HELMHOLTZ
CLIMATE INITIATIVE

PROJECT BRIEFING #2

DEFINING THE GERMAN CARBON BUDGET

VERSION #1 | JUNE 2020

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AIM

Clarification of the overall carbon budget in Cluster I Net-Zero-2050 of the Helmholtz Climate Initiative.

SUMMARY

Net-Zero-2050 aims for a national roadmap for net-zero CO_2 emissions by 2050, including integrated scenario analyses and negative emission technology assessment (*see Project Briefing #1 "P1-Structure"*). This national target to substantially reduce national CO_2 emissions by 2050 stems from the objective to comply with the global long-term temperature limit of well below 2°C of the Paris Agreement (UNFCCC, 2015).

Within Net-Zero-2050 it is therefore important to decide on an approach for deriving a national remaining carbon budget from future global emissions trajectories. Allocating national carbon budgets is a balance of environmental effectiveness, equity, national capacity and ability, political feasibility, economic efficiency and technical requirements (Gignac and Matthews, 2015; Höhne et al., 2003; 2014).

Given Germany's capacity and abilities, we decided to follow a sustainable growth trajectory with a convergence phase to equal-per-capita CO_2 emissions by 2035, and a net-zero CO_2 emissions trajectory after 2050 until the end of the century. This approach leads to a remaining German CO_2 budget (1st January 2018 to 2050 and 2100) of 10 $GtCO_2$, which we propose to be used across the cluster Net-Zero-2050. This remaining carbon budget will serve as a target to be used in all work packages in a concerted way, either qualitatively or quantitatively, and in accordance with other work packages *(see also Project Briefing #4 "Scenario Approach")*.

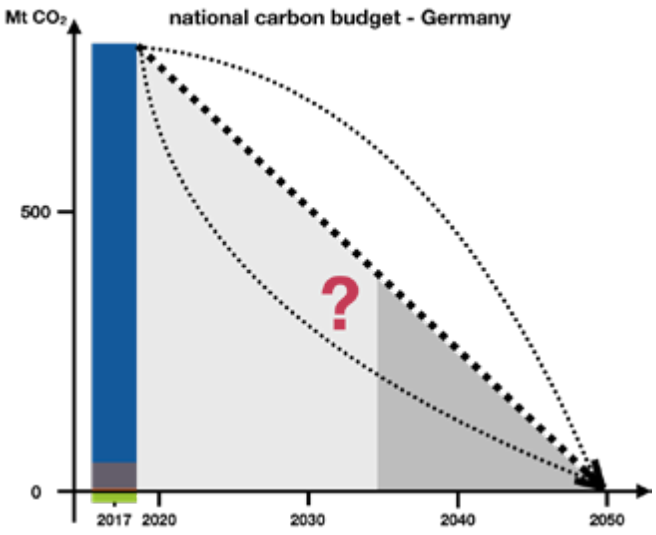

Figure 1: German CO_2 emissions as reported to the UNFCCC in 2017 by sector: Energy (blue), Industrial Processes and Product Use (grey), Agriculture (orange) and Land Use, Land-Use Changes and Forestry (green). Black arrows illustrated possible idealized pathways to Net-Zero-2050.

This national carbon budget is at the lower end of the range of the budget if allocated by the grandfathering approach (emissions are allocated with respect to today's emissions shares: 7.4 to 14.8 $GtCO_2$), but slightly higher than the largest estimate of an equal-per-capita remaining carbon budget (emissions are allocated with respect to Germany's share of the global population: 4.7 to 9.4 $GtCO_2$).

The 10 $GtCO_2$ national remaining CO_2 budget will need to be broken down by category (e.g. energy, land use, industrial processes, and man-made sinks and sources) in order to provide a consistent approach across work packages.

NET-ZERO-2050 CARBON BUDGET ANALYSIS

National carbon budget allocation:

Allocating national carbon budgets is a balance of environmental effectiveness, equity, national capacity and ability, political feasibility, economic efficiency and technical requirements (Gignac and Matthews, 2015; Höhne et al., 2003; 2014). The remaining CO_2 budget (beyond 1st January 2018) for a global mean near-surface air temperature change of 1.5°C amounts to 420 to 840 $GtCO_2$. Key uncertainties surrounding this estimate include: historical temperature uncertainties, the committed warming contribution, non-CO_2 scenario forcing and response uncertainties, recent emissions uncertainties, the distribution uncertainty of the transient climate response to cumulative emissions, and the carbon contribution from unrepresented Earth system feedbacks (like permafrost thawing; Rogelj et al., 2018).

Literature pertaining to the national allocation of future emissions can be framed within two prominent approaches:

1) the 'grandfathering' approach would allocate the remaining carbon budget based on current national shares of emissions (Neumayer, 2000; Caney, 2009; Raupach et al., 2014), and

2) the equal-per-capita approach would allocate a national carbon budget that is equal to the respective share of the nation's world population (Neumayer, 2000; Caney, 2009; Raupach et al., 2014).

Both these approaches include international justice considerations. The grandfathering approach takes the so-called 'lock-in' effect into account, which acknowledges the difficulty to mitigate emissions from developed countries because they are already committed to future emissions due to their existing infrastructure. In contrast, the equal-per-capita approach accounts for international equity and thereby 'simply' allocates the same budget to each person on the planet. Accordingly, the German budget would range from 7.4 to 14.8 $GtCO_2$ under the grandfathering approach (based on German share of fossil-fuel and land-use emissions in 2018 (Friedlingstein et al., 2019; UBA, 2019), i.e., 1,763 %) and from 4.7 to 9.4 $GtCO_2$ for the equal-per-capita approach (based on German share of population in 2018, i.e., 1,1 %).

These two approaches do not, however, take into consideration the historic contribution to climate change – a country's carbon debt or credit. At its most basic, this can be estimated as a function of how much a country would have emitted, had the allocation been divided based on **per capita**, starting at a time when the world can be said to have known about climate change, usually 1990 (Caney, 2009; den Elzen et al., 2005). The idea of accounting for historical contribution to climate change is that the countries that have benefitted from fossil fuel intensive development thereby also have the resources to transform themselves (see e.g. Neumayer, 2000; Pickering & Barry, 2012; Vanderheiden, 2008). Germany's carbon debt has been estimated to about 12 $GtCO_2$ (Matthews, 2016), which would mean that Germany would have a very small or non-existing carbon budget left to spend in the future based on its historic contribution to climate change.

A compromise between approaches to derive national remaining carbon budgets, is the framework for the allocation of emission allowances, called contraction and convergence (C&C). This approach was developed by the Global Commons Institute (Meyer, 2000) and consists of a two-step process. First, the national per capita emissions are decreased/increased for some period of time until they converge to a point of equal per capita emissions at a given year (for example 2035, see Fig. 2), which allows for a transition period where

countries can overcome their respective lock-ins or further develop their nation. In the second part, all nations are entitled to the same annual per capita emissions, and therefore nations stop accumulating carbon debts.

GERMANY'S CO_2 BUDGET AS PROJECTED BY NET-ZERO-2050

The trajectory as used by **Net-Zero-2050** is marked by three phases (see yellow line in Fig. 2):

1) Convergence phase from 2021 until 2035 – This is the time in which Germany's emissions converge to meet their equal per capita share of global emissions in 2035. During this period, Germany's emissions are decreasing most strongly, marking the most ambitious phase of climate mitigation in Germany, with a reduction of 39.8 Mt CO_2/year.

2) equal per capita emissions – After 2035 the German share of emissions follows the equal per capita share of global emissions and population projections following a sustainable 1.5°C scenario with an end of the century global radiative forcing of 1.9 (Shared socio-economic pathway (SSP) 1-1.9 from Rogelj et al., 2018).

3) Net-zero emissions 2050 – In 2050 Germany's emissions reach net-zero and remain at this level until the end of the century. This is employed to avoid possible compensation of 'overspending' the carbon budget in the first half of the century by net negative CO_2 emissions in the second half.

The corresponding carbon budget of this trajectory is 10.0 $GtCO_2$ (integrated between 2018-2100).

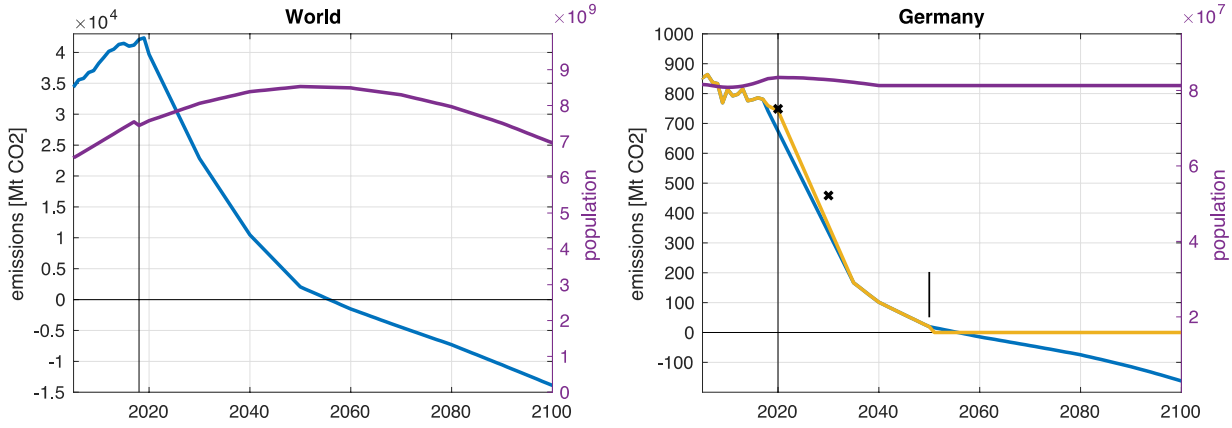

Figure 2: **(left) SSP1** global population development (purple line) and emissions trajectories corresponding to an end of the century temperature change of 1.5 ºC (SSP1-1.9, blue line). **(right)** Germany's population projection (BMWi 2019, purple line), and emissions estimates following SSP1-1.9 (blue), applying the contraction and convergence approach with a convergence year of 2035. The Net-Zero-2050 trajectory as described in Section 3 (yellow). For comparison the CO_2 emissions reduction targets from the German Government as given by BMWi 2019 (black crosses and black bar).

UNCERTAINTIES AND ASSUMPTIONS SURROUNDING THE NATIONAL CARBON BUDGET

Emissions between 2018 and 2021

As of April 2020, the newest data from the German government for emissions past 2018 has not been made available. To start with scenarios in 2021, we extrapolated the 2014-2018 trend of Germany's emissions, resulting in emission estimates of 751 Mt CO_2 in 2019 and 742 Mt CO_2 in 2020.

Emissions between 2021 and 2050

To arrive at a trajectory for Net-Zero-2050, which is needed for some analysis done within the cluster) we assumed that Germany and the rest of the world would follow a trajectory of sustainable growth, corresponding to the **Shared Socioeconomic Pathway 1** (SSP1, from IPCC SR1.5, Rogelj et al., 2018). On a global level this corresponds to a low estimate of population growth, a high economic growth per capita and economic convergence and global cooperation, high human development and technological progress, environmentally oriented technological and behavioural changes including resource-efficient lifestyles, and accordingly low energy and food demand per capita. In Net-Zero-2050 we assume that Germany will be part of this global development.

Furthermore, in agreement with the long-term temperature goal of the Paris Agreement (UNFCCC, 2015; Rogelj et al., 2018), Net-Zero-2050 will keep the overarching carbon budget for Germany between the estimates of an end-of-the-century warming of 1.5°C or 2°C trajectories. As the SSP1-1.9 emissions trajectory reaches net zero in 2055, this will be the approximate reference scenario for our German trajectory.

Net-Zero-2050 applied the C&C approach to estimate the German carbon budget allocation taking into account international equity, national capacity and ability, political feasibility, economic efficiency and technical requirements. The point of equal per capita emissions is projected to be reached in 2035 (Fig. 2). Until then, Germany has time to overcome any infrastructural lock-in. After this point, Germany would be emitting its 'fair share' of global emissions and would accordingly stop accumulating carbon emission debt.

Assumptions on national emissions post-2050

There are two main trajectories after 2050: 1) Germany aims for net-negative emissions, or 2) Germany stays at net-zero emissions:

1) If Germany aimed for net-negative CO_2 emission after 2050, we would follow a so-called 'temperature overshoot' trajectory. The overall remaining carbon budget until 2100 would remain the same to still be in agreement with the end-of-century temperature goals. However, the assumed possibility of net-negative CO_2 emission in the second half of the century combined with discounting the costs of long-term compared to present-day mitigation, would result in higher emissions allowances during the first half of the century. This would correspond to a higher remaining carbon budget until the point of net-zero CO_2 emissions in 2050.

2) In contrast to that, assuming a **net-zero emissions pathway** after 2050 is a more cautious approach. In this case, Germany would aim for temperature stabilisation after 2050 in compliance with the long-term temperature goal of the Paris Agreement (Rogelj et al., 2019b). With **net-zero emissions** after 2050, the 2050-2100 CO_2 budget is zero, and given the same end of the century temperature goals does not act to increase the carbon budget prior to net-zero CO_2 emissions, so the budget for 2018-2050.

For the emission scenarios of Net-Zero-2050 we assumed that Germany will reach net-zero CO_2 emissions in 2050 and remain at this level until the end of the century.

REFERENCES

- BMWi (2019). Entwurf des integrierten nationalen Energie- und Klimaplans, Bundesministerium für Wirtschaft und Energie.
- Caney S 2009 Justice and the distribution of greenhouse gas emissions J. Glob. Ethics 5 125–46
- Collins M et al. 2013 Long-term climate change: projections, commitments and irreversibility Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ed T F Stocker, D Qin, G K Plattner, M Tignor, S K Allen, J Boschung, A Nauels, Y Xia, V Bex and P M Midgley (Cambridge, UK: Cambridge University Press) pp 1–108
- den Elzen, M., Fuglestvedt, J., Höhne, N., Trudinger, C., Lowe, J., Matthews, B., . . . Andronova, N. (2005). Analysing countries' contribution to climate change: scientific and policy-related choices. *Environmental Science & Policy*, 8(6), 614-636. https://doi.org/10.1016/j.envsci.2005.06.007
- Friedlingstein, P., et al. „Global carbon budget 2019." *Earth System Science Data* 11.4 (2019): 1783-1838.
- Gignac, R., and H. D. Matthews. „Allocating a 2 C cumulative carbon budget to countries." *Environmental Research Letters* 10.7 (2015): 075004.
- Höhne N, den Elzen M and Escalante D 2014 Regional GHG reduction targets based on effort sharing: a comparison of studies Clim. Policy 14 122–47
- Höhne N, Galleguillos C, Kornelis B, Harnisch J and Phylipson D 2003 Evolution of Commitments Under the UNFCCC: Involving Newly Industrialized Economies and Developing Countries (Berlin, Germany: Ecofys/Federal Environmental Agency)
- Matthews, H. Quantifying historical carbon and climate debts among nations. *Nature Climate Change* 6, 60–64 (2016). https://doi.org/10.1038/nclimate2774
- Meyer A 2000 Contraction and Convergence: The Global Solution to Climate Change (Foxhole, Devon: Green Books)
- Neumayer E 2000 In defence of historical accountability for greenhouse gas emissions Ecol. Econ. 33 185–92
- Raupach M R, Davis S J, Peters G P, Andrew R M, Canadell J G, Ciais P, Friedlingstein P, Jotzo F, van Vuuren D P and Le Quere C 2014 Sharing a quota on cumulative carbon emissions Nat. Clim. Change 4 873–9
- Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V.Vilariño, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.
- Rogelj, J., Huppmann, D., Krey, V. et al. A new scenario logic for the Paris Agreement long-term temperature goal. *Nature* 573, 357–363 (2019). https://doi.org/10.1038/s41586-019-1541-4
- Pickering, J., & Barry, C. (2012). On the concept of climate debt: its moral and political value. *Critical Review of International Social and Political Philosophy*, 15(5), 667-685. doi:10.1080/13698230.2012.727311
- Umweltbundesamt (UBA), Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen seit 1990, Emissionsentwicklung 1990 bis 2017, Stand 02/2019
- UNFCCC, C. Adoption of the Paris Agreement. I: *Propos. by Pres. (Draft Decis. United Nations Off. Geneva (Switzerland)* (2015).
- Vanderheiden S 2008 *Atmospheric Justice: a Political Theory of Climate Change* (New York: Oxford University Press)

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