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The Regensburg Model: reference values for the (I)NDCs based on converging per capita emissions[1]

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Abstract

A core question still remains after the Paris Agreement: who receives how much of the remaining CO_2 budget (resource/burden/effort sharing), so that the increase in the global average temperature is kept to well below 2°C above pre-industrial levels? If converging per capita emissions serve as a possible answer to this question, the discussion focuses primarily on the approach 'Contraction and Convergence' (C&C). The Regensburg Model now offers a further option for the mathematical implementation of converging per capita emissions. The authors identify features common to C&C and differences from C&C. They show that, of the convergence models they examined, the Regensburg Model is the most favourable option for industrialized countries.

Policy relevance statement

In politics, the concept of converging per capita emissions is often accepted at the abstract level. Civil society in particular can then take politicians at their word wherever they take values calculated using the Regensburg Model as points of reference; then prosperous developed countries in particular whose nationally determined contributions do not come up even to these reference values will find it difficult to justify their contributions.

[1] Related publication of the authors in German: Sargl, Wolfsteiner and Wittmann (2015).

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1. A crucial question still remains after the Paris Agreement: who receives how much of the remaining CO_2 budget?

1.1 What is actually meant by "the remaining CO_2 budget"?

"The removal of all the anthropogenic CO_2 emissions from the atmosphere by natural processes will take a few hundred thousand years" (IPCC, 2013, p. 472). The trend towards global warming and the acidification of the oceans will therefore persist for a very long time even if CO_2 emissions are considerably reduced. The degree of global warming is determined by the cumulative CO_2 emissions and there is an urgent need for action to reduce them (cf. Archer & Brovkin, 2008; Solomon, Plattner, Knutti, & Friedlingstein, 2009).

The IPCC considers a cumulative budget of 2,900 $GtCO_2$ since the beginning of industrialization still to be compatible with the 2°C limit under certain conditions with a probability of over 66%. Of this budget, about 1,890 $GtCO_2$ have already been emitted by the end of 2011[2] (cf. IPCC, 2013, p. 27, 2014, p. 24). The resulting remaining cumulative budget from 2012[3] is approximately 1,000 $GtCO_2$. The global annual anthropogenic emissions are currently about 40 $GtCO_2$.[4]

1.2 Results of the Paris Agreement

In Paris, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (UNFCCC, 2015b, Article 2, paragraph 1). Since the cumulative CO_2 emissions are a critical factor, it would have been reasonable for the Paris Agreement to include a (political) numerical target for the remaining budget for the greenhouse gas CO_2 by the end of the century. Furthermore this would have been a clearer indication of the necessity for a political decision on the probability of adhering to specific temperature limits. In the negotiations it was evidently not possible to determine detailed specifics on this point. Although the remaining cumulative budget is not explicitly mentioned, it is implicitly recognized. In fact, the Paris Agreement refers several times to "best available science", which includes the scenarios of the IPCC which are compatible with the remaining budget. Verbatim: "In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, …, and to undertake rapid reductions thereafter in accordance with best available science, so as to

[2] Correction after publication: Here we have misinterpreted the text of the IPCC. The correct year is: 2010.

[3] Correction after publication: Here we have misinterpreted the text of the IPCC. The correct year is: 2011.

[4] In the year 2014 "emissions from fossil-fuel combustion and from industrial processes (production of cement clinker, metals and chemicals) totalled to 35.7 [$GtCO_2$]" (PBL, 2015, p. 4). According to the IPCC, in 2010 anthropogenic CO_2 emissions from forestry and other land use (FOLU) amount to a good 5 $GtCO_2$ (cf. IPCC, 2014, p. 5, Figure SPM.2).

achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2015b, Article 4, paragraph 1).

To avoid the mistakes made in Copenhagen in 2009, the global community has decided to work with the voluntary targets of individual states. Prior to the Paris Climate Conference, the member states were requested to submit their emission targets for the period after 2020 (INDCs: Intended Nationally Determined Contributions) to the UNFCCC Secretariat. The idea was for the states to align their voluntary targets to comply with scientific findings and the criterion dictating that efforts be shared fairly (cf. UNFCCC, 2014, No. 14). Over 180 of the 195 members of the UNFCCC had submitted INDCs by the end of the Paris talks, representing over 90% of global emissions. In its synthesis report dated 30th October 2015, the UNFCCC Secretariat shows that the national emission targets are unfortunately not sufficient to meet the global 2°C limit. The UNFCCC report suggests that the full implementation of the INDCs to 2030 would only bridge about 22% of the gap between the business-as-usual reference scenarios and 2°C scenarios (cf. UNFCCC, 2015a, p. 44).

For this reason a ratchet up mechanism was agreed upon in Paris, which is intended to contain a rise in temperatures below the 2°C limit or even below the 1.5°C limit on the basis of ever more ambitious nationally determined contributions.[5] According to items 23 and 24 of the Paris decisions parties may update contributions any time and are required to do so at least every five years, starting by 2020 at the latest. In Article 14 it was agreed to revise the nationally determined contributions as part of a 'global stock-take' every five years starting from 2023. In item 20 of the Paris decisions a 'facilitative dialogue' is also mentioned, to take place in 2018.

The process of review and revision agreed upon poses the following urgent questions: on what concrete criteria are the individual states expected to base their propositions when reporting new nationally determined contributions for CO_2? What standards can be taken by civil society to enable it to assess the planned ambitions of individual states? What pointers can science provide to allow politicians and/or society to assess which states are doing too little and which of them are making good progress? In doing so, the scientific community is required to disclose its criteria in a transparent manner.

[5] This is a combination of bottom-up and top-down approaches.

1.3 Converging per capita emissions

A great number of criteria are conceivable to divide up a global budget between states.[6] In this article, the approach 'mathematical solutions for converging per capita emissions' when apportioning the remaining budget is explored. This approach is a possible manifestation of distributive justice in climate change (cf. Mackey & Rogers, 2015) but it is also based on existing structures, and therefore takes the question of economically reasonable structural change into account. This approach has important political advocates, such as Angela Merkel, the German chancellor, who emphasized the importance of identical per capita emissions as a target to be striven for, saying '… As I see it, the only long-term standard possible is for the CO_2 emissions per capita of all the states to be brought into alignment …' (Merkel, 2007).

2. Mathematical solutions for converging per capita emissions

We define converging per capita emissions as follows: the emissions of the individual states are equivalent to the actual emissions in the base year[7] (*BY*) and the per capita emissions converge up to a specific point in time (*CY*; convergence year). The period from the beginning of the year *BY+1* until the end of the year *CY* is termed the convergence period.

The principle of converging per capita emissions was propounded by the Global Commons Institute (GCI; the GCI was founded in 1990 by Aubrey Meyer) in the early 1990s under the designation 'Contraction and Convergence' (C&C©®™) and has met with wide scientific and political interest (see: www.gci.org.uk; Aubrey, 2010). However, there are several mathematical ways to put this principle into practice. We should here like to present another approach, using the Regensburg Formula.

National emissions pathways with converging per capita emissions (convergence) and compatible with a defined cumulative budget (termed 'contraction" under C&C) can be determined in two stages:

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[6] One of these is, for example, historical responsibility, whereby one specific historical date is determined and the budget remaining at this point of time per capita of the world population allocated; another possibility is per capita allocation based on the budget remaining today and yet another per capita allocation starting at a fixed time in the future. Besides viewing the matter from a purely per capita perspective, other criteria, such as GDP, marginal abatement costs, per capita GDP etc. can be included. For a survey of top-down suggestions, see: chapter 6 of IPCC (2014) and Bodansky (2012). On the categorization of suggestions, see: Höhne, den Elzen, and Escalante (2014), Baer, Athanasiou, Kartha, and Kemp-Benedict have developed a tool to combine various criteria (see website 'Greenhouse Development Rights': www.gdrights.org). Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (2009) is an example of immediate per capita allocation.

[7] Also called "grandfathering".

Stage 1: Determination of a global pathway which complies with a cumulative budget corresponding to a specific rise in temperature.

Stage 2: Breakdown of the global pathway for each state. This allocation is designed to lead to converging per capita emissions.

Two basic solutions for the converging period in stage 2 are presented in the next sections:

2.1 Simple weighting formulae

Two easily comprehensible simple weighting formulae are:

$$E_t^i = \left((1 - C_t) * \frac{E_{t-1}^i}{E_{t-1}} + C_t * \frac{P_t^i}{P_t}\right) * E_t \quad (1)$$

$$E_t^i = \left((1 - C_t) * \frac{E_{BY}^i}{E_{BY}} + C_t * \frac{P_t^i}{P_t}\right) * E_t \quad (2)$$

E_t: global emissions in the year *t*

E_t^i: emissions of state *i* in the year *t*

P_t: world population in the year *t*

P_t^i: population of state *i* in the year *t*

C_t: weighting of the per capita allocation

For C_t any monotonically increasing function can be taken, where $C_{BY} = 0$ and $C_{CY} = 1$.

The per capita emissions converge because the allocation formula "emissions in the base year" resp. "emissions in the year *t*-1" is gradually replaced by the allocation formula "population".

In the C&C model, formula (1) is applied, and under LIMITS[8] (a research project funded by the EU) formula (2).[9]

The C&C model offers two alternatives for C_t:

- exponential alternative: $C_t = exp\left(-a\left(1 - \frac{t-BY}{CY-BY}\right)\right)$ with the parameter *a* to be determined.[10]
- linear alternative: $C_t = \frac{t-BY}{CY-BY}$ (cf. Meyer, 1998, p. 21; cf. Spencer, 1998, p. 12).

LIMITS only uses the linear alternative (cf. Tavoni et al., 2013, p. 5).

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[8] LIMITS uses the formula to determine emissions pathways for different regions of the world.

[9] Notations were changed to facilitate the comparison of the models.

[10] Note that in the exponential alternative $C_{BY} = exp(-a)$ is only approximately zero.

2.2 The Regensburg Formula (RF)

$$E_t^i = (1 - C_t) * E_{BY}^i + C_t * E_{CY}^i \quad (3)$$

where

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

E_{CY}: global emissions in the convergence year (*CY*) = global convergence amount

E_{CY}^i: emissions of state *i* in the convergence year (*CY*) = convergence amount of state *i*

C_t: weighting of the per capita allocation ($C_{BY} = 0$ and $C_{CY} = 1$)

C_t is the weight at which the convergence amount takes effect in the year *t*. C_t increases along with the increasing success achieved in reducing global emissions towards the global convergence amount (E_{CY}). The result is converging per capita emissions in the convergence year (*CY)*. This derivation of C_t from the global pathway moreover guarantees that all the national emissions determined according to the Regensburg Formula add up to the amount of global emissions in each year of the convergence period ($\sum_i E_t^i = E_t$).[11] The emissions of state *i* in the convergence year (E_{CY}^i) are determined on the basis of the same per capita emissions (= convergence level $= \frac{E_{CY}}{P_{CY}}$).

The graph in Figure 1 shows the trajectory of the per capita emissions taking three typical countries as examples.

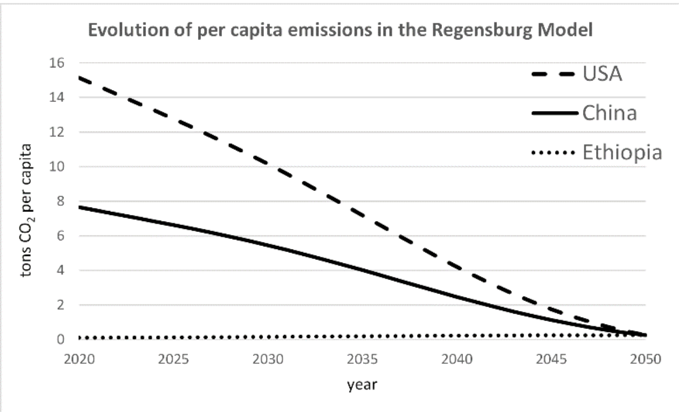

Figure 1: Evolution of per capita emissions in the Regensburg Model

2.3 Common characteristics of the simple weighting formulae and the Regensburg Formula

In both approaches, the following parameters need to be determined:

(1) Determination of the convergence year (*CY*)

The convergence year can be set directly or indirectly by choosing a convergence level.

[11] For mathematical arguments, see Wittmann and Wolfsteiner (2016), p. 6.

In the case of countries with emissions below their convergence amount it is expedient to set as early a date as possible for the convergence year because they will reach the same per capita emissions earlier at a higher convergence level. “The convergence point can be used as a ‘fairness lever’ as the sooner it is reached then the heavier the mitigation burden for the big carbon emitters.” (Makey, no date).

(2) Determination of population figures in the convergence year (P_{CY}^{i})

In order to calculate the national emissions pathways reaching the same convergence level, population figures in the convergence year have to be determined for each state.

Both approaches have specific characteristics with reference to certain types of countries.

(3) First mover (dis)advantage for ambitious countries

Converging per capita emissions can cause disadvantages to countries which had striven to reduce their emissions before the base year. If they had not done this until the base year, they would start at a higher level. As a result these countries would be entitled to a higher cumulative budget. However, early action can also create a first mover advantage if a country is successful in acquiring early know-how in decreasing the dependence of its economy on fossil fuel.

(4) Problematic emerging countries

Emerging countries are often characterised by the fact that their per capita emissions have only recently caught up with those of typical industrial nations. The reason is that these countries have only recently been investing in an infrastructure heavily dependent on fossil fuels. It might cause them serious economic problems if they were confronted with declining per capita emissions straight after the base year, as in the solutions presented here for converging per capita emissions.

(5) Pragmatic approaches

Both approaches start out from actually existing economic structures and can easily be understood. However, they reflect neither historic responsibility for climate change nor economic capabilities. This characteristic is seen as problematic by developing countries.

2.4 Differences between simple weighting formulae and the Regensburg Formula

(1) Monotonic behaviour

The national emissions pathways calculated by the Regensburg Formula are monotonic within the convergence period in the case of decreasing global emissions. In other words, states starting with emissions above their convergence amounts show continually decreasing emissions. Conversely, states starting below their convergence amounts show continually increasing emissions. A principle characteristic of simple weighting formulae is that not all national emissions pathways develop monotonically. This means that the emissions exceed the convergence amount for a certain period of time, particularly in the least developed countries. Figure 2 illustrates this basic difference between a simple weighting formula and the Regensburg Formula. This means that, where the Regensburg Formula is applied, countries starting with emissions below their convergence amount are accorded lower emissions in total than in other convergence formulae.[12]

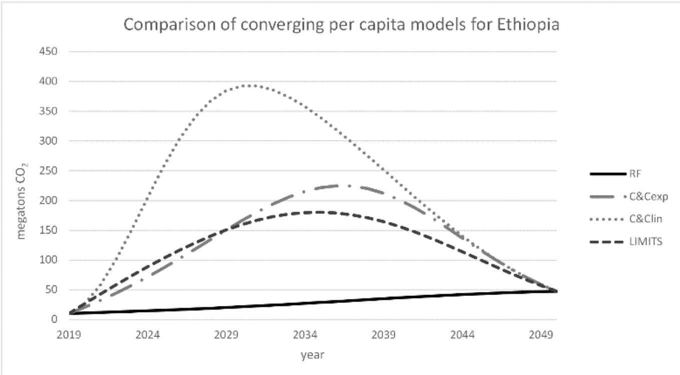

Figure 2: Comparison of converging per capita models for Ethiopia[13]

(2) Dependence on global pathway

A notable characteristic of the Regensburg Formula is that the cumulative budget in the convergence period attributed to a state (BG^i) does not depend on the concrete trajectory of the global emissions pathway as long as these pathways abide by the same global cumulative budget in the convergence period (BG) and the same global convergence amount (E_{CY}). This is shown by adding up all the emissions of a state during the convergence period:[14]

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[12] On www.save-the-climate.info a tool can be downloaded offering a detailed comparison of the various approaches working with the per capita distribution of the remaining budget.

[13] The parameter *a* to be definite in the exponential C&C alternative = 4.

[14] 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 emissions pathways followed by emissions trading between different countries within the

$$BG^i = \sum_{t=BY+1}^{CY} E_t^i = E_{CY}^i * (CY - BY) + (BG - E_{CY} * (CY - BY)) * \; a^i \qquad (4)$$[15]

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 (1) or (2) over the period of convergence, it becomes apparent that the national cumulative budget in the convergence period changes with different global pathways in the case of the simple weighting formulae, even if the global pathways meet the same global cumulative budget in the convergence period and the same global convergence amount.

(3) Behaviour in the case of increasing global emissions

In the simple weighting formulae, C_t is never negative and always increases monotonically. As a consequence per capita weighting has an increasing influence. In the Regensburg Formula, however, C_t is negative if global emissions are increasing. As a consequence, countries with emissions lower than their convergence amount in the base year (generally least developed countries) have to reduce their emissions. Since this effect is not reasonable, our suggestion for the transition period of globally increasing emissions is to apportion

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. For this purpose an alternative approach in the tool is integrated with a fixed convergence year, in which all the global scenarios attain the same global convergence amount (E_{CY}) and show the same cumulative budget in the convergence period. Direct allocations of the global cumulative budget to individual countries should not be made according to the 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 that the top-down allocation of the remaining budget is not on the political agenda, since the global community has at the moment chosen to adopt a policy of voluntary commitments.

[15] According to budget formula (4), 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. For mathematical arguments, see Wittmann and Wolfsteiner (2016), p. 8.

the annual increase between countries, using a simple weighting formula (cf. Sargl, Wolfsteiner, & Wittmann, 2016).

3. Application of the Regensburg Model

3.1 Determination of global pathways

Since a global pathway is required for the deduction of national pathways with converging per capita emissions, the authors have created a tool[16] that facilitates the determination of smooth global emissions pathways from 2020 to 2100 for anthropogenic CO_2 without FOLU emissions. In this tool the main parameters with respect to climate policy can be defined and different types of scenarios are available for calculating the concrete trajectory of the global pathway. The various types of scenarios for the global pathway differ primarily in the trajectory of the annual rates of change, as illustrated in Figure 3 using two selected types of scenarios.

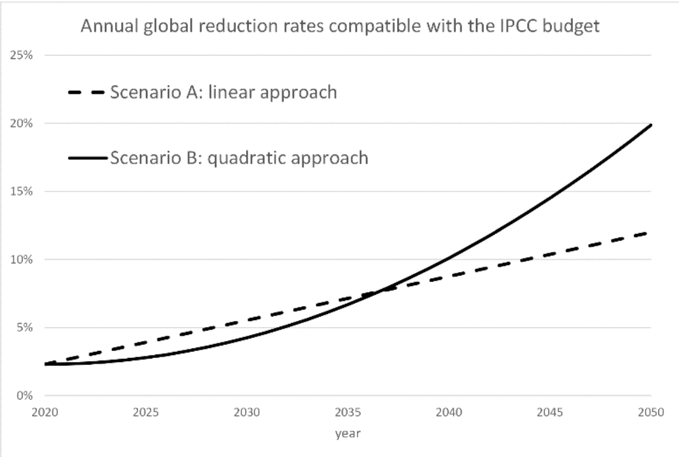

Figure 3: Annual global reduction rates for CO_2[17] compatible with the IPCC cumulative CO_2 budget of 2,900 Gt

The most important (political) parameters to be decided with respect to the determination of the global pathway are:

(1) What potential for global negative emissions should be taken into account?

Negative emissions originate, for example, when regenerative biomass is combusted and the emerging CO_2 captured and stored in a geologic repository (BECCS). However, it remains unclear how well BECCSs will perform.

In the tool, a minimum value can be set for the global emissions in 2100. Since this value can also be negative, global negative emissions can be represented.

[16] Download from www.save-the-climate.info. Correction after publication: ~~A simplified web application is available on line: www.climate-calculator.info, using the fixed convergence year 2050.~~

[17] CO_2 emissions caused by fossil fuels and cement production.

(2) Within what budget period should a given cumulative global budget of 2,900 Gt, for example, be adhered to?

If one permits global negative emissions, the question arises as to what extent occasional overshooting of the cumulative budget specified is compatible with climate change policy targets, such as the long-term undershooting of the 2°C limit or of a specific degree of acidification of the oceans. In our tool, we have taken 2100 as the end of the budget period. At this point occasional overshooting of the cumulative global budget specified must be compensated by global negative emissions. If a different limit to the overshoot amount, with respect either to the time or the quantity, is appropriate from a scientific viewpoint, e. g. because of such factors as tipping points or sinks, this could be incorporated into the tool. In the C&C model, this question is circumvented because it apparently does not foresee the possibility of global negative emissions. The C&C model also in principle takes 2100 as the end of the budget period (called the contraction period in the C&C model).

(3) Initial change in global emissions after the base year

In the tool, the change in global emissions in 2020 as a percentage compared to 2019 can be given as an initial value in some scenarios. Generally speaking, once a cumulative CO_2 budget has been set, it is possible to purchase moderate reductions in the near future (which makes economic sense), in exchange for higher reductions in the distant future (a trade-off). The global annual reduction rates in Figure 3 produce a reduction of 83% of global emissions in 2050 compared to 1990 in scenario A and 89% in scenario B. If the reduction were only 50% for example in 2050, significantly higher annual reduction rates in the 2020s and huge global negative emissions in the second half of the century would be needed. If the reduction is higher in 2050, lower annual reduction rates in the 2020s are possible. To our knowledge, in the C&C model there is no option available to set an initial rate of change in global emissions.

3.2 Reference values for every state in the world using the Regensburg Model

The tool includes a data base making it possible to calculate emissions pathways using the Regensburg Formula for almost every state in the world in such a manner that, on the one hand, these calculations lead to converging per capita emissions in the convergence period and, on the other hand, are compatible with a specific global cumulative budget. The distribution of global emissions among states after the convergence year – especially the distribution of global negative emissions – is not the subject of this article.[18]

To do so, two key input values can be set:

(1) Convergence level: tons per capita
The convergence year (CY) and thus also the global emissions in the convergence year (E_{CY}) result from the global pathway selected.

(2) Methods of determining the population figures for any state
The population figure is needed to calculate the convergence amount in the convergence year of any one state (E_{CY}^{i}).
The tool offers three methods:
   a. based on today's demographic forecast for the convergence year
   b. establishing a minimum figure based on population development with adjustments for the replacement fertility rate and the value forecast for the convergence year
   c. freezing the population data at that of the base year.

If the EU, China and Ethiopia are taken as examples, we arrive at the following rounded reference values (points of reference: 2030 and 2050): [19]

	Scenario A	Scenario B	Scenario A	Scenario B
	emissions ***2030*** compared to ***1990***		emissions ***2050*** compared to ***1990***	
EU	-50%	-45%	-95%	-100%
China	+190%	+220%	-70%	-85%
Ethiopia	+1,400%	+1,200%	+2,700%	+2,700%
	emissions ***2030*** compared to ***2010***		emissions ***2050*** compared to ***2010***	
EU	-40%	-35%	-95%	-95%
China	-15%	-5%	-90%	-95%
Ethiopia	+280%	+230%	+630%	+630%

Table 1: Examples of reference values using the Regensburg Model

Generally one can say that if the reference values according to the Regensburg Model are used, and if a country lags behind its reference values in its ambitions, then another country has to demonstrate higher ambitions than those indicated by its own reference value. This carries particular weight in cases where a state is responsible for a large proportion of global emissions.

[18] It would, for example, be conceivable to distribute negative global emissions on the basis of historic emissions and also to facilitate emissions trading.

[19] Tens rounded to the nearest 5%, hundreds to the nearest 10% and thousands to the nearest 100%.

According to its INDCs, the EU has announced a reduction by 2030 of 40% compared with 1990 so far. Using the Regensburg Formula (or one of the other converging formulae), the emissions from China, which are responsible for approximately one third of the global emissions, would already start to decline in 2020[20]. If China´s emissions continue to rise after 2020, as forecast in its INDCs, other countries, and probably the EU as a whole, would also have to make greater efforts.

The reference values in Table 1 also show that they are influenced by the choice of the global pathway, even though the cumulative budget of a state may be independent of the concrete choice of the global pathway in the special case described above (see Section 2.4[21]). For this reason, when communicating reference values, the underlying global pathway should also be described, at least the cumulative emissions by the point of reference should be mentioned.

The following table contains the parameters used and the results:

			remarks
Scenario Figure 3	A	B	
Type of scenario in the tool for the global pathway	change rates are in principle described by a linear function	change rates are in principle described by a quadratic function	There are four types and one for free input.
Period in which various global paths can be determined with the tool	2020 - 2100		Preset
Global cumulative budget since industrialization	2900 $GtCO_2$		Input values for the global paths
Global cumulative emissions since industrialisation by 2011[22]	1890 $GtCO_2$		
Global cumulative budget 2020 - 2100[23] (from here without FOLU emissions)	551 $GtCO_2$		
Minimum global emissions in 2100	-2 $GtCO_2$		
Rate of change of global emissions in 2020 compared to 2019	-2.3%	-2.3%	
Reduction in global emissions in 2050 compared with 1990	83%	89%	Results
Global cumulative emissions 2020 - 2030	347 $GtCO_2$	362 $GtCO_2$	
Global cumulative emissions 2020 - 2050	587 $GtCO_2$	625 $GtCO_2$	
First year with global negative emissions	2066	2058	
Global cumulative global negative emissions	57 $GtCO_2$	80 $GtCO_2$	
Method of determining population	Forecast		Input values for national paths
Convergence level	0.25 t CO_2 per capita		
BY; start of the convergence period: BY + 1	2019		Preset
CY; end of the convergence period	2053	2050	Results
Scenario used, in Figures	-	1 and 2	-

Table 2: Significant parameters and results

[20] The prerequisites for this statement to be true for China are that global emissions are already on the decline as of 2020, that the emissions from China in the base year are on a level above its convergence amount, and that there is no growth in population in China at the start of the 2020s.

[21] Correction after publication: incorrectly referred to section 2.2 in the publication.

[22] Correction after publication: Here we have misinterpreted the text of the IPCC. It was meant until the end of 2010. See also footnote: 2.

[23] In order to determine the budget as of 2020 for anthropogenic CO_2 without FOLU emissions, FOLU emissions for the period 2012 – 2100 are estimated (169 $GtCO_2$) and emissions for the period 2012 – 2019 are extrapolated (290 $GtCO_2$). These are also input values in the tool. FOLU emissions were not included, because it is difficult to find valid data for countries.

4. Conclusion

Using the Regensburg Model, reference values can be calculated for individual countries which are not only compatible with a specific cumulative budget for CO_2, corresponding to a specific rise in temperature, but which also implement converging per capita emissions.

The Regensburg Formula produces the lowest cumulative budget for the convergence period for the least developed countries of all convergence formulae. Besides this, using a convergence formula ignores a country's historical responsibility, and identical per capita emissions are not achieved until some point in the future. For this reason such a system must be complemented by appropriate financial and technological transfers to developing and especially to the least developed countries. This will comply with the basic principle of "common but differentiated responsibilities and respective capabilities" applicable to each state's contribution under the UN Framework Convention on Climate Change and the Paris Agreement (cf. UNFCCC, 2015b, Article 2, paragraph 2). Financial and technological transfers are already foreseen in the Paris Agreement. The transfer level would depend on the mitigation goals of the developed countries.

If global emissions decrease in the case of emerging countries such as China, it would be a problem to achieve a decrease, too, as would be the requirement in the models. The individual countries could argue that they have "only just" created the infrastructure for higher per capita emissions which they now have to decommission relatively soon. Developing countries, by contrast, would be able to create an infrastructure less dependent on fossil fuels immediately by giving them the corresponding financial and technical support. Considering these positions, the reference values for prosperous developed countries in the Regensburg Model (generally reduction rates) show a value + x. The x could be seen as the extra effort required to allow emerging countries to defer the reduction in their emissions somewhat in relation to the pathway in the Regensburg Model.

The reference values of the Regensburg Model are particularly pertinent where a developed country sets itself a less ambitious target. Such a country would be hard pressed to provide an explanation to justify its nationally determined contribution if it accepts converging per capita emissions in principle.

The Regensburg Model can be a useful starting point for civil society, enabling it to present political bodies, especially those in prosperous developed countries, with concrete reference values. However civil society has to depart from traditional patterns of behaviour. Usually civil society formulates ambitious goals and the political process tends to convert them into pragmatic results.

The reference values by the Regensburg Model, however, already reflect a high degree of pragmatism[24]. Analyses of the requisite global emissions pathways, however, show that higher degrees of national ambition must be targeted very soon to establish investment security required to achieve high annual global reduction rates (see Figure 3). Therefore it is reasonable for civil society to continue pressing for ambitious targets, bolstered up by the reference values produced by the Regensburg Model. It can demonstrate that national contributions made by prosperous developed countries are too small even if an allocation formula favourable to them has been used. Civil society can also demand that these states disclose what criteria they applied to the allocation of the global remaining cumulative CO_2 budget.

Recognizing all the limitations mentioned, the Regensburg Model offers a pragmatic means of combining the 2°C limit with the status quo of current emissions and the principle of "one human – one emission right", derived from Article 1 of the Universal Declaration of Human Rights.

[24] "Contraction and Convergence is a pragmatic approach reflecting the reality that no allocation principle can deliver a perfectly just outcome with respect to all forms of justice and the burdens and responsibilities of both past and future emissions. Its supporters also argue, correctly, that the greatest injustice will result from a failure in the part of the world community to mitigate emissions" (Makey & Rogers, 2015, p. 292 f.).

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