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 ex ecute 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

data status	
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	
800	**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					800 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?	10.0%	-80 Gt	12.9%
international shipping and aviation (ISA) from 2018 on			how much should be reserved?	3.0%	-24 Gt	2.9%
sub sum					696 Gt	
(projected) global CO2 emissions 2018 - 2019					-74 Gt	
global CO2 budget 2020 - 2100 (without FOLU and ISA)					**622 Gt**	A

II.) National CO2 budget 2020 - 2100

weighting population key in the weighted key	50%	selected country:	EU27	sheet: 'reference values'

share selected country in global population 2019	5.769%	weigh-	50%	population in 2019	444,987 thousand	info
share selected country in global emissions 2019	8.158%	ting:	50%	projected emissions in 2019	3,023.61 Mill. t	
weighted key	**6.963%**	**B**		scope of the budget	14.33 years	

national CO2 budget 2020 - 2100; **weighted key applied on the global budget 2020 - 2100**	**43,333**	Mill. t	**= A * B**

national CO2 budget 2020 - 2100; **free input**		Mill. t

national CO2 budget 2020 - 2100 (basis for this tool)	here calculated value	**43,333**	**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.	**0.0%**

minimum annual CO_2 emissions (a negative value stands for net negative emissions); E_{min} :	**0.0**	**Mill. t**

background information to net negative emissions:

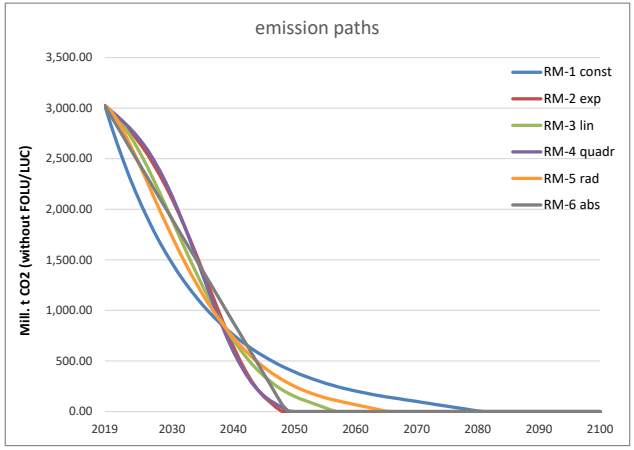
	2019
global CO2 without FOLU and ISA in Gt	37.1
E_min % actual input above	0.00%
≈ E_min global analog in Gt	0.00
total global emissions in Gt	43.8
share of total global emissions	**0.0%**

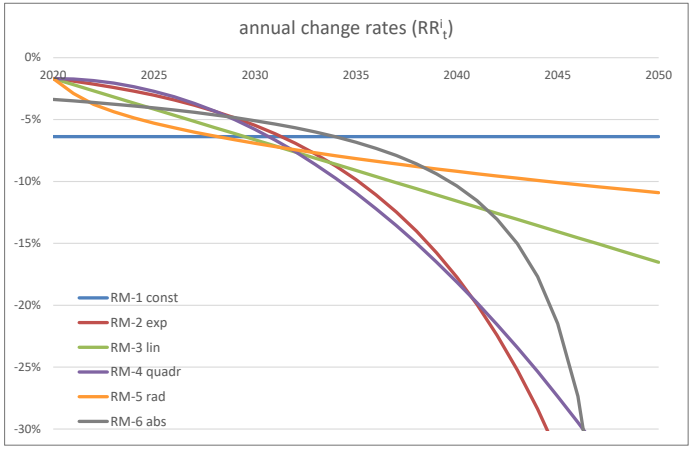
global CO2 without FOLU and ISA in 2019 in Gt	37.1		
IPCC SR15 illustrative model paths in the year 2100 in Gt	P1	P2	average
	-3.52	-4.47	**-4.00**
E_min proposals	**-9.51%**	**-12.07%**	**-10.79%**

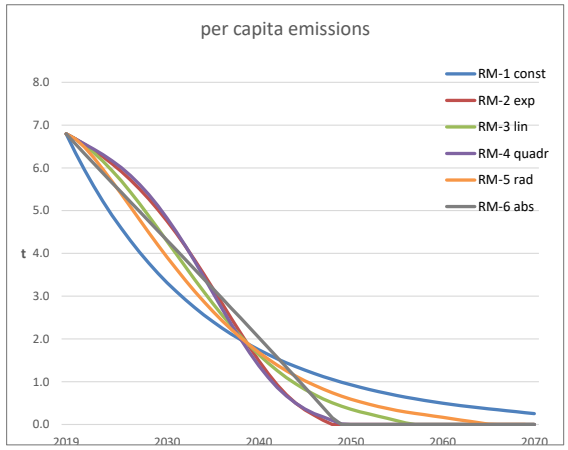
EU27	→ select a country	projection emissions 2019		
			individual change rate sheet 'data countries'	'goal seek' is ok
		base year projection: 2018	-02 % p.a.	sheet 'goal seek'

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

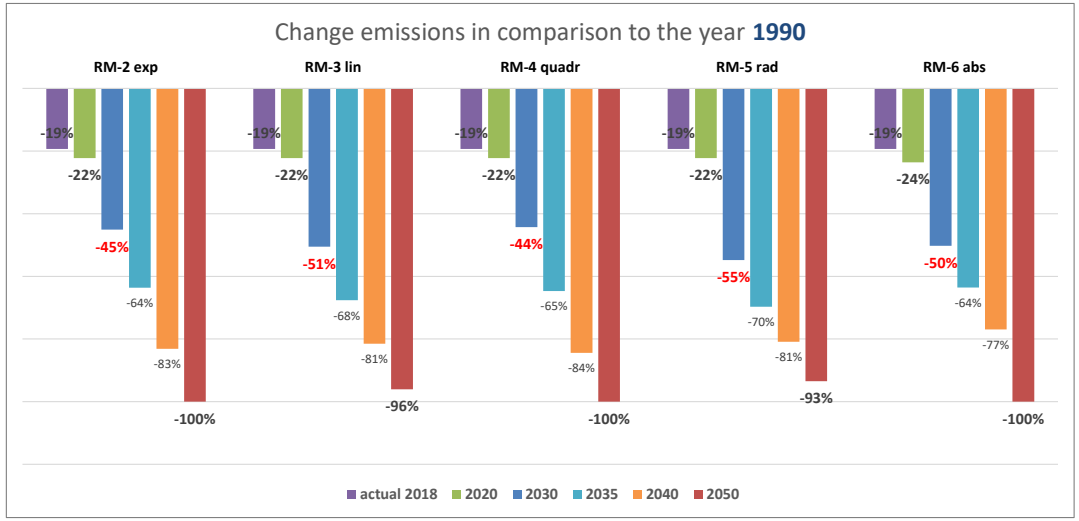
global per capita emissions 2019: 4.8052 t

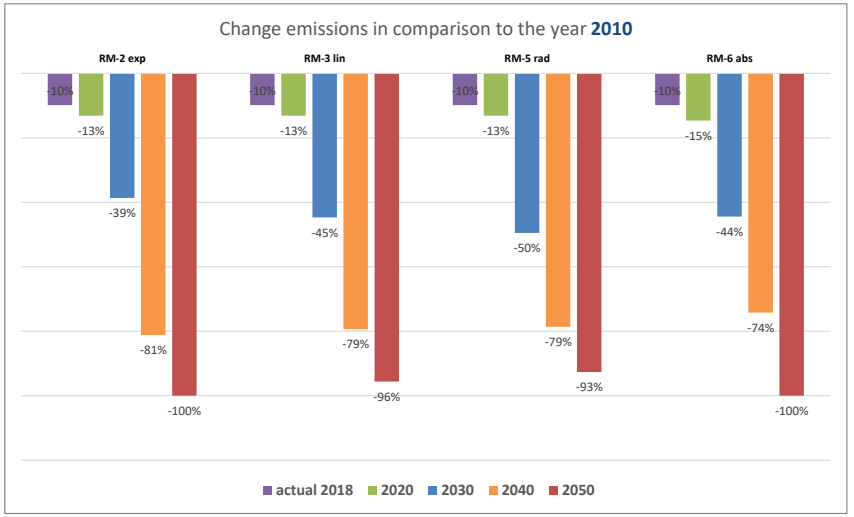




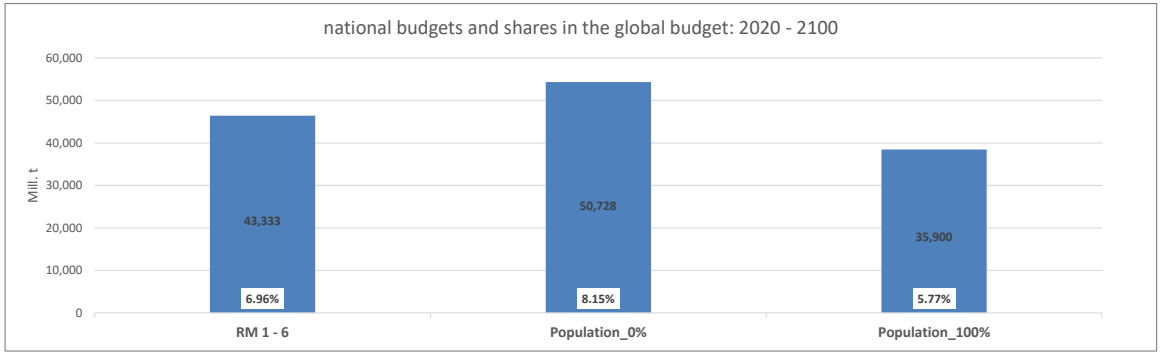


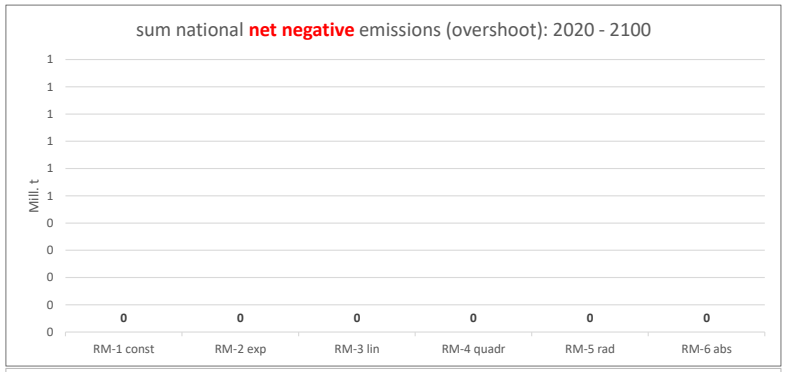
Reference values for the country: EU27

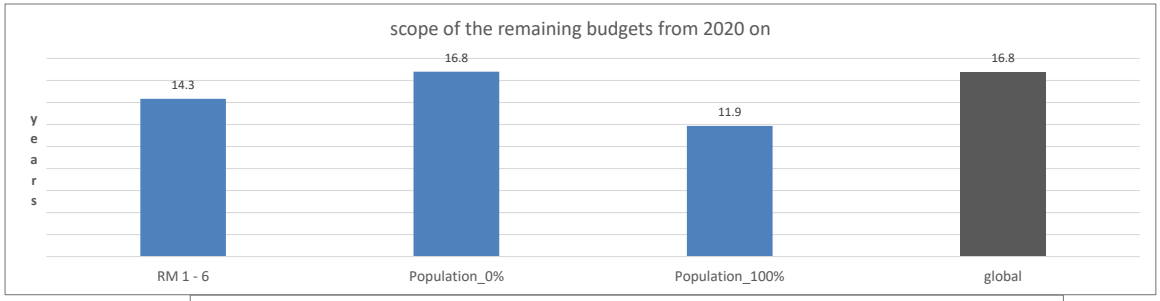




selected country:	EU27







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.

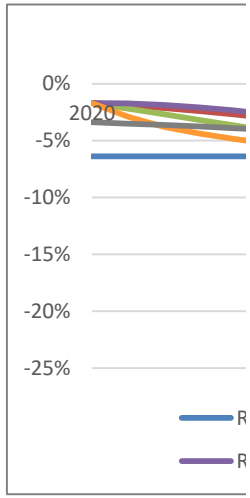
This tool has the advantage that countries can choose their own emission path depending on a remaining national budget. In the end, however, it has to be reviewed in an overall view that the resulting global path is compatible

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		RR_t const	RR_t exp	RR_t lin	RR_t quadr	RR_t rad	RA const	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 (RR_{20})		**-6.38%**	**-1.69%**	**-1.69%**	**-1.69%**	**-1.69%**	**-3.37%**	-2.00%	-1.9%
initial value		*-8%*	*10%*	*-1%*	*0*	*0*	-121		
		RR_t constant	*a*	*a*	*a*	*a*	*RA*		
free parameters are determined by Goal Seek in such a way as that the budget is adhered to.		-6.38%	12.49%	-0.49470%					
					-0.00041086	-0.01697354	**-101.96**		
scenario ∑ 2020 - 2100; sheet 'RM'	Mill. t	43,333	43,333	43,333	43,333	43,333	43,333		
budget ∑ 2020 - 2100; sheet 'base data'	Mill. t	43,333	43,333	43,333	43,333	43,333	43,333		
emissions 2100 scenario; sheet 'RM'	Mill. t	0.0	0.0	0.0	0.0	0.0	0.0		
minimum emissions 2100; sheet 'base data'	Mill. t	0.0	0.0	0.0	0.0	0.0	0.0		
Year E_{min} is achieved		2081	2048	2057	2050	2066	2049		
change rate 2030 / 1990		-62%	-45%	-51%	-44%	**-55%**	-50%		

				from emissions 2019
At which level of emissions (threshold value; ***TV***) shall the annual percentage reduction be change into a constant annual reduction?	**RM 2 - 5:**	105.83	Mill. t	3.50%
	RM-1:	139.09	Mill. t	4.60%



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

RM-1 const

constant annual reduction rate

cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
free paramter	-6.38%

RM-2 exp

exponential increase of annual reduction rates is assumed

cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
RR_20; input value sheet "goal seek"	**-1.69%**
free paramter	**12.49%**

RM-3 lin

linear increase of annual reduction rates is assumed

cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
RR_20; input value sheet "goal seek"	**-1.69%**
free paramter	**-0.49%**

year	RM-1 const: CO2 emissions in Mill. t	RM-1 const: absolute change vs. prev. year in Mill. t	RM-1 const: relative change vs. prev. year		RM-2 exp: CO2 emissions in Mill. t	RM-2 exp: absolute change vs. prev. year in Mill. t	RM-2 exp: relative change vs. prev. year		RM-3 lin: CO2 emissions in Mill. t	RM-3 lin: absolute change vs. prev. year in Mill. t	RM-3 lin: relative change vs. prev. year	
t	*see formula below* E_t	$E_t - E_{t-1}$	RR_t const	actual RR_t	*see formula below* E_t	$E_t - E_{t-1}$	*see formula below*	actual RR_t	*see formula below* E_t	$E_t - E_{t-1}$	*see formula below*	actual RR_t
2019	3,023.61				3,023.61				3,023.61			
2020	2,830.85	-192.76	-6.38%	-6.38%	2,972.63	-50.98	**-1.69%**	-1.69%	2,972.63	-50.98	**-1.69%**	-1.69%
2021	2,650.38	-180.47	-6.38%	-6.38%	2,916.25	-56.38	-1.90%	-1.90%	2,907.81	-64.82	-2.18%	-2.18%
2022	2,481.41	-168.97	-6.38%	-6.38%	2,854.04	-62.21	-2.13%	-2.13%	2,830.01	-77.80	-2.68%	-2.68%
2023	2,323.22	-158.19	-6.38%	-6.38%	2,785.55	-68.49	-2.40%	-2.40%	2,740.30	-89.71	-3.17%	-3.17%
2024	2,175.11	-148.11	-6.38%	-6.38%	2,710.37	-75.19	-2.70%	-2.70%	2,639.87	-100.43	-3.66%	-3.66%
2025	2,036.45	-138.67	-6.38%	-6.38%	2,628.07	-82.29	-3.04%	-3.04%	2,530.06	-109.81	-4.16%	-4.16%
2026	1,906.62	-129.83	-6.38%	-6.38%	2,538.31	-89.76	-3.42%	-3.42%	2,412.31	-117.75	-4.65%	-4.65%
2027	1,785.07	-121.55	-6.38%	-6.38%	2,440.80	-97.52	-3.84%	-3.84%	2,288.10	-124.21	-5.15%	-5.15%
2028	1,671.27	-113.80	-6.38%	-6.38%	2,335.32	-105.48	-4.32%	-4.32%	2,158.97	-129.13	-5.64%	-5.64%
2029	1,564.72	-106.55	-6.38%	-6.38%	2,221.81	-113.52	-4.86%	-4.86%	2,026.45	-132.52	-6.14%	-6.14%
2030	1,464.97	-99.75	-6.38%	-6.38%	2,100.32	-121.48	-5.47%	-5.47%	1,892.03	-134.41	-6.63%	-6.63%
2031	1,371.58	-93.39	-6.38%	-6.38%	1,971.14	-129.18	-6.15%	-6.15%	1,757.18	-134.86	-7.13%	-7.13%
2032	1,284.14	-87.44	-6.38%	-6.38%	1,834.77	-136.37	-6.92%	-6.92%	1,623.24	-133.94	-7.62%	-7.62%
2033	1,202.27	-81.87	-6.38%	-6.38%	1,691.99	-142.78	-7.78%	-7.78%	1,491.48	-131.76	-8.12%	-8.12%
2034	1,125.63	-76.65	-6.38%	-6.38%	1,543.88	-148.11	-8.75%	-8.75%	1,363.04	-128.44	-8.61%	-8.61%
2035	1,053.87	-71.76	-6.38%	-6.38%	1,391.86	-152.02	-9.85%	-9.85%	1,238.91	-124.12	-9.11%	-9.11%
2036	986.68	-67.19	-6.38%	-6.38%	1,237.70	-154.16	-11.08%	-11.08%	1,119.96	-118.95	-9.60%	-9.60%
2037	923.78	-62.90	-6.38%	-6.38%	1,083.49	-154.20	-12.46%	-12.46%	1,006.89	-113.07	-10.10%	-10.10%
2038	864.89	-58.89	-6.38%	-6.38%	931.65	-151.84	-14.01%	-14.01%	900.26	-106.64	-10.59%	-10.59%
2039	809.75	-55.14	-6.38%	-6.38%	784.79	-146.87	-15.76%	-15.76%	800.46	-99.80	-11.09%	-11.09%
2040	758.13	-51.62	-6.38%	-6.38%	645.63	-139.16	-17.73%	-17.73%	707.77	-92.69	-11.58%	-11.58%
2041	709.79	-48.33	-6.38%	-6.38%	516.85	-128.78	-19.95%	-19.95%	622.31	-85.46	-12.07%	-12.07%
2042	664.54	-45.25	-6.38%	-6.38%	400.89	-115.96	-22.44%	-22.44%	544.09	-78.22	-12.57%	-12.57%
2043	622.18	-42.37	-6.38%	-6.38%	299.71	-101.17	-25.24%	-25.24%	473.01	-71.08	-13.06%	-13.06%
2044	582.51	-39.66	-6.38%	-6.38%	214.63	-85.08	-28.39%	-28.39%	408.87	-64.13	-13.56%	-13.56%
2045	545.38	-37.14	-6.38%	-6.38%	146.09	-68.54	-31.93%	-31.93%	351.41	-57.46	-14.05%	-14.05%
2046	510.61	-34.77	-6.38%	-6.38%	93.62	-52.48	-35.92%	-35.92%	300.29	-51.12	-14.55%	-14.55%
2047	478.06	-32.55	-6.38%	-6.38%	41.14	-52.48	-40.40%	-56.05%	255.12	-45.17	-15.04%	-15.04%
2048	447.58	-30.48	-6.38%	-6.38%	0.00	-41.14	-45.45%		215.48	-39.64	-15.54%	-15.54%
2049	419.05	-28.53	-6.38%	-6.38%	0.00	0.00	-51.12%		180.93	-34.55	-16.03%	-16.03%
2050	392.33	-26.71	-6.38%	-6.38%	0.00	0.00	-57.51%		151.03	-29.90	-16.53%	-16.53%
2051	367.32	-25.01	-6.38%	-6.38%	0.00	0.00	-64.68%		125.32	-25.71	-17.02%	-17.02%
2052	343.90	-23.42	-6.38%	-6.38%	0.00	0.00	-72.76%		103.37	-21.95	-17.52%	-17.52%
2053	321.98	-21.92	-6.38%	-6.38%	0.00	0.00	-81.85%		81.42	-21.95	-18.01%	-21.24%
2054	301.45	-20.53	-6.38%	-6.38%	0.00	0.00	-92.06%		59.47	-21.95	-18.51%	-26.96%
2055	282.23	-19.22	-6.38%	-6.38%	0.00	0.00	-103.56%		37.52	-21.95	-19.00%	-36.91%
2056	264.24	-17.99	-6.38%	-6.38%	0.00	0.00	-116.49%		15.56	-21.95	-19.50%	-58.51%
2057	247.40	-16.85	-6.38%	-6.38%	0.00	0.00	-131.03%		0.00	-15.56	-19.99%	
2058	231.62	-15.77	-6.38%	-6.38%	0.00	0.00	-147.39%		0.00	0.00	-20.48%	
2059	216.86	-14.77	-6.38%	-6.38%	0.00	0.00	-165.79%		0.00	0.00	-20.98%	
2060	203.03	-13.82	-6.38%	-6.38%	0.00	0.00	-186.49%		0.00	0.00	-21.47%	
2061	190.09	-12.94	-6.38%	-6.38%	0.00	0.00	-209.77%		0.00	0.00	-21.97%	

calculation RM 1 - 6		RM-1 const constant annual reduction rate				RM-2 exp exponential increase of annual reduction rates is assumed				RM-3 lin linear increase of annual reduction rates is assumed			
	2062	177.97	-12.12	-6.38%	-6.38%	0.00	0.00	-235.96%		0.00	0.00	-22.46%	
	2063	166.62	-11.35	-6.38%	-6.38%	0.00	0.00	-265.42%		0.00	0.00	-22.96%	
	2064	156.00	-10.62	-6.38%	-6.38%	0.00	0.00	-298.56%		0.00	0.00	-23.45%	
	2065	146.06	-9.95	-6.38%	-6.38%	0.00	0.00	-335.84%		0.00	0.00	-23.95%	
	2066	136.75	-9.31	-6.38%	-6.38%	0.00	0.00	-377.77%		0.00	0.00	-24.44%	
	2067	127.43	-9.31	-6.38%	-6.81%	0.00	0.00	-424.93%		0.00	0.00	-24.94%	
	2068	118.12	-9.31	-6.38%	-7.31%	0.00	0.00	-477.99%		0.00	0.00	-25.43%	
	2069	108.81	-9.31	-6.38%	-7.88%	0.00	0.00	-500.00%		0.00	0.00	-25.93%	
	2070	99.50	-9.31	-6.38%	-8.56%	0.00	0.00	-500.00%		0.00	0.00	-26.42%	
	2071	90.19	-9.31	-6.38%	-9.36%	0.00	0.00	-500.00%		0.00	0.00	-26.92%	
	2072	80.88	-9.31	-6.38%	-10.32%	0.00	0.00	-500.00%		0.00	0.00	-27.41%	
	2073	71.57	-9.31	-6.38%	-11.51%	0.00	0.00	-500.00%		0.00	0.00	-27.90%	
	2074	62.26	-9.31	-6.38%	-13.01%	0.00	0.00	-500.00%		0.00	0.00	-28.40%	
	2075	52.94	-9.31	-6.38%	-14.96%	0.00	0.00	-500.00%		0.00	0.00	-28.89%	
	2076	43.63	-9.31	-6.38%	-17.59%	0.00	0.00	-500.00%		0.00	0.00	-29.39%	
	2077	34.32	-9.31	-6.38%	-21.34%	0.00	0.00	-500.00%		0.00	0.00	-29.88%	
	2078	25.01	-9.31	-6.38%	-27.13%	0.00	0.00	-500.00%		0.00	0.00	-30.38%	
	2079	15.70	-9.31	-6.38%	-37.23%	0.00	0.00	-500.00%		0.00	0.00	-30.87%	
	2080	6.39	-9.31	-6.38%	-59.31%	0.00	0.00	-500.00%		0.00	0.00	-31.37%	
	2081	0.00	-6.39	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-31.86%	
	2082	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-32.36%	
	2083	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-32.85%	
	2084	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-33.35%	
	2085	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-33.84%	
	2086	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-34.34%	
	2087	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-34.83%	
	2088	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-35.33%	
	2089	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-35.82%	
	2090	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-36.31%	
	2091	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-36.81%	
	2092	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-37.30%	
	2093	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-37.80%	
	2094	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-38.29%	
	2095	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-38.79%	
	2096	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-39.28%	
	2097	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-39.78%	
	2098	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-40.27%	
	2099	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-40.77%	
	2100	0.00	0.00	-6.38%		0.00	0.00	-500.00%		0.00	0.00	-41.26%	
	sum	**43,333**				**43,333**				**43,333**			
		0	negative emissions in Mill. t			0	negative emissions in Mill. t			0	negative emissions in Mill. t		

RM-4 quadr

quadratic formula for annual reduction rates

cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
RR_20; input value sheet "goal seek"	**-1.69%**
free paramter	**-0.0004**

year	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	
t	*see formula below* E_t	$E_t - E_{t-1}$	*see formula below*	*actual* RR_t
2019	3,023.61			
2020	2,972.63	-50.98	-1.69%	-1.69%
2021	2,921.29	-51.34	-1.73%	-1.73%
2022	2,867.24	-54.05	-1.85%	-1.85%
2023	2,808.29	-58.94	-2.06%	-2.06%
2024	2,742.48	-65.81	-2.34%	-2.34%
2025	2,668.07	-74.41	-2.71%	-2.71%
2026	2,583.63	-84.45	-3.17%	-3.17%
2027	2,488.05	-95.57	-3.70%	-3.70%
2028	2,380.68	-107.37	-4.32%	-4.32%
2029	2,261.31	-119.37	-5.01%	-5.01%
2030	2,130.28	-131.03	-5.79%	-5.79%
2031	1,988.46	-141.82	-6.66%	-6.66%
2032	1,837.29	-151.17	-7.60%	-7.60%
2033	1,678.74	-158.55	-8.63%	-8.63%
2034	1,515.25	-163.49	-9.74%	-9.74%
2035	1,349.63	-165.62	-10.93%	-10.93%
2036	1,184.92	-164.71	-12.20%	-12.20%
2037	1,024.25	-160.67	-13.56%	-13.56%
2038	870.63	-153.61	-15.00%	-15.00%
2039	726.82	-143.81	-16.52%	-16.52%
2040	595.12	-131.70	-18.12%	-18.12%
2041	477.26	-117.86	-19.80%	-19.80%
2042	374.31	-102.95	-21.57%	-21.57%
2043	286.64	-87.66	-23.42%	-23.42%
2044	213.98	-72.67	-25.35%	-25.35%
2045	155.42	-58.55	-27.36%	-27.36%
2046	109.63	-45.79	-29.46%	-29.46%
2047	74.95	-34.69	-31.64%	-31.64%
2048	40.26	-34.69	-33.90%	-46.28%
2049	5.58	-34.69	-36.24%	-86.15%
2050	0.00	-5.58	-38.66%	
2051	0.00	0.00	-41.17%	
2052	0.00	0.00	-43.76%	
2053	0.00	0.00	-46.43%	
2054	0.00	0.00	-49.18%	
2055	0.00	0.00	-52.02%	
2056	0.00	0.00	-54.93%	
2057	0.00	0.00	-57.93%	
2058	0.00	0.00	-61.01%	
2059	0.00	0.00	-64.18%	
2060	0.00	0.00	-67.42%	
2061	0.00	0.00	-70.75%	

RM-5 rad

radical formula for annual reduction rates

correcting factor	0.5
cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
RR_20; input value sheet "goal seek"	**-1.69%**
free paramter	**-0.0170**

	CO2 emissions in Mill. t	absolute change vs. prev. year in Mill. t	relative change vs. prev. year	
	see formula below E_t	$E_t - E_{t-1}$	*see formula below*	*actual* RR_t
2019	3,023.61			
2020	2,972.63	-50.98	-1.69%	-1.69%
2021	2,886.83	-85.80	-2.89%	-2.89%
2022	2,778.15	-108.68	-3.76%	-3.76%
2023	2,656.75	-121.40	-4.37%	-4.37%
2024	2,527.59	-129.16	-4.86%	-4.86%
2025	2,393.97	-133.63	-5.29%	-5.29%
2026	2,258.31	-135.66	-5.67%	-5.67%
2027	2,122.51	-135.80	-6.01%	-6.01%
2028	1,988.06	-134.45	-6.33%	-6.33%
2029	1,856.16	-131.90	-6.63%	-6.63%
2030	1,727.76	-128.40	-6.92%	-6.92%
2031	1,603.60	-124.16	-7.19%	-7.19%
2032	1,484.26	-119.34	-7.44%	-7.44%
2033	1,370.16	-114.10	-7.69%	-7.69%
2034	1,261.61	-108.55	-7.92%	-7.92%
2035	1,158.80	-102.81	-8.15%	-8.15%
2036	1,061.82	-96.97	-8.37%	-8.37%
2037	970.71	-91.11	-8.58%	-8.58%
2038	885.42	-85.29	-8.79%	-8.79%
2039	805.85	-79.57	-8.99%	-8.99%
2040	731.86	-73.99	-9.18%	-9.18%
2041	663.28	-68.58	-9.37%	-9.37%
2042	599.89	-63.39	-9.56%	-9.56%
2043	541.48	-58.41	-9.74%	-9.74%
2044	487.80	-53.68	-9.91%	-9.91%
2045	438.59	-49.21	-10.09%	-10.09%
2046	393.60	-44.99	-10.26%	-10.26%
2047	352.57	-41.03	-10.42%	-10.42%
2048	315.25	-37.33	-10.59%	-10.59%
2049	281.37	-33.88	-10.75%	-10.75%
2050	250.68	-30.68	-10.91%	-10.91%
2051	222.96	-27.73	-11.06%	-11.06%
2052	197.96	-25.00	-11.21%	-11.21%
2053	175.47	-22.49	-11.36%	-11.36%
2054	155.27	-20.20	-11.51%	-11.51%
2055	137.17	-18.10	-11.66%	-11.66%
2056	120.99	-16.19	-11.80%	-11.80%
2057	106.54	-14.45	-11.94%	-11.94%
2058	93.67	-12.87	-12.08%	-12.08%
2059	80.80	-12.87	-12.22%	-13.74%
2060	67.93	-12.87	-12.35%	-15.93%
2061	55.06	-12.87	-12.49%	-18.95%

RM-6 abs

constant absolute annual change

cumulative budget 2020 - 2100 in Mill. t	43,333
scenario sum emissions 2020 - 2100 in Mill. t	43,333
E_min in Mill. t	0.0
scenario emissions in year 2100 in Mill. t	0.0
RR_20; info	**-3.37%**
free paramter	**-101.96**

	CO_2 emissions in Mill. t	absolute change vs. prev. year in Mill. t		relative change vs. prev. year
	see formula below E_t	$E_t - E_{t-1}$	*actual* $E_t - E_{t-1}$	RR_t
2019	3,023.61			
2020	2,921.65	-101.96	-101.96	-3.37%
2021	2,819.69	-101.96	-101.96	-3.49%
2022	2,717.74	-101.96	-101.96	-3.62%
2023	2,615.78	-101.96	-101.96	-3.75%
2024	2,513.82	-101.96	-101.96	-3.90%
2025	2,411.86	-101.96	-101.96	-4.06%
2026	2,309.91	-101.96	-101.96	-4.23%
2027	2,207.95	-101.96	-101.96	-4.41%
2028	2,105.99	-101.96	-101.96	-4.62%
2029	2,004.03	-101.96	-101.96	-4.84%
2030	1,902.08	-101.96	-101.96	-5.09%
2031	1,800.12	-101.96	-101.96	-5.36%
2032	1,698.16	-101.96	-101.96	-5.66%
2033	1,596.21	-101.96	-101.96	-6.00%
2034	1,494.25	-101.96	-101.96	-6.39%
2035	1,392.29	-101.96	-101.96	-6.82%
2036	1,290.33	-101.96	-101.96	-7.32%
2037	1,188.38	-101.96	-101.96	-7.90%
2038	1,086.42	-101.96	-101.96	-8.58%
2039	984.46	-101.96	-101.96	-9.38%
2040	882.50	-101.96	-101.96	-10.36%
2041	780.55	-101.96	-101.96	-11.55%
2042	678.59	-101.96	-101.96	-13.06%
2043	576.63	-101.96	-101.96	-15.02%
2044	474.67	-101.96	-101.96	-17.68%
2045	372.72	-101.96	-101.96	-21.48%
2046	270.76	-101.96	-101.96	-27.36%
2047	168.80	-101.96	-101.96	-37.66%
2048	66.84	-101.96	-101.96	-60.40%
2049	0.00	-101.96	-66.84	
2050	0.00	-101.96		
2051	0.00	-101.96		
2052	0.00	-101.96		
2053	0.00	-101.96		
2054	0.00	-101.96		
2055	0.00	-101.96		
2056	0.00	-101.96		
2057	0.00	-101.96		
2058	0.00	-101.96		
2059	0.00	-101.96		
2060	0.00	-101.96		
2061	0.00	-101.96		

	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	0.00	0.00	-74.16%	42.19	-12.87	-12.62%	-23.38%	0.00	-101.96
2063	0.00	0.00	-77.65%	29.32	-12.87	-12.75%	-30.51%	0.00	-101.96
2064	0.00	0.00	-81.23%	16.45	-12.87	-12.88%	-43.90%	0.00	-101.96
2065	0.00	0.00	-84.88%	3.58	-12.87	-13.01%	-78.24%	0.00	-101.96
2066	0.00	0.00	-88.62%	0.00	-3.58	-13.14%		0.00	-101.96
2067	0.00	0.00	-92.44%	0.00	0.00	-13.26%		0.00	-101.96
2068	0.00	0.00	-96.35%	0.00	0.00	-13.38%		0.00	-101.96
2069	0.00	0.00	-100.33%	0.00	0.00	-13.51%		0.00	-101.96
2070	0.00	0.00	-104.40%	0.00	0.00	-13.63%		0.00	-101.96
2071	0.00	0.00	-108.55%	0.00	0.00	-13.75%		0.00	-101.96
2072	0.00	0.00	-112.78%	0.00	0.00	-13.87%		0.00	-101.96
2073	0.00	0.00	-117.10%	0.00	0.00	-13.98%		0.00	-101.96
2074	0.00	0.00	-121.49%	0.00	0.00	-14.10%		0.00	-101.96
2075	0.00	0.00	-125.97%	0.00	0.00	-14.22%		0.00	-101.96
2076	0.00	0.00	-130.53%	0.00	0.00	-14.33%		0.00	-101.96
2077	0.00	0.00	-135.17%	0.00	0.00	-14.44%		0.00	-101.96
2078	0.00	0.00	-139.90%	0.00	0.00	-14.56%		0.00	-101.96
2079	0.00	0.00	-144.71%	0.00	0.00	-14.67%		0.00	-101.96
2080	0.00	0.00	-149.59%	0.00	0.00	-14.78%		0.00	-101.96
2081	0.00	0.00	-154.57%	0.00	0.00	-14.89%		0.00	-101.96
2082	0.00	0.00	-159.62%	0.00	0.00	-15.00%		0.00	-101.96
2083	0.00	0.00	-164.75%	0.00	0.00	-15.10%		0.00	-101.96
2084	0.00	0.00	-169.97%	0.00	0.00	-15.21%		0.00	-101.96
2085	0.00	0.00	-175.27%	0.00	0.00	-15.32%		0.00	-101.96
2086	0.00	0.00	-180.66%	0.00	0.00	-15.42%		0.00	-101.96
2087	0.00	0.00	-186.12%	0.00	0.00	-15.53%		0.00	-101.96
2088	0.00	0.00	-191.67%	0.00	0.00	-15.63%		0.00	-101.96
2089	0.00	0.00	-197.29%	0.00	0.00	-15.73%		0.00	-101.96
2090	0.00	0.00	-203.01%	0.00	0.00	-15.84%		0.00	-101.96
2091	0.00	0.00	-208.80%	0.00	0.00	-15.94%		0.00	-101.96
2092	0.00	0.00	-214.67%	0.00	0.00	-16.04%		0.00	-101.96
2093	0.00	0.00	-220.63%	0.00	0.00	-16.14%		0.00	-101.96
2094	0.00	0.00	-226.67%	0.00	0.00	-16.24%		0.00	-101.96
2095	0.00	0.00	-232.79%	0.00	0.00	-16.34%		0.00	-101.96
2096	0.00	0.00	-239.00%	0.00	0.00	-16.43%		0.00	-101.96
2097	0.00	0.00	-245.28%	0.00	0.00	-16.53%		0.00	-101.96
2098	0.00	0.00	-251.65%	0.00	0.00	-16.63%		0.00	-101.96
2099	0.00	0.00	-258.10%	0.00	0.00	-16.72%		0.00	-101.96
2100	0.00	0.00	-264.63%	0.00	0.00	-16.82%		0.00	-101.96
sum	**43,333**			**43,333**				**43,333**	
	0	negative emissions in Mill. t		0	negative emissions in Mill. t			0	negative emissions in Mill. t

M-2 exp	RM-3 lin	RM-4 quadr
nnual 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)

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

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	$a \ge 0$	► concave
RM-4 quadr[4]	$RR_t = a * (t - (BY + 1))^2 + RR_{BY+1}$	$y = ax^2 + b$	$a \le 0$	
RM-5 rad[5]	$RR_t = a * \sqrt{t - (BY + 1) - 0.5} + RR_{BY+1}$	$y = a\sqrt{x} + b$	$a \le 0$	► convex
RM-3 lin	$RR_t = a * \left(t - (BY + 1)\right) + RR_{BY+1} = RR_{t-1} + a$	$y = ax + b$	$a \le 0$	► linear
RM-1 const	$RR_t = a$	$y = a$	$a \le 0$	► 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: $E_t = \max\left(E_{min};\ E_{t-1} + RA\right)$

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