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Instructions
for the Tool for the:
Extended Smooth Pathway Model (ESPM)

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

Version: 3.1

Contents

1 Basic idea behind the ESPM[1]

- **National budgets**: A predefined **global CO2 budget** 2020 – 2100 is **distributed** to **countries**. The 'Tool_ESPM' offers the use of a weighted distribution key that includes the 'population' and the 'emissions' in a base year (here: 2019). In this way, current reality and climate justice can be mapped.
- **National paths**: The 'Tool_ESPM' offers the Regensburg Model Scenario Types RM 1 - 6 to derive plausible **national paths** from a national budget. This scenario types cover the range of plausible possibilities well.

2 Brief introduction to the tool for the ESPM

With this tool you can determine national budgets and plausible national emission paths from this budget.

For deriving **national paths,** the tool offers the Regensburg Model 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 'base data'** you can set the basic conditions such as the budgets which are to be met, and the minimum value of national annual emissions (potential for net negative emissions). To determine the national budget a simple weighting model 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 appear 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 a given global budget and **reference values** for the **largest emitters**.

When modifying input data (which the cells shaded in yellow are designated for) or select another country, you must always execute the **macro** in the **sheet 'goal seek'** to adjust the free parameter in the scenarios such as to meet the national budget 2020 - 2100 which is set out in sheet 'base data'.

3 Entries in the sheet 'base data'

I. Entries of data to determine a global budget from 2020 – 2100

In this tool, a global budget 2020 - 2100 is distributed across countries. In a first step, a global budget 2018 - 2100 is set. LUC, ISA, and emissions from 2018 and 2019 are deducted from this budget:

global CO2 budget 2018 - 2100
- LUC budget 2018 - 2100
- international shipping and aviation (ISA) 2018 - 2100
- global emissions 2018 – 2019 without LUC/ISA
= global CO2 budget 2020 - 2100 to distribute here

I. a) Global CO2 budget 2018 – 2100

Input global CO2 budget 2018 - 2100 based for example on the Special Report of the IPCC October 2018 (see Table 2.2 SR15 in the sheet).

[1] (Wiegand, Sargl, Doerenbruch, Wittmann, & Wolfsteiner, 2021)

I. b) Global CO2 emissions 2018 and 2019

Data base: see sheet “EDGAR”.

I. c) Global CO2 budget 2020 – 2100 without LUC and ISA

Since, among other things, it is difficult to find figures for individual countries for CO2 emissions caused by land use changes (LUC), these emissions are not included here and must therefore be deducted.

Enter the LUC budget 2018 – 2100 in Gt. A negative value means that in sum the net negative LUC emissions would be higher than the net positive emissions in this period (see separate paper on this topic: (Wolfsteiner & Wittmann, Treatment of the topics LUC and net negative emissions in the tools: 'Regensburg Model' and 'Extended Smooth Pathway Model')).

Emissions from international shipping and aviation (ISA) also have to be deducted, since attribution to countries is also difficult. The current share of global ISA emissions is given as information.

LUC and ISA are also not included in the national data used (see sheet “EDGAR”).

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

The result is the global budget, which can be distributed across countries in this tool for the period 2020 - 2100.

II. National CO2 budget 2020 – 2100

The national budget used here results from the application of a weighted distribution key to the global budget 2020 - 2100. The distribution key includes: the country's share of the global population and global emissions in 2019:

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

where

B^i	budget of country *i*
B	global budget
E_{BY} resp. E^i_{BY}	global emissions resp. emissions of country *i* in the base year
P_{BY} resp. P^i_{BY}	global population resp. population of country *i* in the base year
C	weighting of population

You can specify the weighting of the population (*C*) here.

You can also enter a freely calculated national budget 2020 - 2100. In this case, please make sure that the national budget does not include LUC/(A)FOLU/LULUCF and ISA.

III. National minimum emissions

Here you can specify which minimum the national paths can achieve in 2100 (*E_min*). If you specify a negative value, this means net negative emissions. This sets the potential for net negative emissions.

The specification is made by entering a percentage that will be applied to national emissions in 2019 of the chosen country (see separate paper on this topic: (Wolfsteiner & Wittmann, Treatment of the topics LUC and net negative emissions in the tools: 'Regensburg Model' and 'Extended Smooth Pathway Model')).

4 Determination of national emission paths

4.1 Entries in the sheet 'goal seek'

- RM 2 – 5: rates of change for 2020 (***RR*$_{20}$**); the last actual change rate of the chosen country is given in this sheet as an orientation
- RM 1; 2 – 5: threshold values (*TV*); in scenarios RM 1 - 5, a constant reduction amount is applied from this threshold values for the transition to **net negative emissions**.[2]

4.2 Where and how the national paths are determined

The **paths** are **calculated** in the **sheet 'RM'**.

The tool offers the Regensburg Model Scenario Types RM 1 - 6 for the determination of national paths (see Chapters 4.4 and 4.4.2 for details). In addition, the paths calculated using the SPM formula from (Raupach, et al., 2014) offered (see sheet 'SPM'; this sheet may be hidden).

When using scenario types RM 1 - 6, the paths are essentially determined indirectly by determining the **annual rates of change** (RM 1 - 5) or the **annual constant reduction amount** (RM-6). From the specified threshold value (*TV*), a constant reduction amount is used until the emissions reach the predefined minimum value (*E_min*).

In the **sheet 'goal seek'** the free parameter of the respective scenario is determined for each scenario type using an iterative solution method so that the budget is adhered to. The **'goal seek' macro** in this sheet uses the target value search integrated in Excel for this purpose (see Chapter 4.5.1).

4.3 Phases determining paths

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*) that you specify in the sheet 'base data' will be applied until 2100.

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

4.4 RM Scenario Types 1 – 6

4.4.1 Description RM Scenario Types 1 – 6

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**:

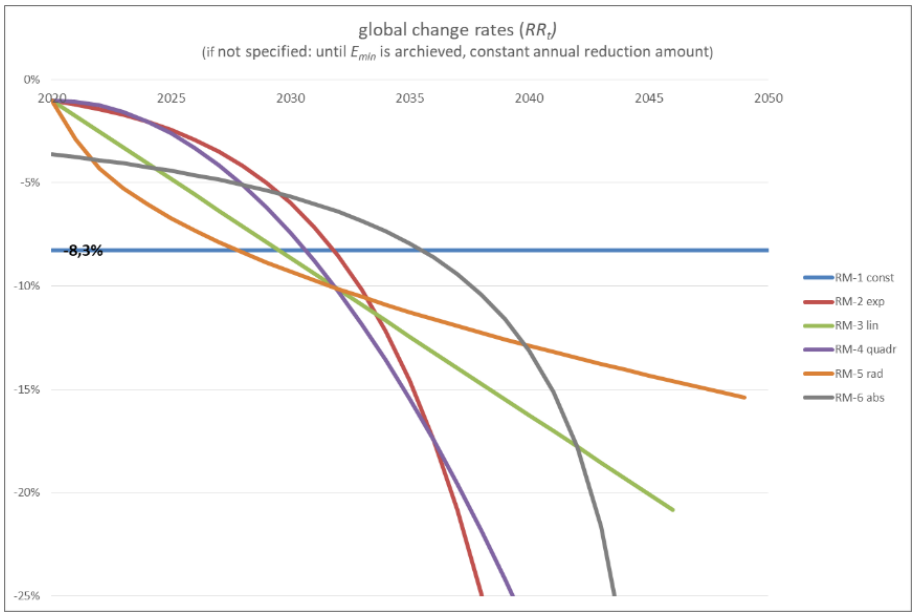
- **RM-1-const:** A **constant annual reduction rate** is assumed.

[2] The **change of method** is necessary, because net negative emissions cannot be implemented by determining the reduction rates. The last reduction amount before the threshold is reached is then used. You set the threshold value by entering a percentage. This percentage is applied to emissions in the base year 2019. Different threshold values can be set for scenario type RM-1 and scenario types of 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.

- **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 which results endogenously. Then the reduction rates initially increase less than proportionally and slowly, in the end increasing very quickly.

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



4.4.2 Mathematical description 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.

Download from

- our website save-the-climate.info
- Zenodo where the description is published (Wolfsteiner & Wittmann, 2021)

Here is a further brief description of the RM Scenario Types.

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

4.5 Macros in the sheet ‘goal seek’

4.5.1 Macro “goal seek”

The **macro 'goal seek'** tries to determine the free parameter in the scenario (row 12 or 13) so that the national 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*).

The macro also tries in scenario RM-1 that the minimum value (E_{min}) specified in the sheet 'base data' is reached (► row 18 = row 19). If this does not succeed straight away, the macro increases the threshold value (*TV*) in the RM-1. If *E_min* can still not be reached, the original *TV* will be reset.

4.5.2 Further macros

Macro 'copy':

If you want to use the same start change rate 2020 in scenarios RM 2 - 5, you can enter this at the intended position and copy it with this macro in RM 2 - 5.

Macro 'goal seek RM-6':

This macro carries out the determination of the free parameter (constant reduction amount) only for RM-6. Experience has shown that 50% of the resulting rate of change in 2020 in the RM-6 represents a good starting value for the scenarios RM 2 - 5. This value is therefore stored in the copy field and can then be transferred with the macro 'copy'.

Macro 'fine-tuning RR_20':

With this macro you can fine-tune the rate of change for 2020 for individual scenarios. After the start, the macro queries which scenario (RM 2 – 5) you want to fine-tune. The macro also queries how many percentage points it should search for a further solution from the entered start value. The 2020 rate of change will be reduced in 0.01 steps. If the macro finds a solution, it takes the lowest value in the specified range. Before this macro can be used, a solution must already exist in the scenario.

4.5.3 Macros finding appropriate framework data

The following macros make it possible to set emission targets and to search for the appropriate global budget, potential for net negative emissions or weighting of the population.

Set emissions target for 2030:

Macro ‘finding budget’

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate** global **budget**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which global budget NDC for 2030 corresponds to with otherwise the same framework data.

The scenario types RM-2, RM-4 and RM-6 are particularly suitable for this analysis. The scenario types RM-3 and RM-5 are less suitable if a country is not very ambitious when it comes to the 2030 emissions target, since in these scenario types a relatively rapid increase in the annual reduction rates

is implemented right from the start. This characteristic does not come into play due to the less ambitious 2030 target. However, the later increase in the reduction rates is only possible to a limited extent with these scenario types. Therefore, a less ambitious target for 2030 requires a relatively high budget for these scenario types.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Macro 'finding NNE'

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate** potential for **net negative emissions**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which potential for net negative emissions correspond to with otherwise the same framework data.

The scenario types RM-2, RM-4 and RM-6 are particularly suitable for this analysis. The scenario types RM-3 and RM-5 are less suitable if a country is not very ambitious when it comes to the 2030 emissions target, since in these scenario types a relatively rapid increase in the annual reduction rates is implemented right from the start. This characteristic does not come into play due to the less ambitious 2030 target. However, the later increase in the reduction rates is only possible to a limited extent with these scenario types. Therefore, a less ambitious target for 2030 requires a relatively high potential for net negative emissions for these scenario types, or no suitable potential for net negative emissions can be found.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Macro 'finding weighting population'

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate weighting of population**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which weighting of population correspond to with otherwise the same framework data.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Specify year emission neutrality:

Macro 'finding budget'

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate** global **budget**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Macro 'finding NNE'

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate** potential for **net negative emissions**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Macro 'finding weighting population'

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate weighting of population**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

Before this macro can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

5 Reference values for every country in the world

In the **sheet 'reference values'**, any country in the world may be chosen from the drop-down list.

Above this sheet you will see whether the target value search must be carried out in the sheet 'goal seek'.

In the sheet 'reference values', it is primarily the ratio of emissions of one country in 2030 resp. 2050 (target years) 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 sum of **national net negative emissions** (overshoots) are also given.

You can also display the results according to the SPM formula for the individual graphics.

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 given global budget and **reference values** for the **largest emitters**. These macros also perform the target value search ('goal seek'). The start change rate 2020 is 50% of the change rate that results in the scenario type RM-6-abs.

In the sheet "goal seek", we also offer macros (see Chapter 4.5.3) with which an **emissions target for 2030** or the **year of emissions neutrality** can be specified and the **appropriate global budget**, **potential for net negative emissions** or **weighting of the population** can be found.

6 References

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