negotiations because of the unanimity rule of over 190 countries (cf. Edenhofer, 2022).
- The figures show that we urgently need a solution to China's looming ambition gap (cf. Fig. 1). This ambition gap is particularly critical for achieving the Paris climate targets, firstly because of China's high share of global emissions and secondly because the rapid reduction in emissions that is actually necessary may not seem feasible.
- But the emissions of emerging nations such as India must also fall soon. If emissions continue to rise in these countries, as they have in recent years, then the Paris climate targets will also not be achievable.
- However, all parties to the Paris Agreement are required to submit NDCs by 2025 reflecting the global reduction needs according to the Global Stocktake (GST).[30]
- Paris-compatible NDCs are the first step. The second, equally important step is to ensure that these targets are actually met. Hard emission caps in emissions trading systems could ensure this, for example (cf. Expertenrat für Klimafragen, 2022).

[30] Cf. (UNFCCC, 2023).

Tools and further exemplary results

For the calculation of the exemplary results in this paper we have used the Excel tool "ESPM" (version 73.0), which can be downloaded from the zenodo platform (Wolfsteiner & Wittmann, 2024b).

Further exemplary results for the six largest emitters with different framework data and RM 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, 2023c)). This web app also shows the emission targets for a linear emission path. This allows the results shown here to be reproducible. Minor deviations may occur due to a different mathematical approach (cf. Wittmann & Wolfsteiner, 2023).

The web app http://paths.climate-calculator.info can be used to calculate emission paths that comply with a predefined CO2 budget (corresponding detailed Excel tool: (Wolfsteiner & Wittmann, 2024a). In addition to linear emission paths, other scenario types are offered there (see Excursus 5: Regensburg Model Scenario Types).

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

Excursuses

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. 18), 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.

correlation	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	0.68	

Tab. 18: 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)] (cf. Sargl, et al., 2023). Using a convergence model implies an implicit weighting of the population that is the same for all countries (cf. Wittmann & Wolfsteiner, 2023). In the Regensburg Model convergence approach, this implicit weighting is around 12% with a linear emission path and a per capita emissions convergence at 0.5 t (cf. Sargl, et al., 2024b). Due to its characteristics, the Regensburg Model can be described as a kind of "moral floor" for the industrialised countries.

Another approach are Integrated Assessment Models (IAMs), which can be used to identify globally cost-efficient national emission paths (cf. van Soest, et al., 2021). See approach (5) above. But the results of IAMs are 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. This means that emissions paths can ultimately be determined politically in a transparent manner in the ESPM, taking socio-economic factors into account.

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., 2023). If this national budget can be estimated (cf. Wolfsteiner, 2023) or, at best, is even directly specified, the implicit weighting of the population depending of a global CO2 budget is given by

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

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, 2023c). 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. 20 in the Annex) resulting from the framework data in Tab. 12 and Tab. 13 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. However, the integrity of emissions trading on this basis is undermined if NDCs are not met.

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. Annual rates of change are used in many areas and are particularly suitable for describing a meaningful course of emission paths. 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 app** http://paths.climate-calculator.info the different scenario types can be graphically traced (see also Tab. 19 and Fig. 3 below). For a comprehensive mathematical description, we refer to: (Wolfsteiner & Wittmann, 2023a).

In the scenario types RM-3, RM-4 and RM-5, emissions that are still rising initially can also be mapped by specifying a corresponding start rate of change for 2020.

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.

In the following, the differences in the scenario types are shown using China as an example (cf. Tab. 15):

global CO2 budget 2020 - 2100 in Gt		550	minimum emissions		-2%
weighting population		15%	LUC budget in Gt		0
scenario type:	RM-1-const	RM-5-rad	RM-6-abs	RM-3-lin	RM-4-quadr
target year	changes versus 2019				
2025	-18%	-6%	-7%	1%	9%
2030	**-48%**	**-36%**	**-31%**	**-28%**	**-15%**
2035	-67%	-63%	-54%	-62%	-65%
2040	-79%	-81%	-78%	-85%	-95%
2045	-87%	-91%	-102%	-96%	-102%
2050	-92%	-96%	-102%	-101%	-102%
year emissions neutrality	**2069**	**2056**	**2045**	**2049**	**2043**
overshoot in Gt	6.9	10.2	13.2	12.0	13.7
national budget in Gt	161				

Tab. 19: RM Scenario Types: Reference values China - B550 / P15 / NNE2 / LUC0

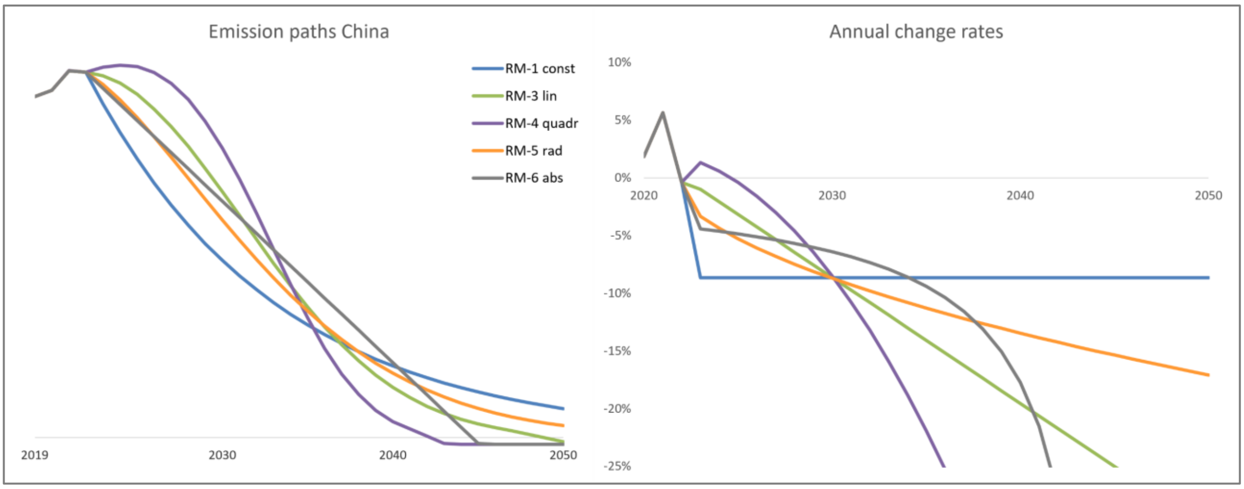

Fig. 3: RM Scenario Types: Emission paths and annual change rates China – B550 / P15 / NNE2 / LUC0

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	135,3	25,4%	11,82	11
India	65,8	12,4%	2,54	26
United States	47,6	8,9%	4,97	10
EU27	36,5	6,9%	2,90	13
Russia	18,7	3,5%	1,88	10
Indonesia	14,0	2,6%	0,64	22
Japan	12,6	2,4%	1,13	11
Brazil	10,8	2,0%	0,47	23
Pakistan	8,5	1,6%	0,20	43
Mexico	8,1	1,5%	0,48	17
Germany	7,9	1,5%	0,69	11
Nigeria	7,8	1,5%	0,12	64
Iran	7,7	1,4%	0,66	12
Bangladesh	6,6	1,2%	0,11	61
South Korea	6,5	1,2%	0,65	10
Türkiye	5,9	1,1%	0,42	14
Vietnam	5,8	1,1%	0,33	17
Canada	5,6	1,1%	0,59	9
South Africa	5,5	1,0%	0,48	11
Saudi Arabia	5,4	1,0%	0,58	9
Egypt	5,2	1,0%	0,23	22
United Kingdom	4,9	0,9%	0,36	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	4,5	0,8%	0,28	16
Ethiopia	3,9	0,7%	0,02	214
Australia	3,9	0,7%	0,41	9
Poland	3,6	0,7%	0,31	12
Spain and Andorra	3,5	0,7%	0,26	14
Dem. Rep. of the Congo	3,0	0,6%	0,00	901
Ukraine	3,0	0,6%	0,20	15
Malaysia	3,0	0,6%	0,25	12
Argentina	2,9	0,5%	0,18	16
Taiwan	2,8	0,5%	0,28	10
Iraq	2,8	0,5%	0,19	15
Algeria	2,8	0,5%	0,18	16
Colombia	2,3	0,4%	0,08	28
Tanzania	2,2	0,4%	0,02	145
Kazakhstan	2,2	0,4%	0,21	10
Myanmar/Burma	2,1	0,4%	0,04	60
Sudan and South Sudan	2,1	0,4%	0,02	86
Uzbekistan	2,0	0,4%	0,12	17
Venezuela	2,0	0,4%	0,11	17
Kenya	1,9	0,4%	0,02	100
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	236
Peru	1,6	0,3%	0,06	27
Afghanistan	1,3	0,3%	0,01	180
Chile	1,3	0,2%	0,09	14
North Korea	1,3	0,2%	0,06	23
Angola	1,3	0,2%	0,03	51
Romania	1,3	0,2%	0,08	16
Ghana	1,2	0,2%	0,02	59
Mozambique	1,1	0,2%	0,01	133
Nepal	1,1	0,2%	0,01	82
Belgium	1,1	0,2%	0,10	11
Czechia	1,1	0,2%	0,10	11
Yemen	1,1	0,2%	0,01	89
sum without EU	489		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	160,0	25,4%	11,82	14
India	77,8	12,4%	2,54	31
United States	56,3	8,9%	4,97	11
EU27	43,2	6,9%	2,90	15
Russia	22,1	3,5%	1,88	12
Indonesia	16,5	2,6%	0,64	26
Japan	14,9	2,4%	1,13	13
Brazil	12,7	2,0%	0,47	27
Pakistan	10,0	1,6%	0,20	51
Mexico	9,6	1,5%	0,48	20
Germany	9,4	1,5%	0,69	13
Nigeria	9,3	1,5%	0,12	75
Iran	9,1	1,4%	0,66	14
Bangladesh	7,8	1,2%	0,11	73
South Korea	7,7	1,2%	0,65	12
Türkiye	7,0	1,1%	0,42	17
Vietnam	6,9	1,1%	0,33	21
Canada	6,6	1,1%	0,59	11
South Africa	6,5	1,0%	0,48	14
Saudi Arabia	6,4	1,0%	0,58	11
Egypt	6,2	1,0%	0,23	26
United Kingdom	5,8	0,9%	0,36	16
Philippines	5,7	0,9%	0,15	38
France and Monaco	5,4	0,9%	0,32	17
Italy, San Marino and the H	5,3	0,8%	0,33	16
Thailand	5,3	0,8%	0,28	19
Ethiopia	4,7	0,7%	0,02	253
Australia	4,6	0,7%	0,41	11
Poland	4,2	0,7%	0,31	14
Spain and Andorra	4,1	0,7%	0,26	16
Dem. Rep. of the Congo	3,6	0,6%	0,00	1.065
Ukraine	3,5	0,6%	0,20	18
Malaysia	3,5	0,6%	0,25	14
Argentina	3,4	0,5%	0,18	19
Taiwan	3,4	0,5%	0,28	12
Iraq	3,3	0,5%	0,19	17
Algeria	3,3	0,5%	0,18	19
Colombia	2,7	0,4%	0,08	34
Tanzania	2,6	0,4%	0,02	172
Kazakhstan	2,6	0,4%	0,21	12
Myanmar/Burma	2,5	0,4%	0,04	71
Sudan and South Sudan	2,4	0,4%	0,02	102
Uzbekistan	2,4	0,4%	0,12	20
Venezuela	2,3	0,4%	0,11	20
Kenya	2,3	0,4%	0,02	118
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	280
Peru	1,8	0,3%	0,06	32
Afghanistan	1,6	0,3%	0,01	213
Chile	1,6	0,2%	0,09	17
North Korea	1,5	0,2%	0,06	27
Angola	1,5	0,2%	0,03	60
Romania	1,5	0,2%	0,08	19
Ghana	1,4	0,2%	0,02	70
Mozambique	1,4	0,2%	0,01	157
Nepal	1,3	0,2%	0,01	97
Belgium	1,3	0,2%	0,10	13
Czechia	1,3	0,2%	0,10	13
Yemen	1,3	0,2%	0,01	106
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	190,7	30,3%	11,82	16
United States	76,9	12,2%	4,97	15
India	54,0	8,6%	2,54	21
EU27	48,0	7,6%	2,90	17
Russia	29,3	4,6%	1,88	16
Japan	18,1	2,9%	1,13	16
Indonesia	12,6	2,0%	0,64	20
Germany	11,2	1,8%	0,69	16
Iran	10,8	1,7%	0,66	16
South Korea	10,2	1,6%	0,65	16
Brazil	9,5	1,5%	0,47	20
Canada	9,2	1,5%	0,59	15
Saudi Arabia	8,9	1,4%	0,58	15
Mexico	8,7	1,4%	0,48	18
South Africa	7,7	1,2%	0,48	16
Türkiye	7,1	1,1%	0,42	17
Australia	6,4	1,0%	0,41	15
Vietnam	6,1	1,0%	0,33	18
United Kingdom	6,1	1,0%	0,36	17
Italy, San Marino and the H	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
Poland	5,0	0,8%	0,31	16
Thailand	5,0	0,8%	0,28	18
Egypt	4,7	0,7%	0,23	20
Taiwan	4,3	0,7%	0,28	16
Spain and Andorra	4,3	0,7%	0,26	17
Nigeria	4,3	0,7%	0,12	35
Malaysia	4,1	0,7%	0,25	16
Bangladesh	3,6	0,6%	0,11	34
Philippines	3,5	0,6%	0,15	24
Ukraine	3,5	0,6%	0,20	17
Kazakhstan	3,4	0,5%	0,21	16
Iraq	3,2	0,5%	0,19	17
Argentina	3,2	0,5%	0,18	18
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	0,4%	0,12	18
Venezuela	2,1	0,3%	0,11	18
Colombia	1,8	0,3%	0,08	22
Czechia	1,6	0,3%	0,10	16
Ethiopia	1,6	0,3%	0,02	88
Chile	1,6	0,3%	0,09	17
Belgium	1,6	0,3%	0,10	16
Qatar	1,5	0,2%	0,10	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	1,3	0,2%	0,06	22
Myanmar/Burma	1,2	0,2%	0,04	33
North Korea	1,1	0,2%	0,06	20
Israel a. Palestine, S. o.	1,1	0,2%	0,06	17
Austria	1,1	0,2%	0,07	16
Democratic Republic of the	1,1	0,2%	0,00	332
Turkmenistan	1,0	0,2%	0,07	16
Greece	1,0	0,2%	0,06	17
Belarus	1,0	0,2%	0,06	17
Sudan and South Sudan	1,0	0,2%	0,02	43
Serbia and Montenegro	1,0	0,2%	0,06	17
sum without EU	593		35	

Tab. 20: Exemplary national budgets with different global framework data[31]

[31] 59 countries plus the EU with the highest resulting national CO2 budgets.