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PROJECT BRIEFING #2

NET-ZERO-2050 CLUSTER: DEFINING THE GERMAN CARBON BUDGET

VERSION #2 | OCTOBER 2021

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AIM

Clarification of the overall carbon budget in Cluster 1: Net-Zero-2050.

SUMMARY

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

Within the cluster it is therefore important to decide on an approach for deriving a national remaining carbon budget from global emissions trajectories in agreement with the Paris Climate Agreement's long-term temperature goal (UNFCCC, 2015). 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 Germany CO_2 budget of 9 $GtCO_2$ (from 1st January 2018 to 2050 and 2100), which we propose to be used across the **Net-Zero-2050** cluster. The 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 fact sheet *Net-Zero-2050 Energy Scenario Approach*).

The calculated budget is at the lower end of the national budget if allocated by the grandfathering approach (emissions are allocated with respect to today's emissions shares: 5.5-13.1 $GtCO_2$), but slightly higher than the highest estimate of an equal-per-capita remaining carbon budget (emissions are allocated with respect to Germany's share of the global population: 3.5-8.4 $GtCO_2$)

The 9 $GtCO_2$ national remaining CO_2 budget, 6.9 $GtCO_2$ from 1st January 2021, will need to be broken down by category (e.g. energy, land use, industrial processes, and man-made sinks and sources; see *Gap Analysis Report*) in order to provide a consistent approach across work packages.

NET-ZERO-2050 CARBON BUDGET ANALYSIS

1. 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 (after 1st January 2018) for a global mean near-surface air temperature change of 1.5ºC (relative to the 1850-1900 base period) amounts to 420 to 840 Gt CO_2 (67th to 33rd percentile, respectively; source IPCC SR1.5). New estimates of the remaining carbon budgets with improved uncertainty constraints give a range of 315 to 755 Gt CO_2 from 1st January 2018 (Matthews et al., 2021). Percentiles of the carbon budget stem from the uncertainty estimated from the transient climate response to cumulative CO_2 emissions (TCRE), which accounts for model uncertainties of this estimate as given in AR5 (Collins et al., 2013). 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 TRCE itself, 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 nations 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. 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). Additional considerations such as existing infrastructure and lock-in in line with the grandfathering approach outlined above can also be included (Matthews, 2016). From a climate justice point of view, the main difference to the grandfathering approach is that grandfathering considers existing lock-in. However, 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 (see e.g. Neumayer, 2000; Pickering & Barry, 2012; Vanderheiden, 2008). Germany's carbon debt has been estimated to about 12 Gt CO_2 (Matthews, 2016), which means that Germany would have a very small or non-existing carbon budget left to spend in the future based on the historic contribution to climate change. On a global level, the remaining carbon budget is small and the challenges associated with the rapid decarbonization it would entail for developed countries and countries with historically large land-use changes to incorporate their carbon debts in their respective carbon budgets important. The debate around carbon debt and credit has instead been used to inform discussions on compensation and remedies (Matthews, 2016).

Accordingly, the German budget would range from 5.6 to 13.3 Gt CO_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 3.5 to 8.3 Gt CO_2 for the equal-per-capita approach (based on German share of population

in 2018, i.e., 1,1 %), both estimates use the updated estimate for the remaining budget from Matthews et al. (2021).

An alternative to these two 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 (e.g., 2035, see Fig. 1), 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 (see Gap Analysis Report).

2. UNCERTAINTIES AND ASSUMPTIONS SURROUNDING THE NATIONAL CARBON BUDGET

2.1 Emissions between 2021 and 2050

To arrive at a trajectory for the Net-Zero-2050 cluster, 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 behavioral changes including resource-efficient lifestyles, and accordingly low energy and food demand per capita. In the Net-Zero-2050 cluster we assume that Germany will be part of this global development. For German population prognosis we follow the National Energy und Climate Plan (NECP) until 2041, and assume constant population thereafter (BMWi 2019).

Furthermore, in agreement with the long-term temperature goal of the Paris Agreement (UNFCCC, 2015; Rogelj et al., 2018), the Net-Zero-2050 cluster will keep the overarching carbon budget for Germany between the estimates of an end of the century radiative forcing of 1.9 (SSP1-1.9, corresponds to a 1.5ºC temperature change trajectory) and 2.6 (SSP1-2.6, corresponds to a 2ºC temperature change trajectory). As the SSP1-1.9 emissions trajectory reaches net zero in 2055, this will be the reference scenario for our German trajectory.

The Net-Zero-2050 cluster 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. 1). Until then, Germany has time to overcome any infrastructural lock-in. After this point, Germany would be emitting its ‘fair share’ of global emissions (which corresponds to the SSP1-1.9 emissions trajectory) and would accordingly stop accumulating carbon emission debt.

2.2 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 substantial 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, so 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 stabilization 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 **Net-Zero-2050** cluster's emission scenarios we assumed that Germany will reach net zero CO_2 emissions in 2050 and remain at this level until the end of the century.

3. GERMANY'S CO_2 BUDGET AS PROJECTED BY THE NET-ZERO-2050 CLUSTER

The trajectory as used by the **Net-Zero-2050** cluster is marked by three phases (see yellow line in Fig. 1):

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 annual emissions are decreasing most strongly, marking the most ambitious phase of climate mitigation in Germany, with a reduction of 30.5 Mt CO_2/year each 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 the 1.5ºC scenario from the IPCC SR1.5, the SSP1 with an end of the century global radiative forcing of 1.9 (SSP1-1.9).

3) Net zero emissions 2050 – In 2050 Germany's emissions reach net zero and remain at this level until the end of the century.

The corresponding carbon budget of this trajectory is 9 Gt CO_2, integrated between 2018-2100, or 6.9 Gt CO_2, integrated between 2021–2100. Due to the initial convergence phase, this estimate is slightly higher than the equal-per-capita share of the 33rd percentile of the 1.5ºC carbon budget estimate from the IPCC SR1.5, but corresponds approximately to the grandfathered share of the 50th percentile of the 1.5ºC carbon budget estimate from the IPCC SR1.5.

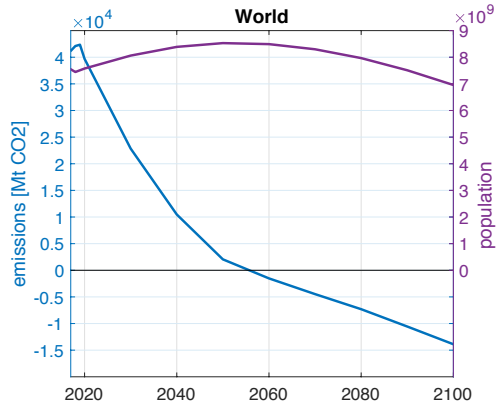
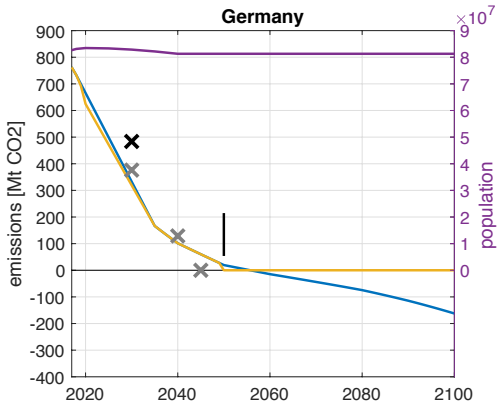


Figure 1: SSP1 global population development (purple line) and emissions trajectories corresponding to an end of the century radiative forcing of 1.9 (SSP1-1.9, corresponds to a 1.5 ºC temperature change trajectory, blue line).



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 CO2 emissions reduction targets from the German Government as given by BMWi 2019 (black crosses and black bar) as well as from its Novella in 2021 (grey crosses) are shown (see BMU 2021).

REFERENCES

- BMU (2021), abgerufen: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Glaeserne_Gesetze/19._Lp/ksg_aendg/Entwurf/ksg_aendg_bf.pdf
- 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). 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
- Umweltbundesamt (UBA), Vorjahreschätzung der deutschen Treibhausgas-Emissionen für das Jahr 2020, Dessau, März 2021, Internet: http://www.umweltbundesamt.de/emissionen
- 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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