Instructions
for the tool for:
The Regensburg Model

Reference Values for NDCs

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The latest version of the tool can be downloaded at: save-the-climate.info.

version: 1.7

Contents

1 Brief introduction to the Regensburg Model

A crucial factor in determining whether we shall be able to achieve any prescribed objective for limiting global warming are the cumulative CO_2 emissions which we will be producing in future.[1]

So the question is: who gets how much of a remaining global budget?

This tool offers six scenario types for converting a **global CO_2 budget** 2020 – 2100 into plausible **global emission paths** (see sheet “graphs global”).

The Regensburg Model enables national emission paths to be derived from any global emission path (see sheet "graphs country"). In the convergence period, the **Regensburg Formula** is used, which leads to **converging emissions per capita**.[2]

2 Brief introduction to the tool for the Regensburg Model

With this Excel tool, you can obtain a quick overview of the concrete challenges to be faced by any particular nation with converging per capita emissions (Regensburg Formula), and how great its leeway is. You can compare the results with the NDCs of countries or to calculate NDC.

Go to the sheet “**graphs country**” in the tool and select a country from those offered in the drop-down list.

The tool calculates national emission paths for six types of global RM-scenarios.

The RM Scenario Types differ primarily in the shape of the curve for annual global reduction rates (RM 1 – 5) resp. annual global reduction amount (RM-6). The free parameter in the scenario type is determined with a macro in the sheet 'goal seek'. You always have to run this macro if you change input data.

The tool offers many ways to adjust the parameters, which we shall cover in more detail in the following chapters. Here we want to show where the most important parameters can be changed:

Important input values:

a. Sheet “base data”:
    i. global CO_2 budget 2018 – 2100
    ii. minimum emissions 2100 (potential global net negative emissions)
    iii. convergence level:
    This means that the national emission pathways are calculated using the Regensburg Formula in such a way that at the point in time at which this value is reached on the global pathway (convergence year) the per capita emissions of every country are at the same level.
b. Sheet "goal seek": the starting change rates for 2020 must be entered in scenarios RM 2 - 5.

In the sheet "dashboard", you get an overview of current input values and important results.

[1] Cf. IPCC SR15 SPM p. 14 C.1.3

[2] Cf. Sargl, M., Wolfsteiner, A. & Wittmann, G.: The Regensburg Model: reference values for the (I)NDCs based on converging per capita emissions. Climate Policy, Published online: 14 Jun 2016, DOI:10.1080/14693062.2016.1176006

3 Global constraints and other original data - entries in sheet “base data”

I. Entry of data to determine <u>global emission paths</u> from 2020 - 2100

I. a) Global CO_2 budget 2018 – 2100 as a basis for national reference values

Input global CO_2 budget 2018 - 2100 based for example on the IPCC report SR15 (see Table 2.2).

I. b) Global emissions 2012 – 2019

You can enter a change rate for the change in emissions in 2019.

I. c) Global budget 2020 – 2100 without AFOLU and int. shipping/aviation

AFOLU is the abbreviation for Agriculture, Forestry & Other Land Use. CO_2 emissions from this sector are caused by land use changes (hence the abbreviation LUC is also used). Because it is still difficult to find numbers for individual countries, FOLU CO2 emissions are not considered and therefore need to be deducted.

You can specify a share of the global budget in the tool that is to be reserved for positive FOLU CO2 emissions. The current share of FOLU CO2 emissions is given as an information.

Emissions from international shipping and aviation (ISA) also have to be deducted, since attribution to countries is difficult here.

Since this tool is designed to calculate emission paths for the period 2020 – 2100, the emissions for the years 2018 – 2019 also need to be deducted.

I. d) Global budget 2020 - 2100

A certain value is calculated from the data entered. You may however also enter your own budget. You can select the value to be used in the tool from the drop-down menu.

I. e) Global emissions in 2019 (base year) and in 2100

For the emissions in the base year 2019 (E_{2019}), the projection calculated in I. b) is used.

For the emissions for 2100, you can set a minimum value (E_{min}) which may not be undercut. In doing so, a negative value is also possible, standing for global negative emissions (net negative emissions).

The sheet also shows suggestions for *E_min* based on the illustrative IPCC model paths P1 and P2. Note: Paths P 3 and P4 have significantly higher net negative emissions. We show the illustrative paths in our tool "global-paths", which you can also download from our website.

II. Initial values for national emission paths

<u>Convergence level</u>

Using the Regensburg Formula, national emission paths in which the per capita emissions converge are deduced from a global path. At this point you can set the **convergence level** at which the per capita emissions should converge. Depending on the global pathway - determined with the sheet “goal seek” or free input (see sheet “FI”) - the smallest value is then sought which is greater than or the same as the convergence level set. This value then constitutes the convergence year of the global pathway. The convergence level in the case of the concrete global pathway will generally be somewhat higher than the value set here.

<u>Population</u>

Since the Regensburg Formula is designed to include converging per capita emissions, the choice of population figures in the convergence year on which the calculations are based is crucial.

We offer two options:

(1) Freeze the population figures at those of the base year, 2019.

(2) Take today's population forecasts into consideration.

III. Increasing global emissions: See page 9.

IV. Further input values

The data are used to calculate the total cumulative CO_2 emissions (including FOLU CO_2) by 2100; but are not used for the calculation of global or national paths.

4 Determination of global emission paths

4.1 Where and how the global paths are determined

Global emission paths are be determined using the scenario types RM 1 – 6. The paths are essentially determined by **specifying** the **annual** rate of **change** (RM 1 - 5) or the annual constant reduction amount (RM-6).

The paths are calculated in the **sheet 'RM'**. The results are transferred to the sheet 'country'.

In scenarios RM 2 - 5, the rate of change for 2020 (*RR_20*) is an input value in the sheet 'goal seek'. The global actual change rates last years is given in this sheet as an orientation.

In scenarios RM 1 - 5 for the transition to **net negative emissions**, a constant reduction amount is applied from a predefined threshold (*TV*). The last reduction amount before the threshold is reached is then used. The **change of method** is necessary, because net negative emissions cannot be implemented by determining the reduction rates. Different threshold values can be set for scenario type RM-1 and scenario types RM 2 - 5. In scenario type RM-1, a higher threshold value can be useful in order to achieve faster net negative emissions. By entering the *TV*, you can freely choose when the method should be changed.

If the path reaches ***E_min***, this value is continued until 2100.

In the **sheet 'goal seek'** the **free parameter** of the respective scenario is determined so that the global budget 2020 - 2100 is adhered to (target value search). The macro 'goal seek' in this sheet uses the target value search integrated in Excel.

This usually leads to the following **three phases** for determining the paths:

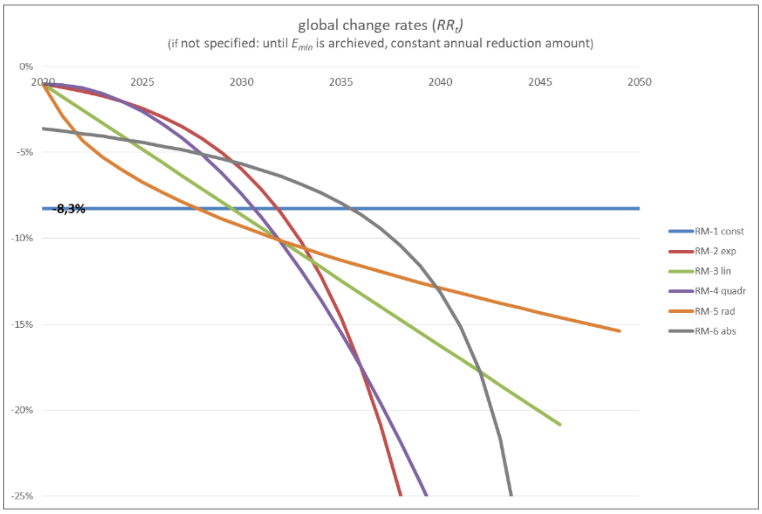
1. Application of the annual reduction rates (RM 1 - 5) or the annual reduction amount (RM-6).
2. Annual emissions less than or equal to *TV*: The last annual absolute reduction is continued.
3. Minimum for the annual emissions (*E_min*) specified in the sheet 'base data'.

These three phases can be found in the formula for the annual emissions in the individual scenario types on the sheet 'RM'.

In the **sheet "FI"** it is possible to enter a global pathway of one's own choice.

4.2 Description of the RM Scenario Types 1 – 6

The following figure shows an example of the property of the scenario types:



The scenarios differ based on the assumptions about property of the annual changes:

(1) RM 1 - 5: Assumption about the course of the **annual rates of change**:

- **RM-1-const:** A **constant annual reduction rate** is assumed.
- **RM-2-exp:** An **exponential increase** of the annual reduction rates is assumed. The initial reduction rate for 2020 (*RR_20*) must be entered. In this scenario type, no positive change rate 2020 can be used. The reduction rate is escalated annually. Initially, the reduction rates increase[3] less than proportionally.
- **RM-3-lin:** A **linear increase** of the annual reduction rates is assumed. For the year 2020, an **initial value** (*RR_20*) must be set.
- **RM-4-quadr:** A **quadratic formula** for the annual reduction rates is used. The initial value (*RR_20*) must be set. Initially, the reduction rates increase less than proportionally.
- **RM-5-rad:** A **radical formula** for the annual reduction rates is used. The initial value (*RR_20*) must be set. Initially, the reduction rates increase more than proportionally.

(2) **RM-6 abs:** A **constant annual reduction amount** is assumed. This scenario type starts with a relatively high reduction rate. Then the reduction rates initially increase less than proportionally and slowly, in the end increasing very quickly.

4.3 Formulae of the RM Scenario Types 1 – 6

For a comprehensive mathematical description, we refer to our paper "Mathematical Description of the Regensburg Model Scenario Types RM 1 - 6", which you can download from our website save-the-climate.info or use this direct link to the PDF.

4.4 Macro in the sheet ‘goal seek’

The **macro 'goal seek'** tries to determine the free parameter in the scenario (row 12 or 13) so that the budget (row 16) is adhered to (► row 15 = row 16). The macro also ensures that the constraints for the free parameter are met.

If this does not work straight away, the macro tries to find a solution with a lower rate of change for 2020 (for example: -2.5% instead of -2%). The start value you specified is therefore changed. If a solution cannot be found either, the macro will inform you and advise you to change the start value for 2020 more significantly or to change the threshold value (*TV*).

In the **sheet ‘graphs global’** you can see the graphical **results**.

[3] “Rising reduction rates” are to be understood here in such a way that the absolute amount increases.

5 Determination of national emission paths using the Regensburg Model

5.1 The Regensburg Formula

The national emission paths are calculated in the sheet "country".

Using the Regensburg Formula, consistent **national emission paths** may be deduced, **independent of the method used to determine the global emission pathway.** The national emission paths yield **converging per capita emissions** in the convergence period.

For mathematical proof, see our separate paper: Resource Sharing Models - A Mathematical Description; download at www.save-the-climate.info.

The Regensburg Formula:[4]

$$\boldsymbol{E_t^i = (1 - C_t) * E_{BY}^i + C_t * E_{CY}^i}$$

where:

$$C_t = \frac{E_{BY} - E_t}{E_{BY} - E_{CY}} \text{ and } E_{CY}^i = \frac{E_{CY}}{P_{CY}} * P_{CY}^i$$

$C_{BY} = 0$; $C_{CY} = 1$

CY = convergence year; *BY* = base year = 2019 in the tool; *P* = population

Was does the Regensburg Formula do?

The allocation formula for actual emissions is gradually substituted by the allocation formula per capita. Global performance against objectives is applied to every country. In this way we can be sure that the global pathway is adhered to and every country reaches its target quantity in the convergence year. The convergence magnitude of any one nation *i* in the convergence year (E_{CY}^i) in the Regensburg Formula is the result of the multiplication of global per capita emissions in the convergence year with the population of the country in the convergence year (P^i_{CY}).

Convergence year

The convergence year results in the respective global path through the convergence level which you can determine in the sheet "base data". This also E_{CY} is determined.

Summary properties of the Regensburg Formula:

- converging per capita emissions; same per capita emissions in the convergence year
- monotonic paths

[4] In the Regensburg Formula there are three representation options. In earlier publications we placed focus on the following option: $E_t^i = E_{t-1}^i + CR_{t-1} * (E_{t-1}^i - TA^i)$ where $CR_{t-1} = (E_t - E_{t-1})/(E_{t-1} - TA)$. See also our paper: Resource Sharing Models - A Mathematical Description; download: www.save-the-climate.info. In the case of increasing global emissions, see: Consideration of increasing global emissions post 2019.

- countries that start with per capita emissions below the convergence level will never exceed this convergence level (no "hot air" for developing countries)
- countries that start above the convergence level with per capita emissions must reduce their emissions from the outset (including emerging countries)

- reference values therefore represent a kind of “moral lower limit” for industrialized countries

5.2 National paths in the Regensburg Model for increasing and negative global emissions

5.2.1 Consideration of increasing global emissions post 2019

In RM-scenarios 3 - 5, a positive RR_{20} can be set. In this case global emissions start off by increasing. In the case of increasing global emissions it is not appropriate to determine E^i_t using the Regensburg Formula, as cited in 5.1, since for countries using $E^i_{t-1} - E^i_{CY} < 0$ (generally developing countries) this would result in the reduction of their emissions whilst global emissions are on the increase.[5] For those years with increasing emissions, the Regensburg Formula was not applied. Instead, global increase was distributed according to the following rule: the proportion PC_t of this increase is distributed according to population in relation to global population, and the proportion (1 - PC_t) of this increase is distributed according to the proportion of emissions in relation to global emissions in year t-1. The weighting of the allocation per capita (PC_{20}) can be entered in sheet “base data” under III. Here a rate of annual escalation (ER_{PC}) of PC_t can be set.

5.2.2 Breakdown of global negative emissions

It would be unacceptable, in our view, that, regardless of historical emissions, each country would have to "produce" the same negative emissions per capita if global emissions are negative. That's why we chose the share of a country's emissions in global emissions in the base year as the key to allocating global negative emissions. This is therefore a small compensation for the fact that the Regensburg Formula is very favourable for industrialized countries.

5.3 Formulae to determine national paths in the Regensburg Model

This results in the following formulae to determine E^i_t in the tool:

Convergence period (2020 - *cy*):

$$\boldsymbol{E_t < E_{t-1}}\ (globally\ decreasing\ emissions)$$

The Regensburg Formula:

$$E^i_t = (1 - C_t) * E^i_{2019} + C_t * E^i_{CY}$$

$$C_t = \frac{E_{2019} - E_t}{E_{2019} - E_{CY}}$$

$$E^i_{CY} = \frac{E_{CY}}{P_{CY}} * P^i_{CY}$$

[5] In the case of globally increasing emissions, C_t would be negative. This leads to decreasing emissions in countries which show rates below their target quantity in the year t, since $|C_t| * E^i_{2019} < |C_t| * E^i_{CY}$.

$$\boldsymbol{E_t > E_{t-1}}\ (globally\ increasing\ emissions)$$

$$E_t^i = E_{t-1}^i + (1 - PC_t) * RR_t * E_{t-1}^i + PC_t * \frac{P_t^i}{P_t} * (E_t - E_{t-1})$$

$$0 \le PC_t \le 1;\ PC_t = PC_{t-1} * (1 + ER_{PC})$$

After the convergence year (cy):

$$\boldsymbol{E_t^i} = \frac{P_t^i}{P_t} * E_t$$

$$\boldsymbol{E_t < 0}$$

(global negative emissions):

$$E_t^i = \frac{E_{by}^i}{E_{by}} * E_t$$

6 Reference values for every country in the world

In the **sheet “graphs country”**, any country in the world may be chosen from the drop-down list. On this basis the tool calculates corresponding emission paths for the country chosen, for all the scenarios. In the same sheet, you can then quickly find a compilation of the results.

<u>Entries in sheets “country” and “data countries”</u>

In order to be able to calculate national emission paths using the Regensburg Formula, the emissions of any one country in 2019, the base year, are required.

For the emissions, we have resorted to data from EDGAR (EU). Extrapolation to 2019 is based in principle on the current figure and an estimate of the annual rate of change on the basis of historic data.

You may embed an individual extrapolation rate in column O for any one country permanently in the sheet “data countries”. For some countries we have already embedded an individualised extrapolation rate.

We were not able to check whether the extrapolation rate resulting from historic data is plausible in the future for every country. For this reason an upper limit and a lower limit can be set in the sheet “data countries”.

You can use the macro provided in the sheet 'data countries' to determine an upper limit for the increase in emissions up to the base year so that the global emissions in the base year correspond to the value entered for the global emissions in the sheet 'base data'.

This extrapolation for 2019 does not lead to realistic results for every country. For this reason you can either enter your own rate of change or a concrete figure for emissions in 2019, the base year, in the sheet “country”. Please delete these entries when you choose a new country.

Population figures are taken from a UN data base (see corresponding sheet).

<u>Reference values</u>

In the sheet “**graphs country**”, it is primarily the ratio of emissions of one country in 2030 resp. 2050 (reference points) in comparison with the reference years 1990 resp. 2010 in the relative scenario which is shown as a **reference value.** The **national budgets** and the **national net negative emissions** are also given.

In the sheet “**output countries**” you can choose a scenario and then the reference values for 2050 and 2030 are calculated for all the countries in the world when the macro is started. The national budgets 2020 - 2100 and the share of a country's emissions in global emissions in 2019 are also calculated.

<u>Convergence</u>

In the sheet “**convergence**”, you can choose three optional countries resp. “global” and a scenario. When you start the macro, the converging trajectory of the per capita emissions is shown.

7 Other features of the Regensburg Model

7.1 Emission trading

The Regensburg Formula also allows easy implementation of emission trading between countries. The national emission pathways would be the basis for the allocation of emission rights.

The amount of certificates held by country *i* in year *t*, and the modification of the target amount through emission trading, would result from the following formulae:

$$E_t^i = (1 - C_t) * E_{2019}^i + C_t * TA_{t-1}^i + T_t^i$$

$$TA_{2019}^i = E_{CY}^i = \frac{E_{CY}}{P_{CY}} * P_{CY}^i$$

$$TA_t^i = TA_{t-1}^i + T_t^i$$

T_t^i = trade volume bought or sold by country *i* for year *t*

TA_t^i = target amount of country *i* in year *t*

Main advantages of emission trading between countries based on national emission pathways:

- Flexibility: no country would have to agree on unalterable emission limitation.
- Cost efficiency: a global price for CO_2 would be generated, which would ensure that reductions would first be made where it is possible in a cost-efficient way.
- Review-process: Annual check-ups can examine whether a country has enough certificates.

7.2 Implicit weighting population[6]

The sheet "IWP" shows that the Regensburg Formula implies a weighting of the population, which is the same for each country and depends only on the chosen global path. That is, if one were to distribute the global budget to be distributed in the convergence period directly to countries containing the population and the emissions in the base year with a weighted distribution key, one can assign to each global path a certain weighting of the population, which results with the Regensburger Formula represents.

The sheet "IWP-T" shows that such an implicit weighting of the population - depending on the chosen global path - can also be given for the national budgets 2020 - 2100 resulting from this tool resp. the Regensburg Model.

This means: If the implicit weighting in relation to a global path is known, the remaining national budget that results in the Regensburg Model can also be calculated directly.

In order to calculate the implicit weighting of the population for the individual scenarios, you first have to enter the budgets for each country with the macro "update data". Then you can use the macro "Solver" to calculate the weighting of the population that minimizes the squared deviation between the national budgets in this tool and distribution according to the weighted distribution key.

The macro "update data" must make the following settings: (1) In the sheet "data countries", the "upper limit" for the increase in emissions by 2019 is set so that global emissions correspond to the sum of countries emission data. (2) In the sheet "base data", the option "Frozen Populations" is selected. (3) The population of countries with known emission data is slightly corrected, so that the

[6] Cf. our paper: Resource Sharing Models - A Mathematical Description; download: www.save-the-climate.info.

global population will be total in 2019. For this, a correction factor is determined, which is then applied in the sheet "countries". This is necessary because a few countries have no emission data. These settings are undone after the macro has ended.

8 Alternative approaches

8.1 Criteria for the determination of national emission paths

The basic idea of the **Regensburg Formula** is as follows: starting with the emissions of any one country in the base year (at the tool: 2019), an emission pathway is described which converts to **gradual equal per capita emissions** (“one human – one emission right”) in the convergence year.

In contrast to this, there are often calls for **immediate climate justice** i. e. the immediate complete allocation of emissions according to population figures. Immediate climate justice can be obtained

- by first determining a global pathway and then allocating in each year the global emissions according to populations figures or
- by first allocating a global remaining budget on countries and then transforming the allocated national budgets into national pathways.

We do not consider immediate climate justice economically expedient. It would probably trigger a world economic crisis, which would do no-one any good.

Instead of an allocation formula based on population, other criteria are conceivable. The United Nations Climate Change Framework Convention of 1992, for example, asks for consideration of the following: “Acknowledging that the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions”. Here, the criteria of **historic responsibility** and **technological** resp. **economic capability** are addressed. These criteria are not explicitly considered in the Regensburg Formula. However, the question remains as to what extent these criteria should not preferably be considered in conjunction with transfer payments rather than with emission pathways.

Emission pathways calculated according to the Regensburg Formula do present a great challenge, particularly to emerging economies, since they would have to reduce their emissions relatively quickly even though their more carbon-dependent infrastructures have only been in place for a short time.

The per capita emissions of developing countries do not exceed the convergence level when applying the Regensburg Formula.

Reference values based on the Regensburg Formula therefore represent a kind of “moral lower limit” for industrialized countries.

8.2 Alternative Resource Sharing Models

See our tool and our paper “Comparison Resource Sharing Models” which can be downloaded at www.save-the-climate.info.

9 Résumé of the Regensburg Model

The Regensburg Model allows plausible global emission paths to be determined which adhere to a specific global budget. Independent of the method used to determine the global emission pathway, **national emission paths** can be determined using the Regensburg Formula in the convergence period. The national paths are compatible with a given **global budget 2020 - 2100** and lead to **converging emissions per capita**.

The **scenarios** can be used to show what leeway we still have for global emissions from 2020 to 2100. The conclusion demonstrated (one which is not surprising in essence, but is perhaps in its dimensions) is that the later we act, the smaller the leeway.

The **reference values** can serve as guidelines when judging the national contributions (NDCs) to be submitted by 2020 at the latest by each country as a result of the process of review and revision agreed upon in Paris. Industrialized countries in particular are in need of explanations if their national contributions are still below the results of the Regensburg Model, because they receive comparatively lighter treatment compared to other resource of sharing models. In our opinion, the results of the Regensburg Model represent so a kind of "moral lower limit" for industrialized countries.