# Instructions
# for the tool:

## The Regensburg Model

# Reference Values for NDCs

Authors:

Professor Manfred Sargl
Andreas Wolfsteiner, Master of Economics
Günter Wittmann, Master of Mathematics

save-the-climate@online.ms (mail to)

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

version: 5 December 2018 – 1.5

# Contents

1 Why this preoccupation with emission pathways? ... 3
2 Brief introduction to the tool ... 4
3 Global constraints and other original data - entries in sheet “base data” ... 5
4 Determination of global emission paths ... 6
4.1 Sheets “goal seek” and “RM” ... 6
4.2 Scenario types RM 1 - 5: Different approaches used in annual reduction rate ... 6
4.3 Sheet „country“ ... 6
5 Determination of national emission paths using the Regensburg Formula ... 7
5.1 The Regensburg Formula ... 7
5.2 Emission trading ... 9
5.3 Implicit weighting population in the Regensburg Formula ... 9
6 Reference values for every country in the world ... 10
7 Alternative approaches ... 12
7.1 Criteria for the determination of national emission paths ... 12
7.2 Alternative Resource Sharing Models ... 12
8 Résumé of the Regensburg Model ... 13

## 1 Why this preoccupation with emission pathways?

A crucial factor in determining whether we shall be able to achieve any prescribed objective for maximum global warming are the cumulative $CO_2$ emissions[1] which we will be producing in future and not so much the reduction achieved by any particular valuation date.[2]

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

This tool offers five scenario types for converting a **$CO_2$ budget** 2020 – 2100 into plausible **global emission pathways** (see sheet "graphs global"). The scenarios and the determination of the free parameters in the sheets "goal seek" show the political leeway available for compliance with a prescribed budget. In the event of a temporary overshooting of the budget, which should be compensated for by global negative emissions, it must be borne in mind that this overshoot can trigger tipping points in the climate system.

Above all, the Regensburg Model makes it possible to deduce consistent **national emission paths** (see "graphs country") from any optional global emission pathway with the **Regensburg Formula**[3] as a result of converging per capita emissions.

[1] Anthropogenic $CO_2$ emissions are composed of emissions from the combustion of fossil fuels, emissions from industrial processes (e. g. the manufacture of cement) and the reduction of $CO_2$ stored in biomass as a result of human intervention (FOLU: Forestry and Other Land Use). The proportion of anthropogenic greenhouse gases measured in $CO_2$ equivalents ($CO_2$eq) in 2010 was as follows: $CO_2$ from fossil fuels and industrial processes 65%, FOLU $CO_2$ emissions 11%, methane and nitrous oxide 22%, fluorinated gases (F-gases) 2 % (source: IPCC WGIII AR5 Figure SPM.1).

[2] IPCC SR15 SPM S. 14 C.1.3

[3] 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

## 2 Brief introduction to the tool

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.

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 five types of RM-scenarios.

The RM-types of scenarios differ primarily in the shape of the curve for annual global reduction rates.

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:

(1) Important input values

  a. Sheet “base data”

     i. global $CO_2$ budget 2018 – 2100

     ii. minimum emissions 2100 can be set (potential global 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 reduction rates for 2020 can be entered in scenarios 2 - 5.

(2) In the sheet "cockpit", you get an overview of current input values and important results.

# 3 Global constraints and other original data - entries in sheet "base data"

### I. Entry of data to determine global emission paths from 2020 - 2100

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

Input global CO2 budget 2018 - 2100 based on the Special Report of the IPCC October 2018.

FOLU is the abbreviation used for $CO_2$ emissions caused by land use, changes in land use, and forestry. Because it is still difficult to find numbers for individual countries, FOLU emissions are not considered and therefore need to be deducted.

### I. b) Emissions 2018 − 2019

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

### I. c) 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. d) Emissions in 2019, the 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 ($E_{2100min}$) which may not be undercut. In doing so, a negative value is also possible, standing for global negative emissions.

### II. Initial values for national emission pathways

Convergence level

Using the Regensburg Formula, national emission pathways in which the per capita emissions converge are deduced from a global pathway. 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" - 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.

Population

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 three options:

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

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

(3) Take the minimum figure from the forecast and consideration of population developments already determined and which cannot be substantially influenced by demographic engineering policies, whichever is the lower. In this way the number of parent generations already born partly determines population development, even if the fertility rate of this generation changes. The population could, for example, be capped at the population figure calculated at a fertility rate which would lead to stable demographic development long-term (replacement fertility rate resp. instant replacement).

### III. Proportionate distribution according to population formula in the event of increasing global emissions: See page 8

# 4 Determination of global emission paths

## 4.1 Sheets "goal seek" and "RM"

Global emission paths can be determined using scenarios 1 – 5 (calculation see sheet "RM"). Under the sheet "goal seek" the free parameter of the respective scenario is determined centrally in such a way that the budget set is adhered to. That is what the macro "goal seek" is designed to do. Under the sheet "FI" it is possible to enter a global pathway of one's own choice.

The global emissions in year *t* ($E_t$) in the period 2020 - 2100 in principle result in scenarios 1 – 5 from the application of an annual reduction rate ($RR_t$). However, in the "goal seek" sheet you can enter a threshold value (*TV*) for the global emissions. If the global emissions are below TV a constant amount will be deducted from the global emissions of the previous year. In doing so the value that resulted from the last application of a reduction rate is used as the constant amount. If goal seek does not find a solution, it may be helpful to change TV.

## 4.2 Scenario types RM 1 - 5: Different approaches used in annual reduction rate

In Scenario 1 a **constant annual reduction rate** is assumed. The constant $RR_t$ to which the budget adheres is determined using the goal seek feature.

$E_t$ = max. ($E_{2100}$; $E_{t-1}$ * (1 + $RR_t$)); where: $RR_t$ = constant.

In Scenario 2 an **exponential increase**[4] of the annual reduction rates is assumed. The **initial value** ($RR_{20}$) may be set. This initial value is escalated annually. The escalation rate ($ER_{RR}$) to which the budget adheres is determined using the goal seek feature.

$E_t$ = max ($E_{2100}$; $E_{t-1}$ * (1 + $RR_t$)); where: $RR_t = RR_{t-1} * (1 + ER_{RR})$

In Scenario 3 the **linear increase** of the annual reduction rates is assumed. For the year 2020, an **initial value** ($RR_{20}$) may be set. The constant negative adjustment (*A*) to which the budget adheres is determined using the goal seek feature.

$E_t$ = max ($E_{2100}$; $E_{t-1}$ * (1 + $RR_t$)); where: $RR_t = RR_{t-1} + A$.

In Scenario 4 a **quadratic formula** for the annual reduction rates is used. An **initial value** ($RR_{20}$) may be set. The parameter to which the budget adheres is determined using the goal seek feature.

$E_t$ = max ($E_{2100}$; $E_{t-1}$ * (1 + $RR_t$)); where: $RR_t = a(t-2020)^2 + RR_{20}$

In Scenario 5 a **radical formula** for the annual reduction rates is used. An **initial value** ($RR_{20}$) may be set. The parameter to which the budget adheres is determined using the goal seek feature.

$E_t$ = max ($E_{2100}$; $E_{t-1}$ * (1 + $RR_t$)); where: $RR_t = a * \sqrt{t - 0{,}5 - 2020} + RR_{20}$

## 4.3 Sheet „country"

The sheet "country" also calculates emission paths from international shipping and aviation. The reduction rates of the respective global path are assumed. These emissions are then subtracted from the global path and then serve as the basis for identifying the national path.

This sheet also calculates the **overshoot** of the individual scenarios.

---

[4] The recursive form $RR_t = RR_{t-1} * (1 + ER_{RR})$ is analogous to the following explicit form: $RR_t = RR_{20} * e^{-(t-2020)*a}$ where $a = -\ln(1 + ER_{RR})$.

# 5 Determination of national emission paths using the Regensburg Formula

## 5.1 The Regensburg Formula

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

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

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

**The Regensburg Formula:**[5]

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

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 head of the population. 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 Model 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 "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

[5] 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 (further) 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

Consideration of (further) increasing global emissions post 2019

In scenarios 3 and 4, a positive $RR_{20}$ can be set. In this case global emissions start off by increasing (further). 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.[6] In such cases the question arises as to **how rights to additional emissions starting 2020 should be allocated per country.** In our tool, the allocation formulae “per capita” and “in percent” are used. The weighting of the allocation per capita ($PC_t$) can be entered in sheet “base data” under III. Here a rate of annual escalation ($ER_{PC}$) of $PC_t$ can be set.

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.

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

**RF scenarios**

**Convergence period (2020 - *CY*):**

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

**The Regensburg Formula:**

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

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

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

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

$$E^i_t = E^i_{t-1} + (1 - PC_t) * RR_t * E^i_{t-1} + PC_t * \frac{P^i_t}{P_t} * (E_t - E_{t-1})$$

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

**After the convergence year:**

$$\boldsymbol{E^i_t} = \frac{P^i_t}{P_t} * E_t$$

$$\boldsymbol{E_t < 0}$$
**(global negative emissions)**

$$E^i_t = \frac{E^i_{by}}{E_{by}} * E_t$$

[6] 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 $|C_t| * E^i_{2019} < |C_t| * E^i_{CY}$.

### 5.2 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 the most cost-efficient way.
- Review-process: Annual check-ups can examine whether a country has enough certificates.

### 5.3 Implicit weighting population in the Regensburg Formula[7]

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.

In order to calculate the implicit weighting of the population for the individual scenarios, you first have to enter the budgets for each country according to the Regensburg Formula in the convergence period 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 according to the Regensburg Formula and distribution according to the weighted distribution key.

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

## 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 pathways for the country chosen, for all the scenarios. In the same sheet, you can then quickly find a compilation of the results.

Entries in sheets "country" and "data countries"

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

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

Where no rates of change can be calculated on the basis of historic data, a standard rate is applied that can be altered in the sheet "data countries" (cell I9).

You may embed an individual extrapolation rate in column M 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 cell L255 resp. L256 in the sheet "data countries".

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.

In order for the reference values for individual countries to be calculated correctly, the total of all the extrapolations for 2019 for all the countries must largely correspond to the global emissions in 2019 as set in the sheet "base data". For this reason any deviation is shown as a percentage in cell N257 (where necessary use the goal seek feature) or other resp. new individual extrapolation rates set. An adjustment of the extrapolation of the global value for 2019 could be considered.

Convergence

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.

Reference values for the Paris process of review and revision (ratchet up mechanism)

All countries were called on to submit their targets for their climate policy post 2020 ("nationally determined contributions", NDCs for short) to the UN Climate Secretariat. On the basis of the NDCs submitted, the UN Climate Secretariat concluded that these targets were not sufficient to adhere to the 2°C limit.

For this reason a process of review and revision was decided upon in Paris (ratchet up mechanism), to be performed in a five-year cycle starting in 2018. The NDCs must be revised by 2020 at the latest. In Paris a decision was also taken that in principle no country may backslide to ambitions below those once set.

In the context of this process of review and revision, the following pressing question now arises: **What can be deemed a fair and economically reasonable proportional contribution for any specific country towards the global efforts which it is necessary to make?** This tool cannot produce any definitive answers to this question but it can provide guidance. Industrial nations are hard pressed for excuses if their ambitions fall below those shown as reference values in the Regensburg Formula.

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.** If you wish to compare various reference values, be they calculated with the tool using other base data, or on other criteria, it is important to give particulars of the global pathway taken as a basis. The cumulative emissions up to the reference point and the cumulative global negative emissions (overshoot) assumed are particularly helpful.

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.

# 7 Alternative approaches

## 7.1 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.

## 7.2 Alternative Resource Sharing Models

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

## 8 Résumé of the Regensburg Model

The Regensburg Model allows plausible global emission paths to be determined which adhere to a specific budget. Independent of the method used to determine the global emission pathway, **national emission paths** can be determined using the Regensburg Formula which **achieve a limit for maximum global warming as set and gradually lead to the convergence of per capita emissions.**

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 important guidelines when judging the national contributions 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. Industrial nations in particular will be hard pressed for excuses if their ambitions fall short of the reference values resulting of the Regensburg Formula, because they receive comparatively lighter treatment compared to other resource of sharing models.