Instruction

Tool to the

- ## Regensburg Model
with the Regensburg Formula

- ## Smooth Pathway Model
with the SPM formula from Raupach et al.

Reference Values for NDCs

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Contents

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.

So the question remains: who receives how much of the remaining CO_2 budget?

This tool offers several scenario types for converting the remaining **CO_2 budget** into plausible **global emission pathways** (see sheet "graphs global"). The scenarios and the determination of the free parameters in the sheets "goal seek" resp. "implicit budget" 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 pathways** (see "graphs country") from any optional global emission pathway with the **Regensburg Formula**[2] as a result of converging per capita emissions.

In addition to the Regensburg Formula, the tool now also includes the **Smooth Pathway Model** from Raupach et al.[3]: distribution of the remaining global budget with a weighted key "population" and "emissions" and plausible emission paths determined for the resulting national budgets using the SPM formula from Raupach et al.

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[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_2eq) 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] 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] Cf. Raupach, M. R. et al., 2014. Sharing a quota on cumulative carbon emissions. Nature Climate Change, Volume 4, pp. 873 - 879.

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) or Smooth Pathway Model (SPM_P), 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 pathways for

- five types of RM-scenarios,
- SPM_G (SPM Formula is used to the global path) and
- SPM_Px (resulting global path SPM_Px is the basis for the Regensburg Formula).

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. Version "goal seek" the **convergence level** can be set in the sheet "base data". 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. In the sheet "goal seek", the starting values for 2020 can be entered in scenarios 2 - 5.

    b. Version "implicit budget" the **convergence year** is set at **2050**. One of the adjustable values in the sheet "implicit budget" is the reduction of global emissions in 2050 compared with 1990.

    c. Sheet "base data"

        i. remaining global CO_2 budget 2018 – 2100

        ii. Minimum emissions 2100 can be set (potential global negative emissions)

    d. Sheet "graphs country": Weighting of the population in the Smooth Pathway Model (SPM_P) can be set.

(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 <u>global emission pathways</u> 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. However, it is still difficult to put a figure on these emissions. This is the reason why no valid data base by individual country exists yet. In this tool, therefore, 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 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

<u>Convergence level</u>

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.

However, we also offer another way of determining global pathways, using the sheet "implicit budget" (see also chapter 5.3; p. 11). If you select "implicit budget" in the sheet "graphs country", the convergence level entered here will not be used.

<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 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 9.

4 Determination of a global emission pathway

The tool in principle offers two methods of determining the RM global pathway:

4.1 Sheet "goal seek"

The convergence level can be dictated in the sheet "base data".

A global emission pathway can be determined using scenarios 1 – 5 (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 Sheet "implicit budget"

The global pathways determined in the sheet "implicit budget" all have the same cumulative emissions for the years 2020 - 2050. This makes the determination of pathways more complicated (see detailed instruction in Chapter 5.3; p. 11).

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

In <u>Scenario 1</u> 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 <u>Scenario 2</u> 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 <u>Scenario 3</u> 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 <u>Scenario 4</u> 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 <u>Scenario 5</u> 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.

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[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 $a = -\ln(1 + ER_{RR})$.

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

4.4 Global path: SPM_G and SPM_P

In the sheet "SPM_G" the Smooth Pathway Formula of Raupach et al. is used to determine a plausible global path that approaches zero. In the sheet "SPM_P" the resulting global path is determined with the use of the SPM formula with a macro.

4.5 Global paths between credibility and cost efficiency

Ideally, the global pathway chosen is such that the cost of conversion to less CO_2-intensive production methods is kept to the minimum (cost efficiency). The most important distinguishing feature of the global pathways in this tool is the shape of the annual reduction rates, whereby three basic versions can be distinguished:

	Trajectory (RR_t)	Scenario	Reasonable from a cost aspect if
1.	constant rate	1	constant technological developments and conversion of the infrastructure are expected.
2.	linear increase	3	a linear increase in technological developments and conversion of the infrastructure are expected.
3.	disproportionate increase	2, 4	it can be assumed that very high reduction rates are possible in future due to an early political announcement.
4.	disproportionate increase	5	relatively rapidly increasing reduction rates as early as the 2020s increase the probability of success in limiting global warming

As a prerequisite for conversion to production methods which can operate at zero CO_2 emissions or even at negative emissions, new products and technologies must be developed, investments in the corresponding infrastructure made and new lifestyles adopted. All this requires forward planning. It is important to recognise the fact that the earlier political initiative is taken, the more economical will be the conversion. Disproportionate trajectories reflect the assumption that, if a political decision is taken early enough, very high reduction rates in technological fields with relatively low conversion costs are possible in the more distant future, since, for example, many investments can be made within normal investment cycles and existing investments devalued at a lower rate. This however depends on political decisions being presented in a wholly convincing manner.

The disproportionate increase in reduction rates therefore holds great potential to minimise conversion costs; relatively high reduction rates in initial years would in contrast tend to increase investors' belief that their politicians mean it seriously.

Furthermore it is important to recognise the fact that the lower the reduction rates at the beginning (which could be economically reasonable), the greater must they be later on (a classic trade-off).

5 Determination of national emission paths using the Regensburg Formula

5.1 The Regensburg Formula

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.

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The Regensburg Formula:[5]

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

where:

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

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

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

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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 ($P^i{}_{CY}$).

The convergence year

Method sheet "goal seek": 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.

If you work with the version "implicit budget", the convergence year is already set at 2050.

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

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[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.

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:

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RF scenarios

Convergence period (2020 – CY):

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

The Regensburg Formula:

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

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

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

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

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

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

After the convergence year:

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

$E_t < 0$
(global negative emissions)

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

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[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:

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

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

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

$$T_t^i = \text{trade volume bought or sold by country } i \text{ for year } t$$

$$TA_t^i = \text{target amount of country } i \text{ in year } t$$

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

- <u>Flexibility</u>: no country would have to agree on unalterable emission limitation.
- <u>Cost efficiency</u>: 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.
- <u>Review-process</u>: Annual check-ups can examine whether a country has enough certificates.

5.3 Implicit budgets and implicit weighting population in the Regensburg Formula[7]

One characteristic of the Regensburg Formula is that the cumulative emissions in the convergence period attributed to a state (BG^i; implicit budget) do not depend on the concrete trajectory of the global emission pathway as long as these pathways abide by the same global cumulative emissions in the convergence period (BG) and the same global convergence amount (E_{CY}).

$$BG^i = \sum_{t=BY+1}^{CY} E_t^i = E_{CY}^i * (CY - BY) + (BG - E_{CY} * (CY - BY)) * a^i \quad [8]$$

Where:

$$a^i = \frac{E_{BY}^i - E_{CY}^i}{E_{BY} - E_{CY}}$$

BG: global cumulative budget in the convergence period
BG^i: cumulative emissions of a state i in the convergence period
a^i: proportional factor of a state i to the global reduction quantity: $\sum_i a^i = 1$

By adding up the emissions of a state according to equation CWF or C&C (which are described in Chapter 8.2 Alternative resource sharing models, page 16) over the period of convergence, it becomes apparent that this property does not apply for these approaches.

Excurse:

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

[8] According to budget formula, at first every state is accorded emissions on the basis of identical per capita emissions in the convergence year. Then the remaining budget in the convergence period is allocated to each state using the proportional factor a^i. a^i is negative for countries starting with emissions below their convergence amount and positive for countries which start with emissions above it.

If the Regensburg Model is used as the basis for the distribution of the remaining budget to states as emission rights in the form of national emission pathways followed by emissions trading between different countries within the context of a global climate agreement, then the negotiations on the determination of the global pathway could concentrate on questions such as which concrete trajectory minimises conversion costs (cost efficiency) or indicates the greatest credibility to investors. Direct allocations of the global cumulative budget to individual countries should not be made according to the implicit budget formula of the Regensburg Model because in this case it would no longer be possible to make annual assessments in the context of emission trading between states as to whether these states actually are on the right path or have purchased emission rights. It should be noted at this point that the top-down allocation of the remaining budget is not on the political agenda, especially since the global community has at the moment chosen to adopt a policy of national determined contributions (NDCs) in the framework of a review process.

By using the version "implicit budget", global pathways can be determined which fulfil the requirements for implicit budgets. However, to do so the global emission pathways must be determined for two stages: (1) 2020 - 2050 (convergence period) and 2051 - 2100. As a first step, the global emissions in the convergence year must be set in the sheet "implicit budget". This is done by entering a reduction rate for global emissions in 2050 in comparison to 1990 (RR_{9050}). In order for the global pathways for 2020 – 2050 to show the same budget, the global pathways post 2050 must be identical. To this end a reduction rate for 2051 (RR_{51}) is set the sheet "implicit budget". The resulting absolute value is then deducted from the previous year's value up to 2100. In doing so, RR_{51} should be aligned with the average of the resulting RR_{50} in scenarios IB-2 - IB-4. This could make several iterations necessary.

The global pathways 2020 - 2050 may then be determined via various macros that are described in more detail in the tool.

The determination of global pathways using the version "implicit budget" has the advantage that national budgets are independent of the global pathway chosen in the convergence period. Its disadvantages are: less leeway for the global pathway, and no consistency in the reduction rates for 2050 and 2051.

If you wish to use the global pathways which were determined in the sheet "implicit budget", you can choose them in the sheet "graphs country" for scenarios 2 – 4.

The sheet "IWP" shows that the Regensburg Formula implies a certain weighting of population, which only depends on the chosen global path if the population is frozen.

6 Determination of national emission paths using the Smooth Pathway Model

Raupach, M. R. *et al.* suggest the following weighted key for allocation the remaining global budget to countries:

$$RB^i = \left(\check{C}_{RB} * \frac{P^i_{BY}}{P_{BY}} + \left(1 - \check{C}_{RB}\right) * \frac{E^i_{BY}}{E_{BY}} \right) * RB$$

where

RB global remaining budget

RB^i remaining budget of country i

$\bar{\bar{C}}_{RB}$ weighting of population

Raupach, M. R. *et al.* also showed how to transform the allocated remaining budget of a country into a positive pathway (i. e. a pathway which has no negative emissions), with a smooth transition from the current pathway and with near-zero emissions at infinity.

In the SPM formula from Raupach et al. the emissions of country i in the year t (E^i_t) are given by

$$E^i_t = -\dot{E}^i_{BY+1} \frac{e^{-m^i(t-BY)}}{(m^i)^2} \left[\left(r^i m^i + \left(m^i\right)^2 \right) (t - BY) + 2m^i + r^i \right]$$

$$+ \dot{E}^i_{BY+1} \frac{e^{-m^i(t-BY-1)}}{(m^i)^2} \left[\left(r^i m^i + \left(m^i\right)^2 \right) (t - BY - 1) + 2m^i + r^i \right],$$

where

$\dot{E}^i_{BY+1}$ emission power, i. e. the derivative of emissions with respect to time or the emissions per unit of time, of country i at the end of the base year,

r^i change rate of the emission power of country i at the end of the base year and

m^i the mitigation rate (or the decay parameter) of country i.

If $r^i > -1/T^i$, the mitigation rate m^i is given by

$$m^i = \frac{1 + \sqrt{1 + r^i T^i}}{T^i},$$

where $T^i = \frac{RB^i}{\dot{E}^i_{BY+1}}$ is the time defined by the remaining budget of country i and the emission power of country i at the end of the base year.

7 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 sheet "country"

In order to be able to calculate national emission pathways using the Regensburg Model, 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 R9). 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.

Entries in sheet "data countries"

You may embed an individual extrapolation rate in column V 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 can be set in cell L255 in the sheet "data countries".

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.

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.

Entry in sheet "graphs country"

In cell Q2, you can specify the weighting of the distribution key "population" for the Smooth Pathway Model (SPM_P).

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 ("intended nationally determined contributions", INDCs for short) to the UN Climate Secretariat in preparation for the climate change conference in Paris in December, 2015. On the basis of the INDCs 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. However, wealthy industrial nations are called upon to re-examine their ambitions as of today. 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 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 addition, the SPM_P offers a good opportunity to implement the effects of other concepts of justice.

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 assumed are particularly helpful.

In the sheet "**output countries**" you can choose a scenario and then the reference values for 2050 and 2030, among other things, are calculated for all the countries in the world when the macro is started.

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 fundamentally 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.

In the case of allocating a global remaining budget smooth pathways can be obtained. Nevertheless, 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.

On the other hand, 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.

In our opinion this means that wealthy industrial states in particular need to demonstrate higher ambitions with regard to their emissions than those which result from calculations under the Regensburg Formula.

8.2 Alternative resource sharing models

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

9 Résumé of the Regensburg Model

The Regensburg Model allows plausible global emission pathways to be determined which adhere to a specific budget. Independent of the method used to determine the global emission pathway, **national emission pathways** 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.