

National paths based on a given national budget (Extended Smooth Pathway Model)

Brief instructions on how to use the tool

With this tool you can determine plausible **national emission paths** and reference values based on a **national CO2 budget 2020 - 2100 you specified**.

In the **sheet 'base data'** you can set the basic conditions such as the budgets which are to be met, and the minimum value of annual emissions (potential for net negative emissions). To determine the national budget a simple weighting model (emissions and population in the base year 2019) is offered.

In the **sheet 'reference values'**, you can select a country from the drop-down list, to get an impression of which challenges the chosen country is confronted with, and can then compare these with the offers this country has submitted so far or plans to submit (NDCs). In particular, the **reference values** for 2050 and 2030 are shown in this sheet.

In the **sheet 'output countries'** you can create a list of all countries in the world, which gives the **national budgets** 2020 - 2100 for a given weighting of the population and **reference values** for the **largest emitters**. The macro can be started without first performing the target value search in the sheet 'goal seek'.

For deriving **national paths** the tool offers the scenario types **RM 1 - 6**. There differ in particular in terms of different assumptions on the trajectory of annual reduction rates resp. reduction amount. In the **sheet 'goal seek'** you have to input **start change rates for 2020** (RM 2 - 5).

When modifying input data (which the cells shaded in yellow are designated for) or select a other country, you must always execute the **macro** in the **sheet 'goal seek'** to adjust the free parameter in the scenarios such as to meet the national budget 2020 - 2100 which is set out in sheet 'base data'.

Entries can be made in the following sheets: base data, reference values (select a country), goal seek (start change rates 2020 and TVs) and data countries (individual change rates 2019).

Cells shaded in yellow in the following sheets are input fields, where you can enter data.

Suggestions and feedback are welcome:

save-the-climate@online.ms

You can download the current version of the tool from the following website:

www.save-the-climate.info

version:	2018 - 2020	37.0
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<u>data status</u>	
global emissions	Sep. 19
emissions countries	Sep. 19
population	2019

There you can download a comprehensive mathematical description of the Regensburg Model Scenario Types or use this direct link
[Mathematicel Description RM 1 - 6](#)
 and a comprehensive instruction to the tool.

base data

input fields	values from the sheet „EDGAR“
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I. Input of base data for the determination of a global budget 2020 - 2100

I. a) Global CO2 budget 2018 - 2100

global CO2 budget from 2018 to 2100 in Gt	
680	see Table 2.2

Ultimately, it is a political decision which CO2 budget we aim to meet by the end of this century, taking into account the current scientific findings.

I. b) Global CO2 Emissions 2018 - 2019

annual change rates		1.7%	0.9%	-0.2%	1.1%	1.2%	1.9%	1.2%		
	year:	2012	2013	2014	2015	2016	2017	2018	2019	sum 2018 - 2019
CO2 emissions without FOLU and ISA (int. shipping/aviation) in Gt		34.3	34.9	35.2	35.1	35.5	35.9	36.6	37.1	74
CO2 emissions incl. FOLU and ISA in Gt									43.8	info

I. c) Global CO2 budget 2020 - 2100 without FOLU and ISA (deduction due to poor data, especially at country level)

global CO2 budget 2018 - 2100						680 Gt	info: actual share
net positive FOLU (npLUC; land-use change) from 2018 on	actual about in Gt	5.5	how much should be reserved?	13.0%		-88 Gt	12.9%
international shipping and aviation (ISA) from 2018 on			how much should be reserved?	3.0%		-20 Gt	2.9%
sub sum						571 Gt	
(projected) global CO2 emissions 2018 - 2019						-74 Gt	
global CO2 budget 2020 - 2100 (without FOLU and ISA)						498 Gt	A

II.) National CO2 budget 2020 - 2100

weighting population key in the weighted key	50%	selected country:	EU27	sheet: 'reference values'
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share selected country in global population 2019 5.769% weight: 50%
 share selected country in global emissions 2019 8.158% ting: 50%

weighted key	6.963%	B
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population in 2019	444,987 thousand	info
projected emissions in 2019	3,023.61 Mill. t	
scope of the budget	11.46 years	

national CO2 budget <u>2020 - 2100</u> ; weighted key applied on the global budget 2020 - 2100	34,643	Mill. t	= A * B
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national CO2 budget <u>2020 - 2100</u> ; free input		Mill. t
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national CO2 budget 2020 - 2100 (basis for this tool)	here calculated value	34,643	Mill. t
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III) National minimum emissions until 2100

emissions in 2019 of the selected country	3,023.6 Mill. t
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What percentage of emissions in 2019 should represent the minimum of emissions by 2100? A negative value stands for net negative emissions.	-6.0%
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minimum annual CO₂ emissions (a negative value stands for net negative emissions); E_{min} :	-181.4	Mill. t
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background information to net negative emissions:

	2019
global CO2 without FOLU and ISA in Gt	37.1
E_min % actual input above	-6.00%
≈ E_min global analog in Gt	-2.22
total global emissions in Gt	43.8
share of total global emissions	-5.1%

global CO2 without FOLU and ISA in 2019 in Gt	37.1		
IPCC SR15 illustrative model paths in the year 2100 in Gt	P1	P2	average
	-3.52	-4.47	-4.00
E_min proposals	-9.51%	-12.07%	-10.79%

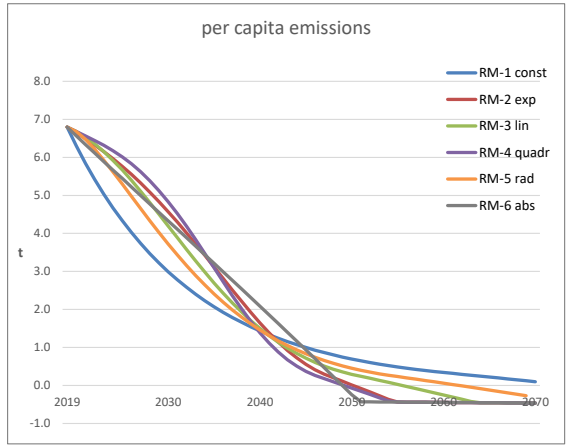
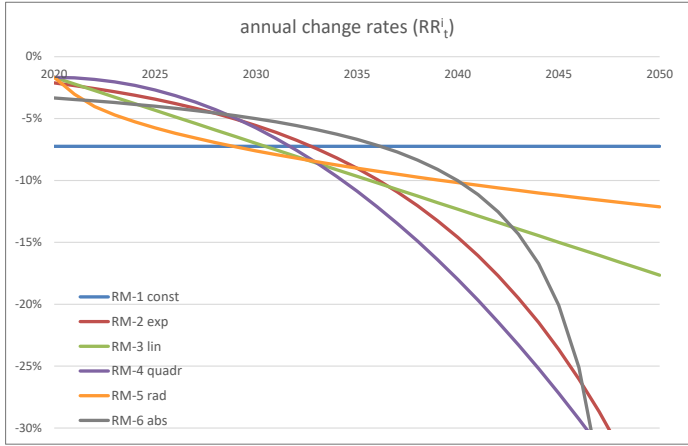
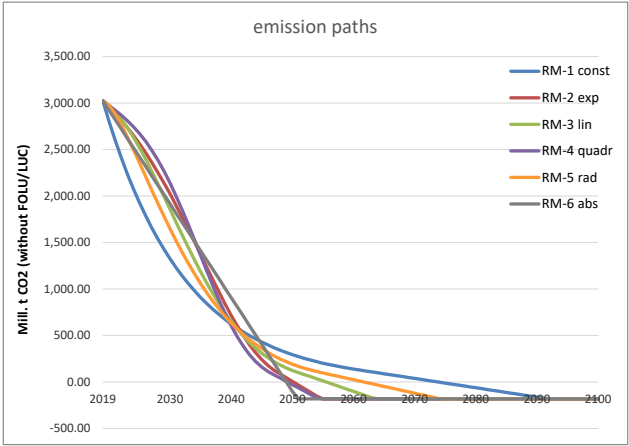
EU27

→ select a country

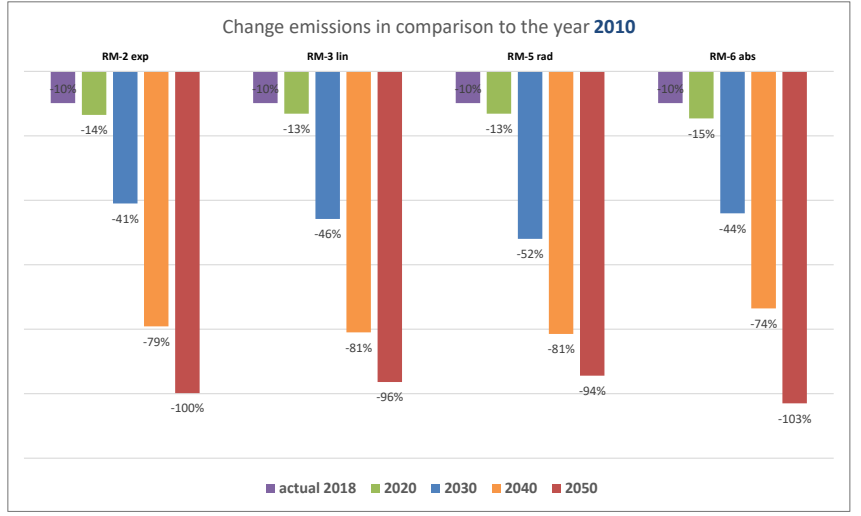
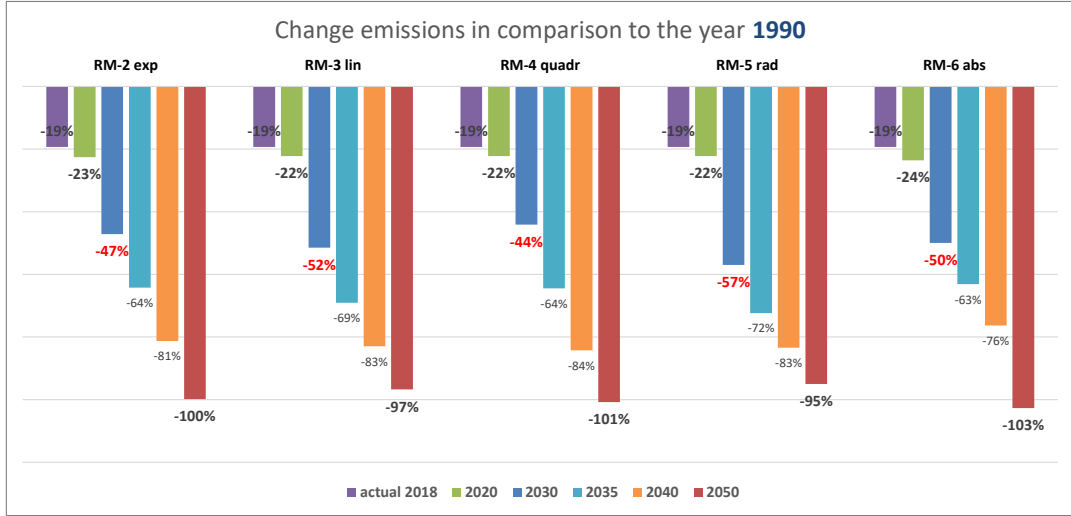
projection emissions 2019		individual change rate sheet 'data countries'	'goal seek' is ok
base year projection: 2018	-02 % p.a.		

50%	share population key RM 1 - 6 and SPM_FP
680	Gt global budget

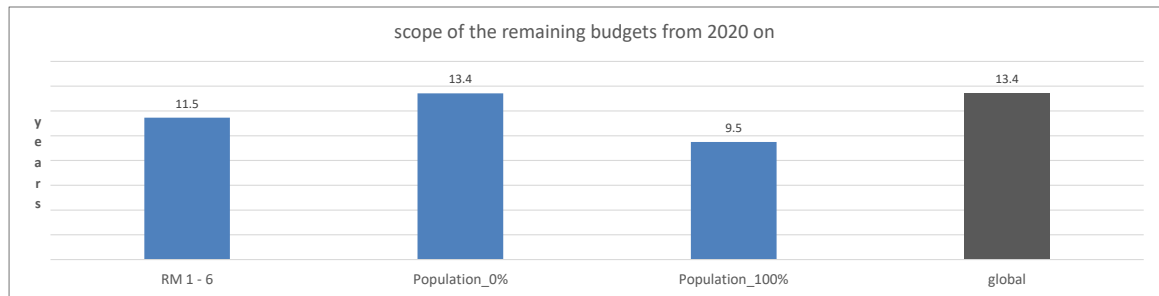
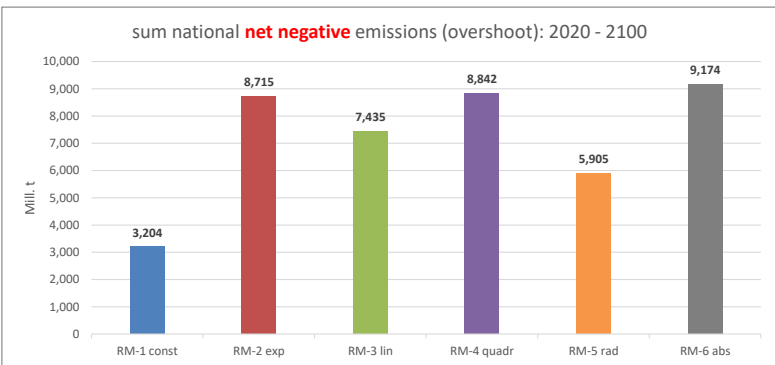
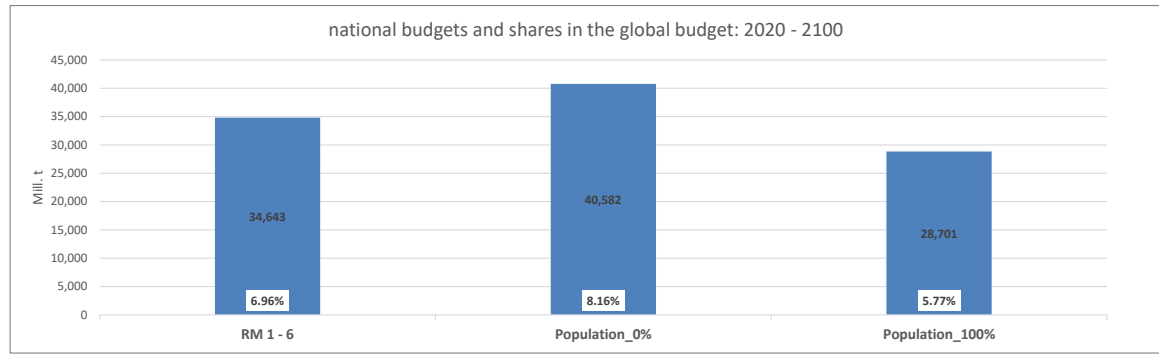
global per capita emissions 2019: 4.8052 t



Reference values for the country: EU27



selected country: **EU27**



Scope of the remaining national resp. global budget with unchanged emissions as in the base year 2019.

Important notes on negative emissions

Since we as humanity have not acted sufficiently, compliance with the 1.5°C limit is only possible with globally negative emissions. However, these global negative emissions mean that the remaining budget is temporarily exceeded. The higher the volume of this "overshoot" and the longer it lasts, the higher the likelihood that tipping points in the climate system will be exceeded. For tipping points with positive feedback effects, global warming may not be limited to, for example, 1.5°C, although mathematically the global negative emissions are sufficient to meet the remaining budget.

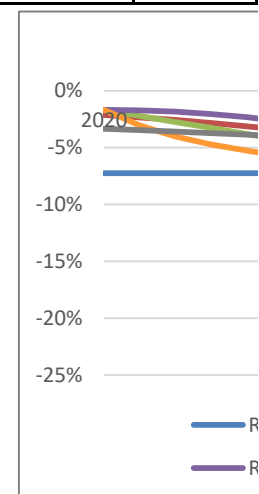
The later we reduce our CO2 emissions, the more we have to rely on global negative emissions and the higher the risks. In addition, the potential and costs of negative emissions are still relatively unclear today.

In this tool, the global overshoot can not be specified. For this one would have to know the results of all countries. However, what you can say is that with the scenario type RM-5-rad, the global paths described by the IPCC (see C.1 Summary for Policy Makers, Special Report 2018) can best be mapped.

This tool has the advantage that countries can choose their own emission path depending on a remaining national budget. In the end, however, it has to be reviewed in an overall view that the resulting global path is compatible

Determination of the free parameter in the RM scenarios 2020 - 2100

input value		determination via "goal seek"	target value of "goal seek"	target is not met			target is met		
RM scenarios:		<u>RM-1 const</u>	<u>RM-2 exp</u>	<u>RM-3 lin</u>	<u>RM-4 quadr</u>	<u>RM-5 rad</u>	<u>RM-6</u>	info	
characteristics of the scenario		<i>RR_t const</i>	<i>RR_t exp</i>	<i>RR_t lin</i>	<i>RR_t quadr</i>	<i>RR_t rad</i>	<i>RA const</i>	basis projection 2019	last actual change rate
A corona effect should not be considered here.			only a negative RR ₂₀ possible	a positive RR ₂₀ is also possible (= increasing emissions after 2019)			info		
change rate 2020 (RR₂₀)		-7.24%	-2.12%	-1.67%	-1.67%	-1.67%	-3.34%	-2.00%	-1.9%
<i>initial value</i>		-8%	10%	-1%	0	0	-121		
		<i>RR_t constant</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>	<i>RA</i>		
free parameters are determined by Goal Seek in such a way as that the budget is adhered to.		-7.24%	10.13%	-0.53280%	-0.00040837	-0.01926089	-100.85		
scenario Σ 2020 - 2100; sheet 'RM'	Mill. t	34,643	34,643	34,643	34,643	34,643	34,643		
budget Σ 2020 - 2100; sheet 'base data'	Mill. t	34,643	34,643	34,643	34,643	34,643	34,643		
emissions 2100 scenario; sheet 'RM'	Mill. t	-181.4	-181.4	-181.4	-181.4	-181.4	-181.4		
minimum emissions 2100 ; sheet 'base data'	Mill. t	-181.4	-181.4	-181.4	-181.4	-181.4	-181.4		
Year <i>E_{min}</i> is achieved		2092	2055	2064	2055	2075	2051		
change rate 2030 / 1990		-65%	-47%	-52%	-44%	-57%	-50%		
		from emissions 2019							
At which level of emissions (threshold value; <i>TV</i>) shall the annual percentage reduction be change into a constant annual reduction?			RM 2 - 5:	105.83	Mill. t	3.50%			
			RM-1:	136.06	Mill. t	4.50%			



calculation
RM 1 - 6
formula
base data
input sheet
'goal seek'
goal seek
sheet "goal seek"

RM-1 const	
constant annual reduction rate	
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
free paramter	-7.24%

RM-2 exp	
exponential increase of annual reduction rates is assumed	
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-2.12%
free paramter	10.13%

RM-3 lin	
linear increase of annual reduction rates is assumed	
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-1.67%
free paramter	-0.53%

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	RR _t const	actual RR _t
t	E _t	E _t - E _{t-1}	see formula below	RR _t const	actual RR _t
2019	3,023.61				
2020	2,804.68	-218.93	-7.24%	-7.24%	
2021	2,601.60	-203.08	-7.24%	-7.24%	
2022	2,413.23	-188.37	-7.24%	-7.24%	
2023	2,238.49	-174.73	-7.24%	-7.24%	
2024	2,076.41	-162.08	-7.24%	-7.24%	
2025	1,926.06	-150.35	-7.24%	-7.24%	
2026	1,786.60	-139.46	-7.24%	-7.24%	
2027	1,657.24	-129.36	-7.24%	-7.24%	
2028	1,537.25	-120.00	-7.24%	-7.24%	
2029	1,425.94	-111.31	-7.24%	-7.24%	
2030	1,322.69	-103.25	-7.24%	-7.24%	
2031	1,226.92	-95.77	-7.24%	-7.24%	
2032	1,138.08	-88.84	-7.24%	-7.24%	
2033	1,055.68	-82.40	-7.24%	-7.24%	
2034	979.24	-76.44	-7.24%	-7.24%	
2035	908.33	-70.90	-7.24%	-7.24%	
2036	842.56	-65.77	-7.24%	-7.24%	
2037	781.56	-61.01	-7.24%	-7.24%	
2038	724.97	-56.59	-7.24%	-7.24%	
2039	672.47	-52.49	-7.24%	-7.24%	
2040	623.78	-48.69	-7.24%	-7.24%	
2041	578.62	-45.17	-7.24%	-7.24%	
2042	536.72	-41.90	-7.24%	-7.24%	
2043	497.86	-38.86	-7.24%	-7.24%	
2044	461.81	-36.05	-7.24%	-7.24%	
2045	428.37	-33.44	-7.24%	-7.24%	
2046	397.35	-31.02	-7.24%	-7.24%	
2047	368.58	-28.77	-7.24%	-7.24%	
2048	341.90	-26.69	-7.24%	-7.24%	
2049	317.14	-24.76	-7.24%	-7.24%	
2050	294.18	-22.96	-7.24%	-7.24%	
2051	272.88	-21.30	-7.24%	-7.24%	
2052	253.12	-19.76	-7.24%	-7.24%	
2053	234.79	-18.33	-7.24%	-7.24%	
2054	217.79	-17.00	-7.24%	-7.24%	
2055	202.02	-15.77	-7.24%	-7.24%	
2056	187.39	-14.63	-7.24%	-7.24%	
2057	173.82	-13.57	-7.24%	-7.24%	
2058	161.24	-12.59	-7.24%	-7.24%	
2059	149.56	-11.67	-7.24%	-7.24%	
2060	138.73	-10.83	-7.24%	-7.24%	
2061	128.69	-10.05	-7.24%	-7.24%	

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	RR _t exp	actual RR _t
t	E _t	E _t - E _{t-1}	see formula below	RR _t exp	actual RR _t
2019	3,023.61				
2020	2,959.58	-64.03	-2.12%	-2.12%	
2021	2,890.56	-69.02	-2.33%	-2.33%	
2022	2,816.31	-74.25	-2.57%	-2.57%	
2023	2,736.64	-79.67	-2.83%	-2.83%	
2024	2,651.38	-85.26	-3.12%	-3.12%	
2025	2,560.41	-90.97	-3.43%	-3.43%	
2026	2,463.65	-96.75	-3.78%	-3.78%	
2027	2,361.12	-102.53	-4.16%	-4.16%	
2028	2,252.90	-108.22	-4.58%	-4.58%	
2029	2,139.17	-113.73	-5.05%	-5.05%	
2030	2,020.25	-118.93	-5.56%	-5.56%	
2031	1,896.55	-123.70	-6.12%	-6.12%	
2032	1,768.66	-127.89	-6.74%	-6.74%	
2033	1,637.31	-131.35	-7.43%	-7.43%	
2034	1,503.39	-133.92	-8.18%	-8.18%	
2035	1,367.96	-135.43	-9.01%	-9.01%	
2036	1,232.25	-135.71	-9.92%	-9.92%	
2037	1,097.61	-134.64	-10.93%	-10.93%	
2038	965.53	-132.08	-12.03%	-12.03%	
2039	837.57	-127.96	-13.25%	-13.25%	
2040	715.33	-122.25	-14.60%	-14.60%	
2041	600.34	-114.99	-16.07%	-16.07%	
2042	494.06	-106.28	-17.70%	-17.70%	
2043	397.73	-96.33	-19.50%	-19.50%	
2044	312.32	-85.41	-21.47%	-21.47%	
2045	238.46	-73.86	-23.65%	-23.65%	
2046	176.35	-62.11	-26.05%	-26.05%	
2047	125.77	-50.59	-28.68%	-28.68%	
2048	86.04	-39.73	-31.59%	-31.59%	
2049	46.30	-39.73	-34.79%	-46.18%	
2050	6.57	-39.73	-38.32%	-85.81%	
2051	-33.16	-39.73	-42.20%		
2052	-72.89	-39.73	-46.48%		
2053	-112.62	-39.73	-51.19%		
2054	-152.35	-39.73	-56.37%		
2055	-181.40	-29.05	-62.09%		
2056	-181.40	0.00	-68.38%		
2057	-181.40	0.00	-75.31%		
2058	-181.40	0.00	-82.94%		
2059	-181.40	0.00	-91.34%		
2060	-181.40	0.00	-100.60%		
2061	-181.40	0.00	-110.79%		

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	RR _t lin	actual RR _t
t	E _t	E _t - E _{t-1}	see formula below	RR _t lin	actual RR _t
2019	3,023.61				
2020	2,973.19	-50.42	-1.67%	-1.67%	
2021	2,907.76	-65.42	-2.20%	-2.20%	
2022	2,828.29	-79.48	-2.73%	-2.73%	
2023	2,735.92	-92.37	-3.27%	-3.27%	
2024	2,631.98	-103.93	-3.80%	-3.80%	
2025	2,517.98	-114.01	-4.33%	-4.33%	
2026	2,395.49	-122.48	-4.86%	-4.86%	
2027	2,266.20	-129.29	-5.40%	-5.40%	
2028	2,131.82	-134.39	-5.93%	-5.93%	
2029	1,994.04	-137.77	-6.46%	-6.46%	
2030	1,854.55	-139.49	-7.00%	-7.00%	
2031	1,714.93	-139.62	-7.53%	-7.53%	
2032	1,576.69	-138.24	-8.06%	-8.06%	
2033	1,441.19	-135.50	-8.59%	-8.59%	
2034	1,309.65	-131.53	-9.13%	-9.13%	
2035	1,183.15	-126.51	-9.66%	-9.66%	
2036	1,062.56	-120.59	-10.19%	-10.19%	
2037	948.59	-113.96	-10.73%	-10.73%	
2038	841.80	-106.79	-11.26%	-11.26%	
2039	742.55	-99.25	-11.79%	-11.79%	
2040	651.04	-91.51	-12.32%	-12.32%	
2041	567.34	-83.70	-12.86%	-12.86%	
2042	491.38	-75.96	-13.39%	-13.39%	
2043	422.97	-68.41	-13.92%	-13.92%	
2044	361.83	-61.14	-14.45%	-14.45%	
2045	307.60	-54.23	-14.99%	-14.99%	
2046	259.86	-47.74	-15.52%	-15.52%	
2047	218.14	-41.72	-16.05%	-16.05%	
2048	181.96	-36.18	-16.59%	-16.59%	
2049	150.81	-31.15	-17.12%	-17.12%	
2050	124.19	-26.62	-17.65%	-17.65%	
2051	101.61	-22.58	-18.18%	-18.18%	
2052	79.03	-22.58	-18.72%	-22.23%	
2053	56.44	-22.58	-19.25%	-28.58%	
2054	33.86	-22.58	-19.78%	-40.01%	
2055	11.27	-22.58	-20.32%	-66.70%	
2056	-11.31	-22.58	-20.85%		
2057	-33.89	-22.58	-21.38%		
2058	-56.48	-22.58	-21.91%		
2059	-79.06	-22.58	-22.45%		
2060	-101.64	-22.58	-22.98%		
2061	-124.23	-22.58	-23.51%		

calculation RM 1 - 6	RM-1 const				RM-2 exp			RM-3 lin				
	constant annual reduction rate				exponential increase of annual reduction rates is assumed			linear increase of annual reduction rates is assumed				
2062	118.64	-10.05	-7.24%	-7.81%	-181.40	0.00	-122.02%	-146.81	-22.58	-24.05%		
2063	108.60	-10.05	-7.24%	-8.47%	-181.40	0.00	-134.38%	-169.39	-22.58	-24.58%		
2064	98.55	-10.05	-7.24%	-9.25%	-181.40	0.00	-148.00%	-181.40	-12.01	-25.11%		
2065	88.51	-10.05	-7.24%	-10.19%	-181.40	0.00	-163.00%	-181.40	0.00	-25.64%		
2066	78.46	-10.05	-7.24%	-11.35%	-181.40	0.00	-179.52%	-181.40	0.00	-26.18%		
2067	68.42	-10.05	-7.24%	-12.80%	-181.40	0.00	-197.71%	-181.40	0.00	-26.71%		
2068	58.37	-10.05	-7.24%	-14.68%	-181.40	0.00	-217.74%	-181.40	0.00	-27.24%		
2069	48.33	-10.05	-7.24%	-17.21%	-181.40	0.00	-239.81%	-181.40	0.00	-27.77%		
2070	38.28	-10.05	-7.24%	-20.79%	-181.40	0.00	-264.11%	-181.40	0.00	-28.31%		
2071	28.24	-10.05	-7.24%	-26.24%	-181.40	0.00	-290.87%	-181.40	0.00	-28.84%		
2072	18.19	-10.05	-7.24%	-35.58%	-181.40	0.00	-320.34%	-181.40	0.00	-29.37%		
2073	8.15	-10.05	-7.24%	-55.22%	-181.40	0.00	-352.81%	-181.40	0.00	-29.91%		
2074	-1.90	-10.05	-7.24%		-181.40	0.00	-388.56%	-181.40	0.00	-30.44%		
2075	-11.95	-10.05	-7.24%		-181.40	0.00	-427.93%	-181.40	0.00	-30.97%		
2076	-21.99	-10.05	-7.24%		-181.40	0.00	-471.29%	-181.40	0.00	-31.50%		
2077	-32.04	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-32.04%		
2078	-42.08	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-32.57%		
2079	-52.13	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-33.10%		
2080	-62.17	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-33.64%		
2081	-72.22	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-34.17%		
2082	-82.26	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-34.70%		
2083	-92.31	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-35.23%		
2084	-102.35	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-35.77%		
2085	-112.40	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-36.30%		
2086	-122.44	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-36.83%		
2087	-132.49	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-37.36%		
2088	-142.53	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-37.90%		
2089	-152.58	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-38.43%		
2090	-162.63	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-38.96%		
2091	-172.67	-10.05	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-39.50%		
2092	-181.40	-8.73	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-40.03%		
2093	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-40.56%		
2094	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-41.09%		
2095	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-41.63%		
2096	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-42.16%		
2097	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-42.69%		
2098	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-43.23%		
2099	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-43.76%		
2100	-181.40	0.00	-7.24%		-181.40	0.00	-500.00%	-181.40	0.00	-44.29%		
sum	34,643				34,643			34,643				
		-3,204	negative emissions in Mill. t			-8,715	negative emissions in Mill. t			-7,435	negative emissions in Mill. t	

RM-4 quadr	
quadratic formula for annual reduction rates	
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-1.67%
free paramter	-0.0004

RM-5 rad	
radical formula for annual reduction rates	
correcting factor	0.5
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-1.67%
free paramter	-0.0193

RM-6 abs	
constant absolute annual change	
cumulative budget 2020 - 2100 in Mill. t	34,643
scenario sum emissions 2020 - 2100 in Mill. t	34,643
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; info	-3.34%
free paramter	-100.85

year	CO2 emissions	absolute change	relative change	
	in Mill. t	vs. prev. year in Mill. t	vs. prev. year	
t	<i>see formula below</i> E_t	<i>see formula below</i> $E_t - E_{t-1}$		<i>actual</i> RR_t
2019	3,023.61			
2020	2,973.19	-50.42	-1.67%	-1.67%
2021	2,922.39	-50.80	-1.71%	-1.71%
2022	2,868.88	-53.51	-1.83%	-1.83%
2023	2,810.50	-58.39	-2.04%	-2.04%
2024	2,745.26	-65.23	-2.32%	-2.32%
2025	2,671.45	-73.81	-2.69%	-2.69%
2026	2,587.63	-83.82	-3.14%	-3.14%
2027	2,492.70	-94.93	-3.67%	-3.67%
2028	2,385.98	-106.72	-4.28%	-4.28%
2029	2,267.27	-118.71	-4.98%	-4.98%
2030	2,136.87	-130.40	-5.75%	-5.75%
2031	1,995.64	-141.22	-6.61%	-6.61%
2032	1,845.01	-150.64	-7.55%	-7.55%
2033	1,686.91	-158.10	-8.57%	-8.57%
2034	1,523.75	-163.15	-9.67%	-9.67%
2035	1,358.33	-165.42	-10.86%	-10.86%
2036	1,193.68	-164.66	-12.12%	-12.12%
2037	1,032.89	-160.78	-13.47%	-13.47%
2038	879.00	-153.89	-14.90%	-14.90%
2039	734.76	-144.24	-16.41%	-16.41%
2040	602.48	-132.28	-18.00%	-18.00%
2041	483.93	-118.55	-19.68%	-19.68%
2042	380.21	-103.72	-21.43%	-21.43%
2043	291.73	-88.48	-23.27%	-23.27%
2044	218.25	-73.49	-25.19%	-25.19%
2045	158.90	-59.34	-27.19%	-27.19%
2046	112.39	-46.52	-29.27%	-29.27%
2047	77.05	-35.33	-31.44%	-31.44%
2048	41.72	-35.33	-33.68%	-45.85%
2049	6.39	-35.33	-36.01%	-84.68%
2050	-28.94	-35.33	-38.42%	
2051	-64.27	-35.33	-40.91%	
2052	-99.61	-35.33	-43.49%	
2053	-134.94	-35.33	-46.14%	
2054	-170.27	-35.33	-48.88%	
2055	-181.40	-11.13	-51.69%	
2056	-181.40	0.00	-54.59%	
2057	-181.40	0.00	-57.57%	
2058	-181.40	0.00	-60.64%	
2059	-181.40	0.00	-63.78%	
2060	-181.40	0.00	-67.01%	
2061	-181.40	0.00	-70.32%	

CO2 emissions	absolute change	relative change	
	in Mill. t	vs. prev. year in Mill. t	
t	<i>see formula below</i> E_t	<i>see formula below</i> $E_t - E_{t-1}$	
2019	3,023.61		
2020	2,973.19	-50.42	-1.67%
2021	2,883.11	-90.08	-3.03%
2022	2,767.02	-116.09	-4.03%
2023	2,636.61	-130.41	-4.71%
2024	2,497.63	-138.98	-5.27%
2025	2,353.93	-143.70	-5.75%
2026	2,208.35	-145.58	-6.18%
2027	2,063.08	-145.27	-6.58%
2028	1,919.85	-143.23	-6.94%
2029	1,780.03	-139.82	-7.28%
2030	1,644.67	-135.36	-7.60%
2031	1,514.59	-130.07	-7.91%
2032	1,390.41	-124.19	-8.20%
2033	1,272.54	-117.87	-8.48%
2034	1,161.26	-111.28	-8.74%
2035	1,056.72	-104.54	-9.00%
2036	958.97	-97.75	-9.25%
2037	867.95	-91.02	-9.49%
2038	783.54	-84.41	-9.73%
2039	705.56	-77.98	-9.95%
2040	633.79	-71.78	-10.17%
2041	567.95	-65.84	-10.39%
2042	507.75	-60.19	-10.60%
2043	452.90	-54.86	-10.80%
2044	403.06	-49.84	-11.00%
2045	357.91	-45.15	-11.20%
2046	317.13	-40.78	-11.39%
2047	280.40	-36.73	-11.58%
2048	247.40	-33.00	-11.77%
2049	217.83	-29.56	-11.95%
2050	191.41	-26.42	-12.13%
2051	167.86	-23.55	-12.30%
2052	146.91	-20.95	-12.48%
2053	128.33	-18.58	-12.65%
2054	111.89	-16.45	-12.82%
2055	97.36	-14.52	-12.98%
2056	82.84	-14.52	-14.92%
2057	68.31	-14.52	-17.53%
2058	53.79	-14.52	-13.46%
2059	39.27	-14.52	-13.62%
2060	24.74	-14.52	-13.77%
2061	10.22	-14.52	-13.93%

CO2 emissions	absolute change	relative change	
	in Mill. t	vs. prev. year in Mill. t	
t	<i>see formula below</i> E_t	<i>actual</i> $E_t - E_{t-1}$	
2019	3,023.61		
2020	2,922.76	-100.85	-3.34%
2021	2,821.92	-100.85	-3.45%
2022	2,721.07	-100.85	-3.57%
2023	2,620.23	-100.85	-3.71%
2024	2,519.38	-100.85	-3.85%
2025	2,418.54	-100.85	-4.00%
2026	2,317.69	-100.85	-4.17%
2027	2,216.85	-100.85	-4.35%
2028	2,116.00	-100.85	-4.55%
2029	2,015.16	-100.85	-4.77%
2030	1,914.31	-100.85	-5.00%
2031	1,813.47	-100.85	-5.27%
2032	1,712.62	-100.85	-5.56%
2033	1,611.77	-100.85	-5.89%
2034	1,510.93	-100.85	-6.26%
2035	1,410.08	-100.85	-6.67%
2036	1,309.24	-100.85	-7.15%
2037	1,208.39	-100.85	-7.70%
2038	1,107.55	-100.85	-8.35%
2039	1,006.70	-100.85	-9.11%
2040	905.86	-100.85	-10.02%
2041	805.01	-100.85	-11.13%
2042	704.17	-100.85	-12.53%
2043	603.32	-100.85	-14.32%
2044	502.48	-100.85	-16.72%
2045	401.63	-100.85	-20.07%
2046	300.79	-100.85	-25.11%
2047	199.94	-100.85	-33.53%
2048	99.09	-100.85	-50.44%
2049	-1.75	-100.85	
2050	-102.60	-100.85	
2051	-181.40	-100.85	-78.80
2052	-181.40	-100.85	
2053	-181.40	-100.85	
2054	-181.40	-100.85	
2055	-181.40	-100.85	
2056	-181.40	-100.85	
2057	-181.40	-100.85	
2058	-181.40	-100.85	
2059	-181.40	-100.85	
2060	-181.40	-100.85	
2061	-181.40	-100.85	

RM-4 quadr					RM-5 rad					RM-6 abs				
quadratic formula for annual reduction rates					radical formula for annual reduction rates					constant absolute annual change				
2062	-181.40	0.00	-73.70%		-4.30	-14.52	-14.08%		-181.40	-100.85				
2063	-181.40	0.00	-77.18%		-18.83	-14.52	-14.22%		-181.40	-100.85				
2064	-181.40	0.00	-80.73%		-33.35	-14.52	-14.37%		-181.40	-100.85				
2065	-181.40	0.00	-84.36%		-47.88	-14.52	-14.52%		-181.40	-100.85				
2066	-181.40	0.00	-88.08%		-62.40	-14.52	-14.66%		-181.40	-100.85				
2067	-181.40	0.00	-91.88%		-76.92	-14.52	-14.80%		-181.40	-100.85				
2068	-181.40	0.00	-95.76%		-91.45	-14.52	-14.94%		-181.40	-100.85				
2069	-181.40	0.00	-99.72%		-105.97	-14.52	-15.08%		-181.40	-100.85				
2070	-181.40	0.00	-103.76%		-120.49	-14.52	-15.22%		-181.40	-100.85				
2071	-181.40	0.00	-107.89%		-135.02	-14.52	-15.36%		-181.40	-100.85				
2072	-181.40	0.00	-112.09%		-149.54	-14.52	-15.49%		-181.40	-100.85				
2073	-181.40	0.00	-116.38%		-164.07	-14.52	-15.62%		-181.40	-100.85				
2074	-181.40	0.00	-120.75%		-178.59	-14.52	-15.76%		-181.40	-100.85				
2075	-181.40	0.00	-125.20%		-181.40	-2.81	-15.89%		-181.40	-100.85				
2076	-181.40	0.00	-129.73%		-181.40	0.00	-16.02%		-181.40	-100.85				
2077	-181.40	0.00	-134.35%		-181.40	0.00	-16.15%		-181.40	-100.85				
2078	-181.40	0.00	-139.04%		-181.40	0.00	-16.27%		-181.40	-100.85				
2079	-181.40	0.00	-143.82%		-181.40	0.00	-16.40%		-181.40	-100.85				
2080	-181.40	0.00	-148.68%		-181.40	0.00	-16.52%		-181.40	-100.85				
2081	-181.40	0.00	-153.62%		-181.40	0.00	-16.65%		-181.40	-100.85				
2082	-181.40	0.00	-158.65%		-181.40	0.00	-16.77%		-181.40	-100.85				
2083	-181.40	0.00	-163.75%		-181.40	0.00	-16.89%		-181.40	-100.85				
2084	-181.40	0.00	-168.94%		-181.40	0.00	-17.02%		-181.40	-100.85				
2085	-181.40	0.00	-174.21%		-181.40	0.00	-17.14%		-181.40	-100.85				
2086	-181.40	0.00	-179.56%		-181.40	0.00	-17.26%		-181.40	-100.85				
2087	-181.40	0.00	-184.99%		-181.40	0.00	-17.37%		-181.40	-100.85				
2088	-181.40	0.00	-190.50%		-181.40	0.00	-17.49%		-181.40	-100.85				
2089	-181.40	0.00	-196.09%		-181.40	0.00	-17.61%		-181.40	-100.85				
2090	-181.40	0.00	-201.77%		-181.40	0.00	-17.72%		-181.40	-100.85				
2091	-181.40	0.00	-207.53%		-181.40	0.00	-17.84%		-181.40	-100.85				
2092	-181.40	0.00	-213.37%		-181.40	0.00	-17.95%		-181.40	-100.85				
2093	-181.40	0.00	-219.29%		-181.40	0.00	-18.07%		-181.40	-100.85				
2094	-181.40	0.00	-225.29%		-181.40	0.00	-18.18%		-181.40	-100.85				
2095	-181.40	0.00	-231.38%		-181.40	0.00	-18.29%		-181.40	-100.85				
2096	-181.40	0.00	-237.54%		-181.40	0.00	-18.40%		-181.40	-100.85				
2097	-181.40	0.00	-243.79%		-181.40	0.00	-18.51%		-181.40	-100.85				
2098	-181.40	0.00	-250.12%		-181.40	0.00	-18.62%		-181.40	-100.85				
2099	-181.40	0.00	-256.53%		-181.40	0.00	-18.73%		-181.40	-100.85				
2100	-181.40	0.00	-263.03%		-181.40	0.00	-18.84%		-181.40	-100.85				
sum	34,643				34,643				34,643					
	-8,842	negative emissions in Mill. t				-5,905	negative emissions in Mill. t				-9,174	negative emissions in Mill. t		

M-2 exp	RM-3 lin	RM-4 quadr
annual reduction rates is assumed	linear increase of annual reduction rates is assumed	quadratic formula for annual reduction rates

3 Formulae Regensburg Model Scenario Types

3.1 Determination of paths via annual rates of change (scenario types RM 1 – 5)

$$E_t = \begin{cases} \max(E_{min}; E_{t-1} * (1 + RR_t)) & \text{for } E_{t-1} > TV \\ \max(E_{min}; E_{t-1} + (E_{t-1} - E_{t-2})) & \text{for } E_{t-1} \leq TV \end{cases}$$

where:

E_t emissions in the year t ; here: 2020 – 2100

The **reduction rates** in the individual scenario types are based on the following formulae:

name scenario type	formula	basic function type	con-straint	property course of the reduction rates
RM-2 exp ³	$RR_t = RR_{t-1} * (1 + a)$	e^x	$a \geq 0$	► concave
RM-4 quadr ⁴	$RR_t = a * (t - (BY + 1))^2 + RR_{BY+1}$	$y = ax^2 + b$	$a \leq 0$	
RM-5 rad ⁵	$RR_t = a * \sqrt{t - (BY + 1) - 0.5} + RR_{BY+1}$	$y = a\sqrt{x} + b$	$a \leq 0$	► convex
RM-3 lin	$RR_t = a * (t - (BY + 1)) + RR_{BY+1} = RR_{t-1} + a$	$y = ax + b$	$a \leq 0$	► linear
RM-1 const	$RR_t = a$	$y = a$	$a \leq 0$	► constant

In the scenario types RM 2, 5 and 3 for $t = BY + 1$ the predefined RR_{BY+1} (see chapter 2) must be used. Thus the equations above hold for $t > BY + 1$ (here: $t > 2020$).

The free parameter a is determined for each scenario type with the target value search integrated in Excel so that the budget (B) is met. The target value search is integrated in a macro in the Excel tools, which also ensures that the constraints are met.

3.2 Determination of paths via annual change amount (scenario type RM-6)

RM-6 abs: $E_t = \max(E_{min}; E_{t-1} + RA)$

The free parameter RA (constant reduction amount) is determined with the target value search integrated in Excel so that the budget (B) is met.