Working paper

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

DOI 10.5281/zenodo.5510034
Published on zenodo

Version: 15/09/2021

Prof. Manfred Sargl

Dr. phil. Daniel Wiegand, M.Sc. M.A.

Günter Wittmann, Graduate Mathematician

Andreas Wolfsteiner, Graduate Economist

www.save-the-climate.info

save-the-climate@online.ms

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 framework data on the available budget and the sharing mechanism to calculate top-down national emissions targets using the Extended Smooth Pathway Model (ESPM). The Paris ambition mechanism provides a combination of top-down and bottom-up approaches.[2] For each country in the word the question arises to what extent their bottom-up targets fit with global needs. This might initiate a discourse on the global framework data that contributes to Paris-compatible NDCs in sum.

[1] This paper is essentially an update of a publication in the "Zeitschrift für Umweltpolitik & Umweltrecht" (Sargl, et al., 2021a) due to the publication of the IPCC's AR6 WGI on 09/08/2021 (IPCC, 2021), in which more recent figures on the remaining budgets were published.

[2] For a description of the ambition mechanism see (BMU, 2019). The Parties should have submitted their revised NDCs in 2020. Unofficially, this first round of revisions was extended until the climate conference in Glasgow (COP26) in November 2021, which was postponed due to Corona. The UNFCCC also intends to submit an updated synthesis report by then (cf. UNFCCC, 2021). The second round of amendments has so far been scheduled for 2025. In 2023, the Paris Agreement provides for a global stocktake on progress towards the Paris climate goals. In our view, the public discourse on whether NDCs are Paris-compatible is part of the Paris ambition mechanism.

Content

List of tables

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.

Warming	Remaining carbon budgets			Scenario variation	Geophysical uncertainties			
				Non-CO2 scenario variation	Non-CO2 forcing and response uncertainty	Historical temperature uncertainty	ZEC uncertainty	Recent emissions uncertainty
Probabilities:	*50%*	*67%*	*83%*					
[°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.*"

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

The need to assess socio-economic consequences in the speed of decarbonisation, the compliance probabilities and the bandwidths of variations and uncertainties in the budgets mentioned by the IPCC require a scientifically based political decision on the global CO2 budget to which nationally determined contributions (NDCs) should be oriented. In a landmark decision in 2021 the Federal Constitutional Court in Germany made this clear: Climate policy must be oriented towards remaining CO2 budgets (cf. BVerfG, 2021).[5]

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

[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). The given probabilities indicate the percentage of the examined scenarios in which the temperature target is met (cf. MCC, 2020). For further scientific background information, please refer to the IPCC report. In 2019, emissions were around 43 GtCO2 (Global Carbon Project, 2021).

[5] See also Excursus 1: 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.

	emis-sions 1990 in Gt	emis-sions 2010 in Gt	emis-sions 2019 in Gt	per capita 2019 in t	share in global emissions 2019	accumu-lated share	share in global population 2019	accumu-lated share
China	2.4	9.2	11.5	8.0	31%	31%	19%	19%
United States	5.1	5.9	5.1	15.5	14%	45%	4%	23%
EU27	3.8	3.7	2.9	6.6	8%	53%	6%	29%
India	0.6	1.2	2.6	1.9	7%	60%	18%	47%
Russia	2.4	1.7	1.8	12.3	5%	65%	2%	49%
Japan	1.1	1.3	1.2	9.1	3%	68%	2%	51%
Nigeria	0.07	0.10	0.10	0.5	0.3%		2.6%	
Global	22.1	29.1	36.7	4.8				

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

At the climate summit in April 2021 initiated by US President Biden, the commitments listed in Tab. 3 - some of which are new - were made by the six largest emitters, which together are currently responsible for around 70% of annual global CO2 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	33 to 35% lower emission intensity in relation to the national product	2005	per capita emissions should never exceed those of the developed world
Russia	-25% to -30%	1990	reduce emissions significantly by 2050
China	turning point CO2 emissions before 2030	-	CO2 neutrality before 2060

Tab. 3: Current emission targets of the six largest emitters[7]

Are these commitments sufficient to meet the Paris climate targets, especially for the target year 2030? 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.

[6] These are the CO2 emissions from fossil fuel use (except international shipping and aviation; ISA) and cement production (EDGAR, 2020). CO2 emissions from land use change (LUC) are therefore not included here.

[7] Sources: Climate Action Tracker (https://climateactiontracker.org) and current reporting.

Calculation of national emission paths with the Extended Smooth Pathway Model

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

(1) Determining national budgets

In order to derive national budgets from a global budget, an **allocation key** is needed.[8] 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).[9] With this two-dimensional distribution key, the current emissions reflect the current reality and the population shares address the issue of climate justice.[10]

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

where

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

(2) Derivation of national emission paths

Plausible emission paths are derived that adhere to the national budget. With the Regensburg Model Scenario Types (see Excursus 3), we offer the entire range of plausible possibilities. For reasons of simplification, a linear course of the **emission paths** (RM-6) is assumed below.

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, 2020).

[8] In contrast, in convergence models, such as the Regensburg Model, a global pathway is divided among countries, with per capita emissions converging (cf. Sargl, et al., 2017). Both the ESPM and convergence models can be classified as resource sharing models (cf. Sargl, et al., 2021b).

[9] 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.

[10] Other criteria that could be considered include: responsibility for historical emissions and the economic performance of a country (e.g. in the form of per capita income). The inclusion of historical responsibility leads to more unrealistic results, but makes the responsibility of the "old" industrialised countries for the decarbonisation process clear. The 10 countries with the highest per capita incomes according to the World Bank have a share of just under 2% of global emissions (own calculation). Including GDP per capita would therefore not lead to significantly different results for the six largest emitters. For a discussion of the question of a 'fair' national share within the principled framework of international environmental law, we refer for example to (Rajamani, et al., 2021).

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

The assumption about the global LUC budget has a significant impact on the concrete emission targets for countries. For the LUC budget, the illustrative model pathways P1 - P4 of the IPCC from its Special Report 2018 could be used as a reference. However, the cumulative LUC emissions range from -230 Gt to +140 Gt for the period 2020 - 2100 (cf. Wolfsteiner & Wittmann, 2021c).[11] In the following calculations of the reference values for the six largest emitters, a value of zero is used for the LUC budget (except in Tab. 15 and Tab. 16). This implies that annual net positive LUC emissions occurring until 2100 are completely compensated by annual net negative LUC emissions.[12]

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

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

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

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

[11] Currently assumed to be around +7 GtCO2 of LUC emissions annually (cf. Global Carbon Project, 2021).

[12] In the Excel tool used (Wolfsteiner & Wittmann, 2021b) other values can also be used for LUC emissions.

[13] In the Excel tool used (Wolfsteiner & Wittmann, 2021b) other values can also be used for ISA emissions.

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

Exemplary national emission targets for the six largest emitters

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

(1) Global CO2 budget 2020 - 2100

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

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

(4) Inclusion of a negative global LUC budget

Points (3) and (4) do not change the predefined global budget, so that ultimately only two parameters are varied: the global budget and the weighting of the population.

Variation of the global budget and population weighting

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

global CO2 budget 2020 - 2100 in Gt				400		minimum annual emissions			0%
weighting population				100%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	-12%	-77%	-82%	-100%	-100%	72	6	0.0	2032
United States	-100%	-100%	-100%	-100%	-100%	17	3	0.0	2026
EU27	-75%	-72%	-68%	-100%	-100%	22	8	0.0	2035
India	245%	17%	-20%	84%	-37%	69	26	0.0	2072
Russia	-100%	-100%	-100%	-100%	-100%	7	4	0.0	2028
Japan	-91%	-92%	-91%	-100%	-100%	6	6	0.0	2031
Nigeria	43%	18%	7%	59%	31%	10	101	0.0	-

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

[15] Structure of the reference value tables: For the two target years 2030 and 2050, the change in emissions in percent compared to the reference years 1990 and 2010 is given for a linear emissions path. The percentage given for the minimum annual emissions is applied to the country's emissions in 2019. The result represents the possible minimum of the country's emissions until 2100. A temporary overshoot is possible if this minimum is negative (see below). The budget for the period 2020 - 2100 results from applying the weighted distribution key to the global budget to be distributed here (see calculation logic Tab. 4). The scope in years is obtained by dividing the national budget by the country's emissions in 2019 (see Tab. 2). The year of emissions neutrality is the year in which positive emissions reach their minimum (see also footnote 18). 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	89%	-50%	-61%	-100%	-100%	99	9	0.0	2037
United States	-100%	-100%	-100%	-100%	-100%	23	4	0.0	2028
EU27	-62%	-57%	-50%	-100%	-100%	31	10	0.0	2040
India	268%	25%	-15%	151%	-15%	94	36	0.0	2092
Russia	-92%	-90%	-90%	-100%	-100%	10	6	0.0	2031
Japan	-68%	-69%	-68%	-100%	-100%	9	8	0.0	2035
Nigeria	60%	32%	19%	106%	70%	14	139	0.0	-

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

Obviously, the framework data underpinned here are not realistic. This is particularly evident in the numbers for countries with high per capita emissions, such as the USA and Russia.

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

global CO2 budget 2020 - 2100 in Gt				550		minimum annual emissions			0%
weighting population				50%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	161%	-31%	-46%	-100%	-100%	133	12	0.0	2043
United States	-55%	-59%	-55%	-100%	-100%	48	9	0.0	2038
EU27	-56%	-50%	-42%	-100%	-100%	37	13	0.0	2045
India	241%	16%	-21%	74%	-41%	66	25	0.0	2070
Russia	-64%	-50%	-52%	-100%	-100%	18	10	0.0	2040
Japan	-47%	-49%	-48%	-100%	-100%	13	11	0.0	2042
Nigeria	32%	9%	-1%	28%	6%	8	77	0.0	-

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

Here it is doubtful that China is able to reduce its emissions by about 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.

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

[16] Tab. 17 in the appendix shows by way of example the 60 highest national budgets resulting from these framework data.

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	193%	-23%	-39%	-100%	-100%	157	14	0.0	2047
United States	-40%	-46%	-41%	-100%	-100%	67	13	0.0	2046
EU27	-52%	-47%	-38%	-100%	-100%	41	14	0.0	2047
India	203%	3%	-30%	-34%	-77%	46	18	0.0	2055
Russia	-55%	-38%	-40%	-100%	-100%	24	13	0.0	2046
Japan	-39%	-42%	-39%	-100%	-100%	16	13	0.0	2046
Nigeria	12%	-7%	-16%	-28%	-40%	3	33	0.0	2086

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

Using this framework data to calculate the reduction from individual reference years USA, EU27, Russia and Japan (ranging from 1990 to 2013) and comparing it to the commitments of these countries give the following results:

	current targets (see Tab. 3)		framework data Tab. 8
country	target year 2030	reference year	change 2030 vs. individual reference year
United States	-50%	2005	**-49%**
EU27	-55%	1990	**-52%**
Russia	-25% to -30%	1990	**-55%**
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).[17] According to Tab. 8 however, China would have to reduce its emissions by about 40% by 2030 compared to 2019. Even India and Nigeria, would have to reduce their emissions significantly by 2030, despite far below-average per capita emissions in 2019 (see Tab. 2).

If the share of population is neglected ("grandfathering"), all six countries would have to reduce their emissions by almost 40% by 2030 compared to 2019, as Tab. 10 shows.

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	204%	-20%	-37%	-100%	-100%	168	15	0.0	2049
United States	-36%	-42%	-37%	-100%	-100%	74	15	0.0	2049
EU27	-51%	-45%	-37%	-100%	-100%	43	15	0.0	2049
India	175%	-6%	-37%	-100%	-100%	38	15	0.0	2049
Russia	-53%	-34%	-37%	-100%	-100%	26	15	0.0	2049
Japan	-36%	-39%	-37%	-100%	-100%	17	15	0.0	2049
Nigeria	-15%	-30%	-37%	-100%	-100%	1	15	0.0	2049

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

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

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

global CO2 budget 2020 - 2100 in Gt				650		minimum annual emissions			0%
weighting population				50%		LUC budget 2020 - 2100 in Gt			0
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	193%	-23%	-39%	-100%	-100%	158	14	0.0	2047
United States	-46%	-51%	-47%	-100%	-100%	57	11	0.0	2042
EU27	-51%	-45%	-36%	-100%	-100%	43	15	0.0	2049
India	255%	21%	-18%	114%	-27%	78	30	0.0	2080
Russia	-58%	-42%	-44%	-100%	-100%	21	12	0.0	2043
Japan	-40%	-43%	-41%	-100%	-100%	15	13	0.0	2046
Nigeria	38%	14%	3%	46%	21%	9	90	0.0	-

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

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	221%	-16%	-33%	-67%	-91%	186	16	0.0	2052
United States	-34%	-40%	-35%	-97%	-98%	79	15	0.0	2050
EU27	-48%	-42%	-32%	-93%	-93%	48	16	0.0	2052
India	223%	10%	-26%	22%	-59%	55	21	0.0	2062
Russia	-51%	-32%	-34%	-97%	-96%	28	16	0.0	2051
Japan	-33%	-36%	-33%	-94%	-94%	18	16	0.0	2051
Nigeria	15%	-5%	-14%	-18%	-33%	4	39	0.0	2098

Tab. 12 : Reference values - B650 / P15 / 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.[18] The potential net negative emissions are included in the model by a percentage of a country's emissions in 2019.[19] The result represents the potential minimum emissions by 2100. Depending on the potential for net negative emissions, the volume overshoot is higher or lower.

Two 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).

[18] 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.

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

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

Combining a volume 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.[20]

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	179%	-27%	-42%	-110%	-103%	133	12	12.7	2045
United States	-49%	-53%	-49%	-102%	-102%	48	9	6.0	2041
EU27	-53%	-48%	-39%	-102%	-102%	37	13	3.1	2047
India	243%	17%	-21%	80%	-39%	66	25	1.4	2072
Russia	-60%	-45%	-47%	-101%	-102%	18	10	2.1	2042
Japan	-43%	-45%	-43%	-102%	-102%	13	11	1.3	2044
Nigeria	32%	9%	-1%	28%	6%	8	77	0.0	-

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

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

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	206%	-20%	-36%	-110%	-103%	157	14	11.8	2049
United States	-37%	-43%	-38%	-102%	-102%	67	13	5.3	2048
EU27	-50%	-45%	-36%	-100%	-100%	41	14	3.0	2049
India	209%	5%	-29%	-17%	-72%	46	18	2.2	2057
Russia	-53%	-35%	-37%	-101%	-102%	24	13	1.9	2048
Japan	-36%	-39%	-37%	-102%	-102%	16	13	1.2	2049
Nigeria	12%	-7%	-16%	-27%	-40%	3	33	0.0	2086

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

The temporary volume overshoot resulting from this volume 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.[21] Despite these concerns, we add a LUC budget of -100 Gt to a global budget of 400 Gt and a 50% weighting of the population, and get the results in Tab. 15.

[20] 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, 2021c).

[21] 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				50%		LUC budget 2020 - 2100 in Gt			-100
reference values (linear emission paths)						budget 2020 - 2100 in Gt	scope years	temporary overshoot in Gt	year emissions neutrality
target year:	2030			2050					
reference year:	1990	2010	2019	1990	2010				
China	164%	-31%	-45%	-110%	-103%	122	11	13.1	2043
United States	-52%	-57%	-53%	-102%	-102%	44	9	6.2	2039
EU27	-56%	-50%	-42%	-102%	-102%	34	11	3.2	2045
India	236%	14%	-23%	58%	-46%	61	23	1.7	2067
Russia	-63%	-49%	-50%	-101%	-102%	17	9	2.1	2040
Japan	-46%	-49%	-47%	-102%	-102%	12	10	1.3	2042
Nigeria	29%	7%	-4%	20%	-1%	7	70	0.0	-

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

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

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	192%	-23%	-39%	-110%	-103%	144	12	12.2	2047
United States	-40%	-46%	-41%	-102%	-102%	61	12	5.5	2046
EU27	-53%	-47%	-38%	-102%	-102%	37	13	3.1	2047
India	199%	2%	-31%	-46%	-82%	42	16	2.4	2054
Russia	-55%	-38%	-40%	-101%	-102%	22	12	1.9	2046
Japan	-39%	-42%	-40%	-102%	-102%	14	12	1.2	2046
Nigeria	10%	-9%	-18%	-33%	-44%	3	30	0.0	2081

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

Conclusions

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

Agenda:

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

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

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

The calculations also show that in any case China has to reduce its emissions significantly before 2030. This is a major requirement for China, especially since its share of historical emissions is still relatively small. However, our calculations demonstrate that an orientation towards the 1.5°C limit cannot be achieved without a substantial contribution from the world’s largest emitter.

The ESPM approach provides a useful complement to other approaches such as Integrated Assessment Models (IAMs), which are also used to identify globally cost-effective national emission pathways (cf. van Soest, et al., 2021). But the results of IAMs are based on several scientific, economic and technological assumptions, that show a wide range of variation, and the way they are derived is largely a "black box" for society and decision-makers. For the ESPM approach, on the other hand, only a few framework data need to be specified. The resulting emission paths and emission targets are much easier to understand, and equity aspects can be explicitly considered. But IAMs can indirectly provide valuable guidance for the ESPM approach in the political specification of framework data, e.g. with regard to the course of annual rates of change. The course of the rates of change of the emission paths can be specified in the ESPM via the choice of a scenario type, whereby a selection can be made from the entire range of plausible possibilities (see Excursus 3).

Tools and further exemplary results

At http://www.save-the-climate.info we offer tools to calculate reference values for every country with different framework data. For this paper the tool "ESPM" was used (Wolfsteiner & Wittmann, 2021b).

At http://eu.climate-calculator.info we offer a web application for the EU that takes into account LUC and ISA emissions and at http://espm.climate-calculator.info an app that can be used to calculate plausible emission paths for any country based on a predefined budget.

At https://www.klima-retten.info/results_espm.html, further exemplary results are shown for the six largest emitters with different framework data and scenario types.

Digressions

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: Federal Constitutional Court on CO2 budgets

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: Federal Constitutional Court on freedom opportunities for future generations

Regensburg Model Scenario Types

From an overall perspective of climate policy, courses other than a linear emissions path (straight line) may make more sense (cf. Wiegand, et al., 2021). 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. The following four basic types can be distinguished with regard to the increase in annual reduction rates with a monotonous course:

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

In addition, the scenario type RM-6 depicts 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, 2021a).

The following questions can play a role in the assessment of 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 mortgage for the future, as these later require very high reduction rates?
(3) Could high later reduction rates even make sense because they provide a greater lead time for the necessary investments? 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 refraining 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 objection would also apply to the RM-2/4 scenario types.

The ruling of the Federal Constitutional Court in April 2021 on the Climate Protection Act also implicitly poses the question of which annual reduction rates we must already provide today and which we can expect society to provide in the 2030s or 2040s (see Excursus 2: 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 RM5 are -suitable.

For the comparison of emission targets for the six largest emitters, linear emission paths are nevertheless used 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 3: Regensburg Model Scenario Types

Relationship between the weighting of the population and the potential to generate certificates

The national budgets resulting from the framework data in Tab. 11 and Tab. 12 (see Tab. 17 Annex) show by way of example: The lower the weighting of the population, the smaller the scope for newly industrialising and developing countries to generate certificates within the framework of international emissions trading in accordance with Article 6 (2) of the Paris Agreement. The stated scopes of the national budgets can serve as a measure of this leeway. With a lower weighting of the population, however, the new pledges of the EU, USA and Japan could result in leeway to help out China with certificates, for example. The higher the weighting of the population, the higher the demand for certificates of the industrialised countries plus China, which have been less ambitious so far. Emissions trading alone therefore does not solve the basic problem of the now extremely tight global CO2 budget.

We won't discuss here the status of negotiations and implementation of Article 6 of the Paris Agreement and the flexible mechanisms of the Kyoto Protocol. In principle, international emissions trading must ensure that there is no double counting. The functioning of emissions trading between states could be ensured in particular by reaching an agreement on the binding allocation of a global CO2 budget among countries before allowing emissions trading between countries. However, such a (global) agreement possibility seems rather unlikely at the moment. Another possibility would be to allow emissions trading on the basis of existing NDCs that are Paris-compatible in total. But this also presupposes that national CO2 budgets have been set in the NDCs, which is not on the political agenda at the moment either. If national CO2 budgets are not set before the start of an emissions trading system, it is very difficult to ensure the integrity of emissions trading.

Excursus 4: Relationship between the weighting of the population and the potential to generate certificates

Bibliography

BMU, 2019. *Hintergrundpapiere zum 10. Petersberger Klimadialog.* [Online]
Available at: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/ambitionsmechanismus_pariser_abkommen_bf.pdf
[Accessed 20 04 2020].

BVerfG, 2021. *Beschluss des Ersten Senats vom 24. März 2021- 1 BvR 2656/18 -, Rn. 1-270.* [Online]
Available at: http://www.bverfg.de/e/rs20210324_1bvr265618.html

EDGAR, 2020. *European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR).* [Online]
Available at: https://edgar.jrc.ec.europa.eu/
[Accessed 30 09 2020].

Global Carbon Project, 2021. [Online]
Available at: https://www.globalcarbonproject.org/

IPCC, 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* [Online]
Available at: https://www.ipcc.ch/report/ar6/wg1/

MCC, 2020. *That's how fast the carbon clock is ticking.* [Online]
Available at: https://www.mcc-berlin.net/forschung/co2-budget.html
[Accessed 21 12 2020].

PIK, 2018. *Auf dem Weg in die "Heißzeit"? Planet könnte kritische Schwelle überschreiten.* [Online]
Available at: https://www.pik-potsdam.de/aktuelles/pressemitteilungen/auf-dem-weg-in-die-heisszeit-planet-koennte-kritische-schwelle-ueberschreiten
[Accessed 25 06 2019].

Rajamani, L. et al., 2021. National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law. *Climate Policy*.

Raupach, M. R. et al., 2014. Sharing a quota on cumulative carbon emissions. *Nature Climate Change*, Volume 4, pp. 873 - 879.

Sargl, M., Wiegand, D., Wittmann, G. & Wolfsteiner, A., 2021a. Berechnung Paris-kompatibler Emissionsziele für die sechs größten Emittenten mit dem ESPM. *Zeitschrift für Umweltpolitik & Umweltrecht*, Issue 3/2021, pp. 269 - 286.

Sargl, M., Wiegand, D., Wittmann, G. & Wolfsteiner, A., 2021b. *Distribution of a Global CO2 Budget - A Comparison of Resource Sharing Models.* [Online]
Available at: https://doi.org/10.5281/zenodo.4603032

Sargl, M., Wolfsteiner, A. & Wittmann, G., 2017. The Regensburg Model: reference values for the (I)NDCs based on converging per capita emissions. *Climate Policy*, 17(5), p. 664 – 677.

SRU, 2020. *Environmental Report 2020 - Chapter 2: Using the CO2 budget to meet the Paris climate targets.* [Online]
Available at: https://www.umweltrat.de

UNFCCC, 2021. *NDC Synthesis Report.* [Online]
Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs/ndc-synthesis-report

van Soest, H. L., den Elzen, M. G. J. & van Vuuren, D. P., 2021. Net-zero emission targets for major emitting countries consistent with the Paris Agreement. *Nat Commun 12*.

Wiegand, D. et al., 2021. Berechnung Paris-kompatibler Emissionspfade mit dem ESP-Modell am Beispiel der EU. *Wirtschaftsdienst*, Februar, pp. 127 - 133.

Wolfsteiner, A. & Wittmann, G., 2021a. *Mathematical Description of the Regensburg Model Scenario Types RM 1 – 6.* [Online]
Available at: https://doi.org/10.5281/zenodo.4540475

Wolfsteiner, A. & Wittmann, G., 2021b. *Tool for the Calculation of Paris-compatible Emission Paths with the ESPM.* [Online] Available at: https://doi.org/10.5281/zenodo.4580310

Wolfsteiner, A. & Wittmann, G., 2021c. *Tool for the Calculation of Paris-compatible Global Emission Paths with the RM Scenario Types.* [Online] Available at: https://doi.org/10.5281/zenodo.4584562

Appendix: Exemplary national budgets with different global framework data

global budget 2020 - 2100 in Gt		550	LUC budget	0
weighting population		50%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	133,5	25,0%	11,535	12
India	66,2	12,4%	2,597	25
United States	48,5	9,1%	5,107	10
EU28	41,8	7,8%	3,304	13
EU27	36,8	6,9%	2,939	13
Russia	18,1	3,4%	1,792	10
Indonesia	13,9	2,6%	0,626	22
Japan	12,8	2,4%	1,154	11
Brazil	10,8	2,0%	0,478	23
Pakistan	9,1	1,7%	0,224	41
Germany	8,0	1,5%	0,703	11
Iran	8,0	1,5%	0,702	11
Mexico	7,9	1,5%	0,485	16
Nigeria	7,7	1,4%	0,100	77
South Korea	6,5	1,2%	0,652	10
Bangladesh	6,4	1,2%	0,110	58
Turkey	5,9	1,1%	0,416	14
Saudi Arabia	5,7	1,1%	0,615	9
South Africa	5,6	1,1%	0,495	11
Vietnam	5,6	1,0%	0,305	18
Canada	5,5	1,0%	0,585	9
Egypt	5,3	1,0%	0,255	21
United Kingdom	5,0	0,9%	0,365	14
Philippines	4,8	0,9%	0,151	32
France and Monaco	4,5	0,9%	0,315	14
Italy, San M. a. t. H. S.	4,5	0,8%	0,332	14
Thailand	4,4	0,8%	0,275	16
Australia	4,0	0,8%	0,433	9
Ethiopia	4,0	0,8%	0,018	220
Poland	3,6	0,7%	0,318	11
Spain and Andorra	3,5	0,7%	0,259	14
Dem. Rep. of the Congo	3,0	0,6%	0,003	1.013
Argentina	3,0	0,6%	0,199	15
Ukraine	3,0	0,6%	0,196	15
Malaysia	2,9	0,5%	0,249	12
Taiwan	2,8	0,5%	0,277	10
Algeria	2,8	0,5%	0,181	16
Iraq	2,8	0,5%	0,198	14
Kazakhstan	2,7	0,5%	0,277	10
Colombia	2,4	0,4%	0,087	27
Myanmar/Burma	2,2	0,4%	0,048	46
Tanzania	2,1	0,4%	0,013	158
Sudan and South Sudan	2,0	0,4%	0,023	90
Kenya	2,0	0,4%	0,020	99
United Arab Emirates	2,0	0,4%	0,223	9
Uzbekistan	1,8	0,3%	0,095	19
Morocco	1,8	0,3%	0,074	24
Venezuela	1,8	0,3%	0,110	16
Netherlands	1,7	0,3%	0,156	11
Uganda	1,6	0,3%	0,005	294
Peru	1,5	0,3%	0,056	27
Afghanistan	1,4	0,3%	0,011	127
Chile	1,3	0,2%	0,090	15
Angola	1,3	0,2%	0,026	50
Romania	1,2	0,2%	0,079	16
North Korea	1,2	0,2%	0,042	28
Ghana	1,2	0,2%	0,017	70
Belgium	1,2	0,2%	0,104	11
Czechia	1,1	0,2%	0,106	11
Mozambique	1,1	0,2%	0,009	121
Nepal	1,1	0,2%	0,015	73
sum without EU	488		34	

global budget 2020 - 2100 in Gt		650	LUC budget	0
weighting population		50%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	157,8	25,0%	11,535	14
India	78,2	12,4%	2,597	30
United States	57,4	9,1%	5,107	11
EU28	49,4	7,8%	3,304	15
EU27	43,5	6,9%	2,939	15
Russia	21,4	3,4%	1,792	12
Indonesia	16,4	2,6%	0,626	26
Japan	15,1	2,4%	1,154	13
Brazil	12,7	2,0%	0,478	27
Pakistan	10,8	1,7%	0,224	48
Germany	9,5	1,5%	0,703	13
Iran	9,4	1,5%	0,702	13
Mexico	9,4	1,5%	0,485	19
Nigeria	9,1	1,4%	0,100	91
South Korea	7,7	1,2%	0,652	12
Bangladesh	7,6	1,2%	0,110	69
Turkey	7,0	1,1%	0,416	17
Saudi Arabia	6,7	1,1%	0,615	11
South Africa	6,6	1,1%	0,495	13
Vietnam	6,6	1,0%	0,305	22
Canada	6,6	1,0%	0,585	11
Egypt	6,3	1,0%	0,255	25
United Kingdom	5,9	0,9%	0,365	16
Philippines	5,7	0,9%	0,151	38
France and Monaco	5,4	0,9%	0,315	17
Italy, San M. a. t. H. S.	5,3	0,8%	0,332	16
Thailand	5,2	0,8%	0,275	19
Australia	4,8	0,8%	0,433	11
Ethiopia	4,7	0,8%	0,018	260
Poland	4,3	0,7%	0,318	13
Spain and Andorra	4,1	0,7%	0,259	16
Dem. Rep. of the Congo	3,6	0,6%	0,003	1.197
Argentina	3,5	0,6%	0,199	18
Ukraine	3,5	0,6%	0,196	18
Malaysia	3,4	0,5%	0,249	14
Taiwan	3,4	0,5%	0,277	12
Algeria	3,3	0,5%	0,181	18
Iraq	3,3	0,5%	0,198	17
Kazakhstan	3,1	0,5%	0,277	11
Colombia	2,8	0,4%	0,087	32
Myanmar/Burma	2,6	0,4%	0,048	54
Tanzania	2,5	0,4%	0,013	186
Sudan and South Sudan	2,4	0,4%	0,023	106
Kenya	2,3	0,4%	0,020	117
United Arab Emirates	2,3	0,4%	0,223	10
Uzbekistan	2,2	0,3%	0,095	23
Morocco	2,1	0,3%	0,074	29
Venezuela	2,1	0,3%	0,110	19
Netherlands	2,0	0,3%	0,156	13
Uganda	1,9	0,3%	0,005	347
Peru	1,8	0,3%	0,056	32
Afghanistan	1,6	0,3%	0,011	150
Chile	1,5	0,2%	0,090	17
Angola	1,5	0,2%	0,026	59
Romania	1,5	0,2%	0,079	19
North Korea	1,4	0,2%	0,042	33
Ghana	1,4	0,2%	0,017	82
Belgium	1,4	0,2%	0,104	13
Czechia	1,3	0,2%	0,106	13
Mozambique	1,3	0,2%	0,009	143
Nepal	1,3	0,2%	0,015	86
sum without EU	576		34	

global budget 2020 - 2100 in Gt		650	LUC budget	0
weighting population		15%		
sorted by national budget	national budget 2020 - 2100	weighted key	emissions 2019	scope years
	Gt		Gt	
China	186,2	29,5%	11,535	16
United States	78,7	12,5%	5,107	15
India	54,7	8,7%	2,597	21
EU28	54,6	8,7%	3,304	17
EU27	48,4	7,7%	2,939	16
Russia	28,0	4,4%	1,792	16
Japan	18,4	2,9%	1,154	16
Indonesia	12,5	2,0%	0,626	20
Germany	11,3	1,8%	0,703	16
Iran	11,3	1,8%	0,702	16
South Korea	10,2	1,6%	0,652	16
Brazil	9,6	1,5%	0,478	20
Saudi Arabia	9,4	1,5%	0,615	15
Canada	9,0	1,4%	0,585	15
Mexico	8,7	1,4%	0,485	18
South Africa	8,0	1,3%	0,495	16
Turkey	7,1	1,1%	0,416	17
Australia	6,6	1,1%	0,433	15
United Kingdom	6,2	1,0%	0,365	17
Pakistan	5,9	0,9%	0,224	26
Vietnam	5,6	0,9%	0,305	18
Italy, San M. a. t. H. S.	5,6	0,9%	0,332	17
France and Monaco	5,4	0,9%	0,315	17
Poland	5,1	0,8%	0,318	16
Egypt	5,0	0,8%	0,255	19
Thailand	4,9	0,8%	0,275	18
Spain and Andorra	4,4	0,7%	0,259	17
Taiwan	4,3	0,7%	0,277	16
Kazakhstan	4,3	0,7%	0,277	15
Malaysia	4,0	0,6%	0,249	16
Nigeria	3,9	0,6%	0,100	39
Bangladesh	3,6	0,6%	0,110	33
Philippines	3,5	0,6%	0,151	23
Argentina	3,5	0,5%	0,199	17
Ukraine	3,4	0,5%	0,196	17
United Arab Emirates	3,4	0,5%	0,223	15
Iraq	3,4	0,5%	0,198	17
Algeria	3,2	0,5%	0,181	18
Netherlands	2,5	0,4%	0,156	16
Venezuela	2,0	0,3%	0,110	18
Colombia	1,9	0,3%	0,087	22
Uzbekistan	1,8	0,3%	0,095	19
Czechia	1,7	0,3%	0,106	16
Belgium	1,7	0,3%	0,104	16
Ethiopia	1,6	0,3%	0,018	90
Qatar	1,6	0,3%	0,107	15
Chile	1,5	0,2%	0,090	17
Morocco	1,5	0,2%	0,074	21
Kuwait	1,5	0,2%	0,099	15
Oman	1,4	0,2%	0,093	15
Turkmenistan	1,4	0,2%	0,091	15
Romania	1,4	0,2%	0,079	18
Myanmar/Burma	1,4	0,2%	0,048	28
Peru	1,2	0,2%	0,056	22
Austria	1,2	0,2%	0,072	16
Israel a. Palest., State of	1,2	0,2%	0,068	17
Serbia and Montenegro	1,1	0,2%	0,071	16
Dem. Rep. of the Congo	1,1	0,2%	0,003	371
Greece	1,1	0,2%	0,066	17
Belarus	1,1	0,2%	0,066	16
Sudan and South Sudan	1,0	0,2%	0,023	44
sum without EU	592		35	

Tab. 17: Exemplary national budgets with different global framework data[22]

[22] 59 countries plus the EU with the highest resulting budgets.