

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
----------	-------------	------

<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“
--------------	-------------------------------

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	
<u>420</u>	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						420 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%		-55 Gt	12.9%
international shipping and aviation (ISA) from 2018 on			how much should be reserved?	3.0%		-13 Gt	2.9%
sub sum						353 Gt	
(projected) global CO2 emissions 2018 - 2019						-74 Gt	
global CO2 budget 2020 - 2100 (without FOLU and ISA)						279 Gt	A

II.) National CO2 budget 2020 - 2100

weighting population key in the weighted key	100%	selected country:	EU27	sheet: 'reference values'
---	-------------	-------------------	-------------	---------------------------

share selected country in global population 2019 5.769% weight: 100%
 share selected country in global emissions 2019 8.158% weight: 0%

population in 2019	444,987 thousand	info
projected emissions in 2019	3,023.61 Mill. t	
scope of the budget	5.33 years	

weighted key	5.769%	B
---------------------	---------------	----------

national CO2 budget <u>2020 - 2100</u> ; weighted key applied on the global budget 2020 - 2100	16,102	Mill. t	= A * B
---	---------------	---------	----------------

national CO2 budget <u>2020 - 2100</u> ; free input		Mill. t
--	--	---------

national CO2 budget 2020 - 2100 (basis for this tool)	here calculated value	16,102	Mill. t
--	------------------------------	---------------	---------

III) National minimum emissions until 2100

emissions in 2019 of the selected country	3,023.6 Mill. t
What percentage of emissions in 2019 should represent the minimum of emissions by 2100? A negative value stands for net negative emissions.	-6.0%

minimum annual CO₂ emissions (a negative value stands for net negative emissions); E_{min} :	-181.4	Mill. t
--	---------------	---------

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%

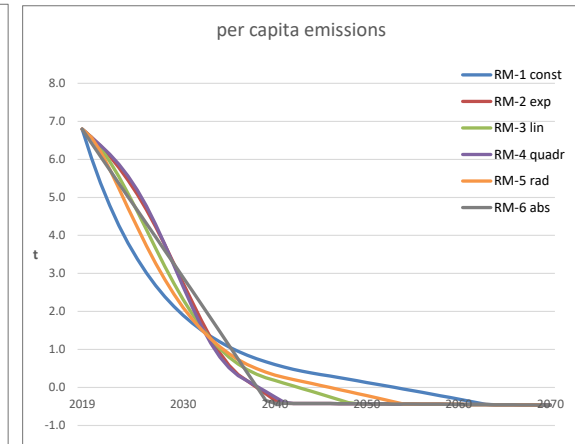
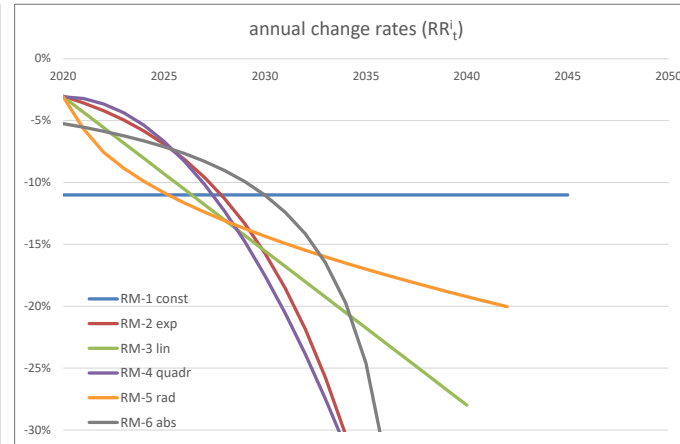
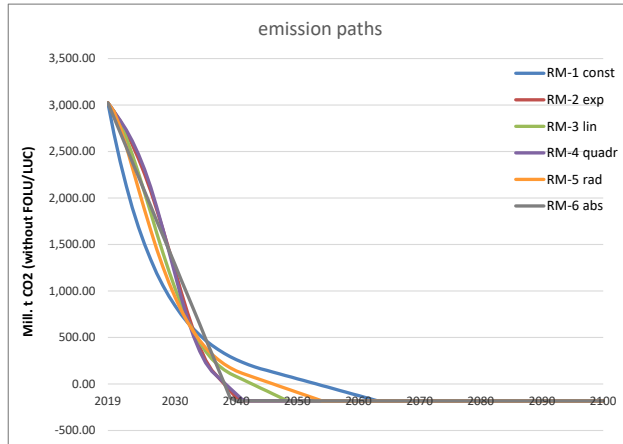
EU27

→ select a country

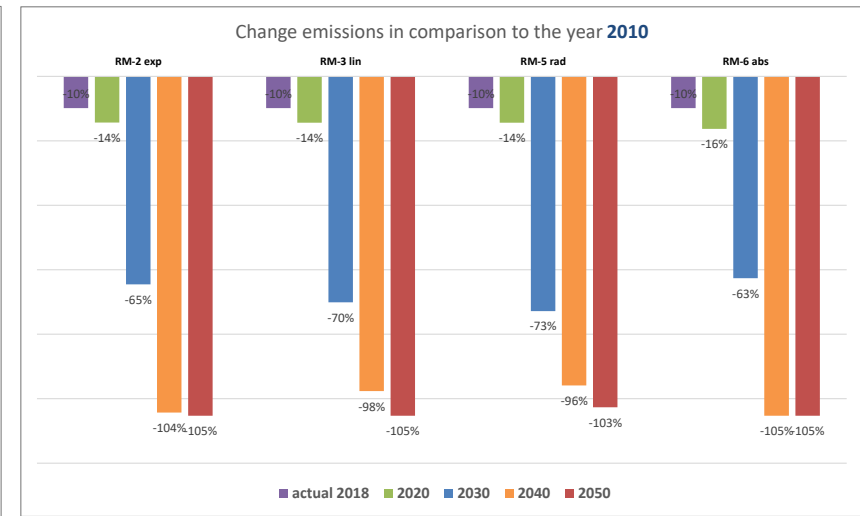
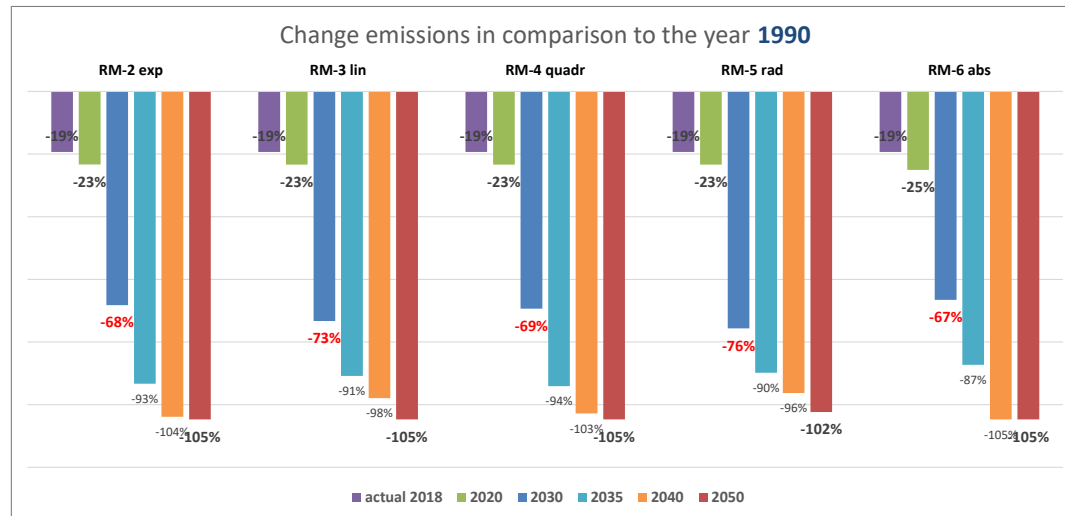
projection emissions 2019	
	individual change rate sheet 'data countries'
base year projection: 2018	-02 % p.a.
'goal seek' is ok	
sheet 'goal seek'	

100%	share population key RM 1 - 6 and SPM_FP
420	Gt global budget

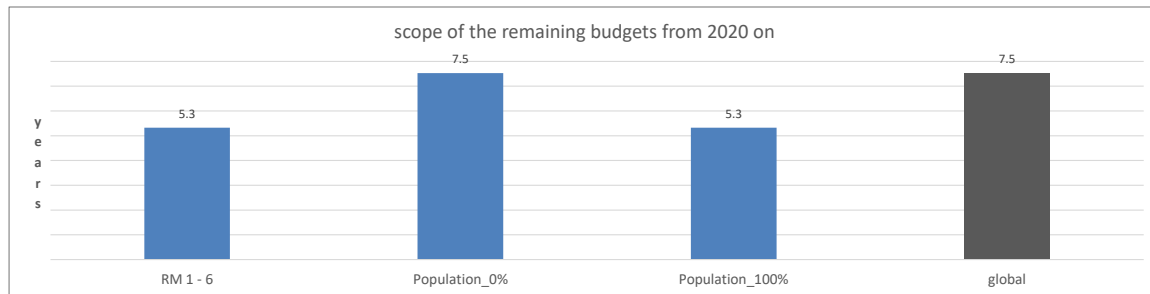
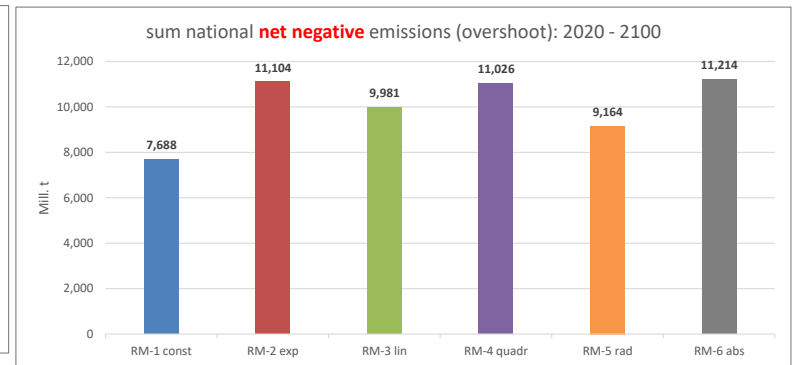
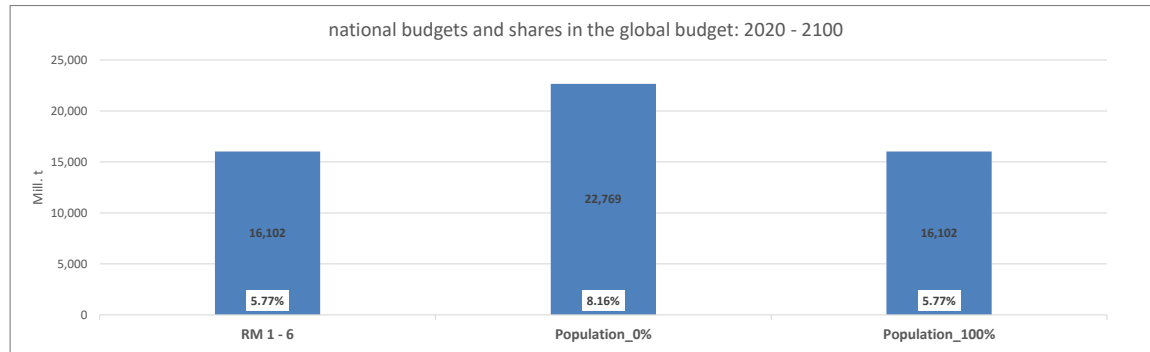
global per capita emissions 2019: 4.8052 t



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.

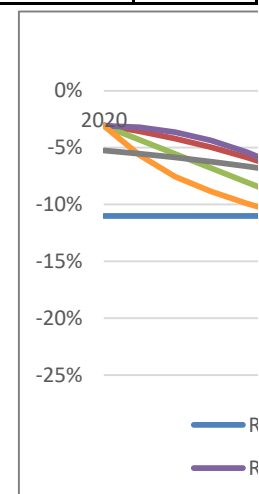
The later we reduce our CO2 emissions, the more we have to rely on global negative emissions and the higher the risks. In addition, the potential and costs of negative emissions are still relatively unclear today.

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:		RM-1 const	RM-2 exp	RM-3 lin	RM-4 quadr	RM-5 rad	RM-6	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)		-11.00%	-3.02%	-3.07%	-3.07%	-3.07%	-5.25%	-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.		-11.00%	17.92%	-1.24564%	-0.00144514	-0.03657234	-158.60			
scenario Σ 2020 - 2100; sheet 'RM'	Mill. t	16,102	16,102	16,102	16,102	16,102	16,102			
budget Σ 2020 - 2100; sheet 'base data'	Mill. t	16,102	16,102	16,102	16,102	16,102	16,102			
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		2064	2041	2049	2042	2054	2040			
change rate 2030 / 1990		-78%	-68%	-73%	-69%	-76%	-67%			
		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:		148.16	Mill. t	4.90%				



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	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
free paramter	-11.00%

RM-2 exp	
exponential increase of annual reduction rates is assumed	
cumulative budget 2020 - 2100 in Mill. t	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-3.02%
free paramter	17.92%

RM-3 lin	
linear increase of annual reduction rates is assumed	
cumulative budget 2020 - 2100 in Mill. t	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-3.07%
free paramter	-1.25%

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	
t	E_t	$E_t - E_{t-1}$	RR_t const	actual RR_t
2019	3,023.61			
2020	2,690.88	-332.73	-11.00%	-11.00%
2021	2,394.76	-296.12	-11.00%	-11.00%
2022	2,131.23	-263.53	-11.00%	-11.00%
2023	1,896.70	-234.53	-11.00%	-11.00%
2024	1,687.97	-208.72	-11.00%	-11.00%
2025	1,502.22	-185.75	-11.00%	-11.00%
2026	1,336.91	-165.31	-11.00%	-11.00%
2027	1,189.79	-147.12	-11.00%	-11.00%
2028	1,058.86	-130.93	-11.00%	-11.00%
2029	942.34	-116.52	-11.00%	-11.00%
2030	838.64	-103.70	-11.00%	-11.00%
2031	746.35	-92.29	-11.00%	-11.00%
2032	664.22	-82.13	-11.00%	-11.00%
2033	591.12	-73.09	-11.00%	-11.00%
2034	526.07	-65.05	-11.00%	-11.00%
2035	468.18	-57.89	-11.00%	-11.00%
2036	416.66	-51.52	-11.00%	-11.00%
2037	370.81	-45.85	-11.00%	-11.00%
2038	330.00	-40.81	-11.00%	-11.00%
2039	293.69	-36.32	-11.00%	-11.00%
2040	261.37	-32.32	-11.00%	-11.00%
2041	232.61	-28.76	-11.00%	-11.00%
2042	207.01	-25.60	-11.00%	-11.00%
2043	184.23	-22.78	-11.00%	-11.00%
2044	163.96	-20.27	-11.00%	-11.00%
2045	145.91	-18.04	-11.00%	-11.00%
2046	127.87	-18.04	-11.00%	-12.37%
2047	109.83	-18.04	-11.00%	-14.11%
2048	91.79	-18.04	-11.00%	-16.43%
2049	73.74	-18.04	-11.00%	-19.66%
2050	55.70	-18.04	-11.00%	-24.47%
2051	37.66	-18.04	-11.00%	-32.39%
2052	19.62	-18.04	-11.00%	-47.91%
2053	1.57	-18.04	-11.00%	-91.98%
2054	-16.47	-18.04	-11.00%	
2055	-34.51	-18.04	-11.00%	
2056	-52.55	-18.04	-11.00%	
2057	-70.60	-18.04	-11.00%	
2058	-88.64	-18.04	-11.00%	
2059	-106.68	-18.04	-11.00%	
2060	-124.72	-18.04	-11.00%	
2061	-142.77	-18.04	-11.00%	

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	
t	E_t	$E_t - E_{t-1}$	see formula below	actual RR_t
2019	3,023.61			
2020	2,932.22	-91.39	-3.02%	-3.02%
2021	2,827.70	-104.52	-3.56%	-3.56%
2022	2,708.84	-118.86	-4.20%	-4.20%
2023	2,574.57	-134.27	-4.96%	-4.96%
2024	2,424.08	-150.49	-5.85%	-5.85%
2025	2,256.99	-167.09	-6.89%	-6.89%
2026	2,073.52	-183.46	-8.13%	-8.13%
2027	1,874.76	-198.76	-9.59%	-9.59%
2028	1,662.84	-211.92	-11.30%	-11.30%
2029	1,441.18	-221.66	-13.33%	-13.33%
2030	1,214.63	-226.55	-15.72%	-15.72%
2031	989.47	-225.16	-18.54%	-18.54%
2032	773.17	-216.30	-21.86%	-21.86%
2033	573.86	-199.31	-25.78%	-25.78%
2034	399.41	-174.45	-30.40%	-30.40%
2035	256.23	-143.18	-35.85%	-35.85%
2036	147.91	-108.32	-42.27%	-42.27%
2037	74.17	-73.74	-49.85%	-49.85%
2038	0.44	-73.74	-58.79%	-99.41%
2039	-73.30	-73.74	-69.33%	
2040	-147.03	-73.74	-81.75%	
2041	-181.40	-34.37	-96.41%	
2042	-181.40	0.00	-113.69%	
2043	-181.40	0.00	-134.07%	
2044	-181.40	0.00	-158.10%	
2045	-181.40	0.00	-186.44%	
2046	-181.40	0.00	-219.85%	
2047	-181.40	0.00	-259.26%	
2048	-181.40	0.00	-305.74%	
2049	-181.40	0.00	-360.54%	
2050	-181.40	0.00	-425.16%	
2051	-181.40	0.00	-500.00%	
2052	-181.40	0.00	-500.00%	
2053	-181.40	0.00	-500.00%	
2054	-181.40	0.00	-500.00%	
2055	-181.40	0.00	-500.00%	
2056	-181.40	0.00	-500.00%	
2057	-181.40	0.00	-500.00%	
2058	-181.40	0.00	-500.00%	
2059	-181.40	0.00	-500.00%	
2060	-181.40	0.00	-500.00%	
2061	-181.40	0.00	-500.00%	

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	
t	E_t	$E_t - E_{t-1}$	see formula below	actual RR_t
2019	3,023.61			
2020	2,930.70	-92.90	-3.07%	-3.07%
2021	2,804.15	-126.56	-4.32%	-4.32%
2022	2,648.13	-156.02	-5.56%	-5.56%
2023	2,467.80	-180.33	-6.81%	-6.81%
2024	2,269.02	-198.79	-8.06%	-8.06%
2025	2,057.98	-211.04	-9.30%	-9.30%
2026	1,840.94	-217.04	-10.55%	-10.55%
2027	1,623.85	-217.08	-11.79%	-11.79%
2028	1,412.14	-211.71	-13.04%	-13.04%
2029	1,210.44	-201.70	-14.28%	-14.28%
2030	1,022.47	-187.97	-15.53%	-15.53%
2031	850.95	-171.52	-16.77%	-16.77%
2032	697.61	-153.34	-18.02%	-18.02%
2033	563.21	-134.40	-19.27%	-19.27%
2034	447.69	-115.52	-20.51%	-20.51%
2035	350.28	-97.40	-21.76%	-21.76%
2036	269.71	-80.57	-23.00%	-23.00%
2037	204.31	-65.40	-24.25%	-24.25%
2038	152.22	-52.09	-25.49%	-25.49%
2039	111.52	-40.70	-26.74%	-26.74%
2040	80.31	-31.21	-27.99%	-27.99%
2041	49.10	-31.21	-29.23%	-38.86%
2042	17.89	-31.21	-30.48%	-63.56%
2043	-13.32	-31.21	-31.72%	
2044	-44.53	-31.21	-32.97%	
2045	-75.73	-31.21	-34.21%	
2046	-106.94	-31.21	-35.46%	
2047	-138.15	-31.21	-36.70%	
2048	-169.36	-31.21	-37.95%	
2049	-181.40	-12.04	-39.20%	
2050	-181.40	0.00	-40.44%	
2051	-181.40	0.00	-41.69%	
2052	-181.40	0.00	-42.93%	
2053	-181.40	0.00	-44.18%	
2054	-181.40	0.00	-45.42%	
2055	-181.40	0.00	-46.67%	
2056	-181.40	0.00	-47.92%	
2057	-181.40	0.00	-49.16%	
2058	-181.40	0.00	-50.41%	
2059	-181.40	0.00	-51.65%	
2060	-181.40	0.00	-52.90%	
2061	-181.40	0.00	-54.14%	

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	-160.81	-18.04	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-55.39%	
2063	-178.85	-18.04	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-56.63%	
2064	-181.40	-2.55	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-57.88%	
2065	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-59.13%	
2066	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-60.37%	
2067	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-61.62%	
2068	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-62.86%	
2069	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-64.11%	
2070	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-65.35%	
2071	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-66.60%	
2072	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-67.85%	
2073	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-69.09%	
2074	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-70.34%	
2075	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-71.58%	
2076	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-72.83%	
2077	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-74.07%	
2078	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-75.32%	
2079	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-76.57%	
2080	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-77.81%	
2081	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-79.06%	
2082	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-80.30%	
2083	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-81.55%	
2084	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-82.79%	
2085	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-84.04%	
2086	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-85.28%	
2087	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-86.53%	
2088	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-87.78%	
2089	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-89.02%	
2090	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-90.27%	
2091	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-91.51%	
2092	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-92.76%	
2093	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-94.00%	
2094	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-95.25%	
2095	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-96.50%	
2096	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-97.74%	
2097	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-98.99%	
2098	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-100.23%	
2099	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-101.48%	
2100	-181.40	0.00	-11.00%		-181.40	0.00	-500.00%		-181.40	0.00	-102.72%	
sum	16,102				16,102				16,102			
	-7,688	negative emissions in Mill. t			-11,104	negative emissions in Mill. t			-9,981	negative emissions in Mill. t		

RM-4 quadr	
quadratic formula for annual reduction rates	
cumulative budget 2020 - 2100 in Mill. t	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-3.07%
free paramter	-0.0014

RM-5 rad	
radical formula for annual reduction rates	
correcting factor	0.5
cumulative budget 2020 - 2100 in Mill. t	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; input value sheet "goal seek"	-3.07%
free paramter	-0.0366

RM-6 abs	
constant absolute annual change	
cumulative budget 2020 - 2100 in Mill. t	16,102
scenario sum emissions 2020 - 2100 in Mill. t	16,102
E_min in Mill. t	-181.4
scenario emissions in year 2100 in Mill. t	-181.4
RR_20; info	-5.25%
free paramter	-158.60

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>see formula below</i> $\frac{E_t - E_{t-1}}{E_{t-1}}$	actual RR_t
2019	3,023.61			
2020	2,930.70	-92.90	-3.07%	-3.07%
2021	2,836.42	-94.28	-3.22%	-3.22%
2022	2,732.87	-103.55	-3.65%	-3.65%
2023	2,613.36	-119.52	-4.37%	-4.37%
2024	2,472.63	-140.73	-5.38%	-5.38%
2025	2,307.32	-165.31	-6.69%	-6.69%
2026	2,116.39	-190.93	-8.28%	-8.28%
2027	1,901.50	-214.89	-10.15%	-10.15%
2028	1,667.20	-234.29	-12.32%	-12.32%
2029	1,420.82	-246.38	-14.78%	-14.78%
2030	1,171.84	-248.98	-17.52%	-17.52%
2031	930.92	-240.92	-20.56%	-20.56%
2032	708.59	-222.33	-23.88%	-23.88%
2033	513.76	-194.83	-27.50%	-27.50%
2034	352.46	-161.31	-31.40%	-31.40%
2035	227.02	-125.43	-35.59%	-35.59%
2036	136.06	-90.96	-40.07%	-40.07%
2037	75.05	-61.00	-44.84%	-44.84%
2038	14.05	-61.00	-49.90%	-81.28%
2039	-46.96	-61.00	-55.24%	
2040	-107.96	-61.00	-60.88%	
2041	-168.97	-61.00	-66.80%	
2042	-181.40	-12.43	-73.02%	
2043	-181.40	0.00	-79.52%	
2044	-181.40	0.00	-86.31%	
2045	-181.40	0.00	-93.39%	
2046	-181.40	0.00	-100.76%	
2047	-181.40	0.00	-108.42%	
2048	-181.40	0.00	-116.37%	
2049	-181.40	0.00	-124.61%	
2050	-181.40	0.00	-133.13%	
2051	-181.40	0.00	-141.95%	
2052	-181.40	0.00	-151.05%	
2053	-181.40	0.00	-160.45%	
2054	-181.40	0.00	-170.13%	
2055	-181.40	0.00	-180.10%	
2056	-181.40	0.00	-190.36%	
2057	-181.40	0.00	-200.91%	
2058	-181.40	0.00	-211.75%	
2059	-181.40	0.00	-222.88%	
2060	-181.40	0.00	-234.29%	
2061	-181.40	0.00	-246.00%	

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>see formula below</i> $\frac{E_t - E_{t-1}}{E_{t-1}}$	actual RR_t
2019	3,023.61			
2020	2,930.70	-92.90	-3.07%	-3.07%
2021	2,764.87	-165.84	-5.66%	-5.66%
2022	2,556.07	-208.80	-7.55%	-7.55%
2023	2,329.72	-226.35	-8.86%	-8.86%
2024	2,098.74	-230.98	-9.91%	-9.91%
2025	1,871.43	-227.31	-10.83%	-10.83%
2026	1,653.41	-218.01	-11.65%	-11.65%
2027	1,448.44	-204.97	-12.40%	-12.40%
2028	1,258.87	-189.58	-13.09%	-13.09%
2029	1,085.96	-172.91	-13.74%	-13.74%
2030	930.18	-155.78	-14.34%	-14.34%
2031	791.36	-138.81	-14.92%	-14.92%
2032	668.90	-122.46	-15.47%	-15.47%
2033	561.86	-107.04	-16.00%	-16.00%
2034	469.09	-92.76	-16.51%	-16.51%
2035	389.35	-79.74	-17.00%	-17.00%
2036	321.33	-68.02	-17.47%	-17.47%
2037	263.72	-57.61	-17.93%	-17.93%
2038	215.27	-48.45	-18.37%	-18.37%
2039	174.79	-40.48	-18.80%	-18.80%
2040	141.19	-33.60	-19.22%	-19.22%
2041	113.47	-27.72	-19.63%	-19.63%
2042	90.74	-22.73	-20.03%	-20.03%
2043	68.02	-22.73	-20.42%	-25.05%
2044	45.29	-22.73	-20.80%	-33.42%
2045	22.56	-22.73	-21.18%	-50.19%
2046	-0.17	-22.73	-21.54%	
2047	-22.90	-22.73	-21.90%	
2048	-45.63	-22.73	-22.25%	
2049	-68.36	-22.73	-22.60%	
2050	-91.09	-22.73	-22.94%	
2051	-113.82	-22.73	-23.27%	
2052	-136.55	-22.73	-23.60%	
2053	-159.28	-22.73	-23.92%	
2054	-181.40	-22.12	-24.24%	
2055	-181.40	0.00	-24.55%	
2056	-181.40	0.00	-24.86%	
2057	-181.40	0.00	-25.17%	
2058	-181.40	0.00	-25.47%	
2059	-181.40	0.00	-25.77%	
2060	-181.40	0.00	-26.06%	
2061	-181.40	0.00	-26.35%	

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> $E_t - E_{t-1}$	actual RR_t	
2019	3,023.61			
2020	2,865.01	-158.60	-5.25%	
2021	2,706.42	-158.60	-5.54%	
2022	2,547.82	-158.60	-5.86%	
2023	2,389.23	-158.60	-6.22%	
2024	2,230.63	-158.60	-6.64%	
2025	2,072.03	-158.60	-7.11%	
2026	1,913.44	-158.60	-7.65%	
2027	1,754.84	-158.60	-8.29%	
2028	1,596.25	-158.60	-9.04%	
2029	1,437.65	-158.60	-9.94%	
2030	1,279.06	-158.60	-11.03%	
2031	1,120.46	-158.60	-12.40%	
2032	961.87	-158.60	-14.15%	
2033	803.27	-158.60	-16.49%	
2034	644.67	-158.60	-19.74%	
2035	486.08	-158.60	-24.60%	
2036	327.48	-158.60	-32.63%	
2037	168.89	-158.60	-48.43%	
2038	10.29	-158.60	-93.91%	
2039	-148.30	-158.60		
2040	-181.40	-158.60	-33.10	
2041	-181.40	-158.60		
2042	-181.40	-158.60		
2043	-181.40	-158.60		
2044	-181.40	-158.60		
2045	-181.40	-158.60		
2046	-181.40	-158.60		
2047	-181.40	-158.60		
2048	-181.40	-158.60		
2049	-181.40	-158.60		
2050	-181.40	-158.60		
2051	-181.40	-158.60		
2052	-181.40	-158.60		
2053	-181.40	-158.60		
2054	-181.40	-158.60		
2055	-181.40	-158.60		
2056	-181.40	-158.60		
2057	-181.40	-158.60		
2058	-181.40	-158.60		
2059	-181.40	-158.60		
2060	-181.40	-158.60		
2061	-181.40	-158.60		

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	-257.99%								
2063	-181.40	0.00	-270.28%								
2064	-181.40	0.00	-282.85%								
2065	-181.40	0.00	-295.71%								
2066	-181.40	0.00	-308.86%								
2067	-181.40	0.00	-322.30%								
2068	-181.40	0.00	-336.03%								
2069	-181.40	0.00	-350.05%								
2070	-181.40	0.00	-364.36%								
2071	-181.40	0.00	-378.95%								
2072	-181.40	0.00	-393.84%								
2073	-181.40	0.00	-409.01%								
2074	-181.40	0.00	-424.47%								
2075	-181.40	0.00	-440.23%								
2076	-181.40	0.00	-456.27%								
2077	-181.40	0.00	-472.60%								
2078	-181.40	0.00	-489.22%								
2079	-181.40	0.00	-506.12%								
2080	-181.40	0.00	-523.32%								
2081	-181.40	0.00	-540.81%								
2082	-181.40	0.00	-558.58%								
2083	-181.40	0.00	-576.65%								
2084	-181.40	0.00	-595.00%								
2085	-181.40	0.00	-613.64%								
2086	-181.40	0.00	-632.57%								
2087	-181.40	0.00	-651.79%								
2088	-181.40	0.00	-671.30%								
2089	-181.40	0.00	-691.10%								
2090	-181.40	0.00	-711.19%								
2091	-181.40	0.00	-731.57%								
2092	-181.40	0.00	-752.23%								
2093	-181.40	0.00	-773.19%								
2094	-181.40	0.00	-794.43%								
2095	-181.40	0.00	-815.96%								
2096	-181.40	0.00	-837.78%								
2097	-181.40	0.00	-859.89%								
2098	-181.40	0.00	-882.29%								
2099	-181.40	0.00	-904.98%								
2100	-181.40	0.00	-927.96%								
sum	16,102			16,102				16,102			
	-11,026	negative emissions in Mill. t			-9,164	negative emissions in Mill. t			-11,214	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.