



German Advisory Council  
on the Environment

# Where do we stand with Germany's CO<sub>2</sub> budget? An update

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**STATEMENT** | October 2024

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*Note: This text is a translation of the statement “Wo stehen wir beim CO<sub>2</sub>-Budget? Eine Aktualisierung” , originally published in German in March 2024, updated in October 2024. However, the “Report on the review of the GHG-Projection-Data 2024” by the Council of Experts on Climate Change (ERK 2024) published in June 2024 has been included in the English translation in two text passages.*

# 1. Introduction: An update of the remaining CO<sub>2</sub> budget from 2024

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The upper limits for global warming of 1.5 °C and “well below 2 °C” agreed in the Paris Climate Agreement (Art. 2.1a) can be used to derive CO<sub>2</sub> budgets on the basis of scientific calculations. A global CO<sub>2</sub> budget specifies the total amount of emissions that may still be emitted in order to stay within the respective climate limit with a certain probability. On the basis of a few necessary further assumptions, a fair share for Germany can be derived from this, i.e. a sufficient, appropriate and fair German CO<sub>2</sub> budget. The German Advisory Council on the Environment (SRU) proposed a calculation method in its 2020 environmental report and in a statement from 2022 and identified CO<sub>2</sub> budgets depending on the selected temperature target and a probability of achieving the target. It recommended that the Federal Government commit to a CO<sub>2</sub> budget in its climate policy (SRU 2020, chap. 2; 2022). The Federal Constitutional Court has also emphasised that a national CO<sub>2</sub> budget is a suitable benchmark for a transparent climate policy (BVerfG, decision of 24 March 2021 – 1 BvR 2656/18). It allows an assessment of whether national targets are in line with the Paris Climate Agreement.

The methodology used by the SRU to calculate fair CO<sub>2</sub> budgets for Germany and the EU is based on well-founded derivations (SRU 2020, chap. 2). The Federal Constitutional Court spoke of “comprehensible assumptions and conclusive calculation steps” (BVerfG, decision of 24 March 2021 – 1 BvR 2656/18, para. 220 et seq.). The necessary assumptions in the calculation path that exist due to scientific uncertainties and necessary normative decisions were deliberately chosen generously in favour of Germany’s budget share (SRU 2022, Question 11). For example, Germany’s high historical emissions were neglected. Instead, the allocation of the global budget was based on Germany’s share of the global population in 2016, when the Paris Climate Agreement formally came into force. There are strong arguments in favour of distribution approaches according to which Germany would be entitled to a significantly lower national budget. In the opinion of the SRU, a politically agreed German CO<sub>2</sub> budget should therefore be based at least on the budget proposed by the SRU. It can be used as a benchmark for contextualising and evaluating the actual trajectory of

emissions and a politically, economically and technologically feasible emissions reduction pathway.

To date, however, neither has a German CO<sub>2</sub> budget been anchored in climate policy, nor has the German government clearly explained whether and according to which assumptions the reduction pathway of the current Federal Climate Protection Act (KSG) is in line with the temperature targets of the Paris Climate Agreement (transparency gap). The cumulative emissions resulting from the KSG are significantly higher than the CO<sub>2</sub> budgets the SRU considers a fair contribution to the goals of the Paris Climate Agreement (ambition gap). Germany has made significant progress in climate protection in important areas and unplanned developments (weak economy, warm winter) have led to additional emission reductions. The Federal Environment Agency considers the emissions reduction target for 2030 to be achievable, but the targets for the land use, land use change and forestry (LULUCF) sector also set out in the KSG are projected to be missed by a wide margin (UBA 2024b). However, in its assessment of the German Environment Agency’s latest projection report, the Council of Experts on Climate Change (ERK) again concludes that the greenhouse gas emission reduction goals set out in the KSG for the period 2021 to 2030 are more likely to be missed than achieved (ERK 2024). In the buildings and transport sectors, the climate protection measures are still not sufficient, meaning that there will at least be a gap between cumulative emissions over the period 2021 to 2030 and the targets of the EU Climate Protection Regulation (UBA 2024b; ERK 2023b). In view of the considerable consequences of looming global warming, a significant further development of climate policy and corresponding climate protection measures therefore remains a key task for German policy.

With this update, the SRU actualises its CO<sub>2</sub> budget calculations to reflect the latest scientific findings. It takes into account the CO<sub>2</sub> emissions emitted since the SRU’s last update and identifies points for discussion arising from the significantly reduced or even depleted budgets. The calculation method and other aspects of national CO<sub>2</sub> budgets are discussed in more detail in the previous reports (SRU 2020, chap. 2; 2022).

## 2. The updated CO<sub>2</sub> budget for Germany and the EU-27 from 2024

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In the following, the SRU updates its CO<sub>2</sub> budgets for Germany and the EU to the beginning of 2024 (Table 1). The calculation method itself has not changed (see SRU 2022, Question 7; 2020, Box 2-2). However, new emissions data for the years since the last update of the SRU (UBA 2024a; FRIEDLINGSTEIN et al. 2023) and scientific updates of the remaining global CO<sub>2</sub> budget by FORSTER et al. (2023) are used. This update of the evaluation in IPCC AR6 WG I (Report of Working Group I in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC 2021b) takes into account the CO<sub>2</sub> emissions of recent years (IPCC AR6 budgets were valid from 2020) as well as more recent calculations of current global warming. Furthermore it uses a newer version of a climate model. This model, which was already applied in AR6 WG III (IPCC 2022), depicts the previously underestimated cooling effect of aerosols better than before. However, as aerosol emissions will decrease in the medium term due to the declining combustion of fossil fuels and their cooling effect will therefore decrease, greater warming than previously forecast is to be expected for the same emission scenarios when the stronger cooling effect is accounted for. This reduces the remaining budgets more than would have been the case based solely on the emissions of recent years and the current global warming (see Fig. 2 in the Appendix). In addition, the database of emission pathways for the model has also been updated and now employs the newer scenarios from AR6 WG III. AR6 WG I was based on the older scenario database from the SR1.5 Special Report (IPCC 2018). More detailed explanations of the methodological updates compared to IPCC AR6 WG I can be found in the Appendix.

Due to the methodologically improved global budget estimates, the CO<sub>2</sub> emitted since the last update and the increased global average temperature, the remaining CO<sub>2</sub> budgets have become smaller: The upper limit of Germany's fair share of the remaining global CO<sub>2</sub> budget for 1.5 °C has already been used up according to the SRU method (where currently largely speculative measures such as future removal of CO<sub>2</sub> from the atmosphere or budget purchases abroad are not considered). The German CO<sub>2</sub> budget for a warming limit of 1.75 °C and a probability of 67 % to stay within this limit will last for around 12 years when assuming a linear reduction in emissions until net-zero CO<sub>2</sub> emissions. The situation in

the EU is not much better: the budgets for 1.5 °C are about to be exceeded within a few years. The budget for 1.75 °C with a 67 % probability will be exhausted in 22 years if emissions are reduced linearly.

The choice of a budget distribution based on the proportion of the world's population is a well-founded, pragmatic way of determining a fair and sufficient upper limit for the CO<sub>2</sub> budget, both in terms of ethical issues and from the perspective of international climate policy (see SRU 2022, Question 9): Among conceivable alternative distribution principles, it represents a middle way between international climate justice and the results of analyses on the economic optimality of the global distribution of emission reductions. The latter generally favour countries with high emissions, as these are particularly dependent on existing fossil fuel infrastructures, which has economic implications of international relevance. It is also argued that the most macroeconomically favourable solutions offer the best opportunities for real progress in climate protection. However, this is countered by the fact that, from the perspective of climate justice (in accordance with the polluter pays principle), those industrialised countries that have caused the majority of historical greenhouse gas emissions and thus global warming bear a particularly large responsibility to reduce emissions quickly. The German Advisory Council on Global Change (WBGU) already recognised this in 2009 when it first recommended the concept of a CO<sub>2</sub> budget to the German government (WBGU 2009). Furthermore, the improved economic, technical and structural capacity of rich countries to act provides an additional argument in favour of an even more substantial contribution by these countries to climate protection. This is also suggested by the principle of common but differentiated responsibilities in the Paris Climate Agreement (Art. 2.2). Countries with low historical or current emissions refer to this and regularly emphasise in international climate negotiations the need for industrialised countries with high emissions to take on a pioneering role.

The SRU's calculation method chooses a middle ground between these two argumentations by referring to Germany's share of the population. However, the effects of altered assumptions based on these two positions can be illustrated exemplarily:

- If the polluter-pays principle as an expression of international climate justice and thus Germany's historical emissions were taken more into account, 1992 could be chosen as the base year instead of 2016. At that time, the UN Framework Convention on Climate Change was adopted as the basis for international climate policy, in particular the subsequent Paris Climate Agreement, and signed by 154 countries. In this case, Germany's CO<sub>2</sub> budget for the temperature target of 1.75 °C would have already been exceeded many years ago.
- On the other hand, due to economic and political considerations, the dependence of industrialised countries

on fossil infrastructures with their higher current emissions and their role in global trade can be taken more into account. A hypothetical case is examined to illustrate the effects of Germany being granted a 25 % larger share than would result from the population share. In this case the budgets for 1.5 °C would not be used up yet but they would still be very small and would amount to 0.6 Gt CO<sub>2</sub> (67 % probability of achieving the target) or 1.5 Gt CO<sub>2</sub> (50 %). With a linear reduction in emissions, they would be used up by 2026 and 2029, respectively. The budget for 1.75 °C (67 %) would amount to 6.1 Gt CO<sub>2</sub> and would last until 2044 with a linear reduction in emissions.

### Table 1

SRU proposal: Maximum CO<sub>2</sub> budgets from the beginning of 2024

Maximum CO <sub>2</sub> budget in Gt CO <sub>2</sub>		World					
		1.75 °C, 67 %		1.5 °C, 50 %		1.5 °C, 67 %	
IPCC AR6 <sup>1</sup>	from 2020	775		500		400	
IPCC AR6 <sup>1</sup> (minus emissions 2020–2022)	from 2023	655		380		280	
FORSTER et al. <sup>2</sup>	from 2023	569		231		168	
Maximum CO <sub>2</sub> budget in Gt CO <sub>2</sub> from 2024		Germany			EU		
		1.75 °C, 67 %	1.5 °C, 50 %	1.5 °C, 67 %	1.75 °C, 67 %	1.5 °C, 50 %	1.5 °C, 67 %
based on IPCC AR6 <sup>1</sup>		4.7	1.7	0.6	33.6	17.4	11.4
based on FORSTER et al. <sup>2</sup>		3.8	0.1	-0.6	28.7	8.7	4.9
Year in which the CO <sub>2</sub> budget is (or was) used up assuming a linear emissions reduction							
based on IPCC AR6 <sup>1</sup>		2039	2029	2026	2050	2037	2033
based on FORSTER et al. <sup>2</sup>		2036	2024	2021	2046	2030	2027

Notes:

1. The German CO<sub>2</sub> budget for 1.5 °C/50 % is positive in the table, but the amount of CO<sub>2</sub> emissions stated there is likely to have already been emitted in the first quarter of 2024.

2. The CO<sub>2</sub> emissions analysed include LULUCF emissions.

3. Updated global budget figures are not only given in FORSTER et al. (2023), but also in LAMBOLL et al. (2023) (for two variants: “default update” and “recommended update”). In the latter publication, however, uncertainties relating to the further course and influence of non-CO<sub>2</sub> greenhouse gas emissions are included differently in the presentation of the results than in FORSTER et al. (2023). In particular, the values for probabilities greater or less than 50 % are therefore not directly comparable with those of FORSTER et al. (ibid.) and the IPCC AR6 (IPCC 2021b). In contrast, FORSTER et al. (2023) offers better comparability with the IPCC reports, which is why it is used as the basis for this update of the German budget figures. For comparison: The German CO<sub>2</sub> budget for 1.5 °C/50 % amounts to 1.0 Gt CO<sub>2</sub> (default update) and 0.3 Gt CO<sub>2</sub> (recommended update) with the figures from LAMBOLL et al. (2023). The CO<sub>2</sub> budget for the EU amounts to 13.7 Gt CO<sub>2</sub> (default update) and 9.6 Gt CO<sub>2</sub> (recommended update) for the 1.5 °C/50 % case using the figures from LAMBOLL et al. (ibid.). See Appendix for further explanations.

Sources: <sup>1</sup> IPCC 2021b; <sup>2</sup> FORSTER et al. 2023; UBA 2024a; LAMBOLL et al. 2023; FRIEDLINGSTEIN et al. 2023

Figure 1 shows the historical development of CO<sub>2</sub> emissions (blue line) in Germany and the resulting cumulative CO<sub>2</sub> emissions (black line) on the left. The bars on the right-hand side of the figure correspond to different CO<sub>2</sub> budgets, which vary in size depending on the temperature target, the probability of achieving the target and the base year selected. It becomes clear that all budgets with a base year of 1992 have already been exceeded. Only the 1.75 °C budget with a 67 % probability of achieving the target and base year 2016 still leaves open the opportunity for Germany to act within the CO<sub>2</sub> budget (see also Table 1).

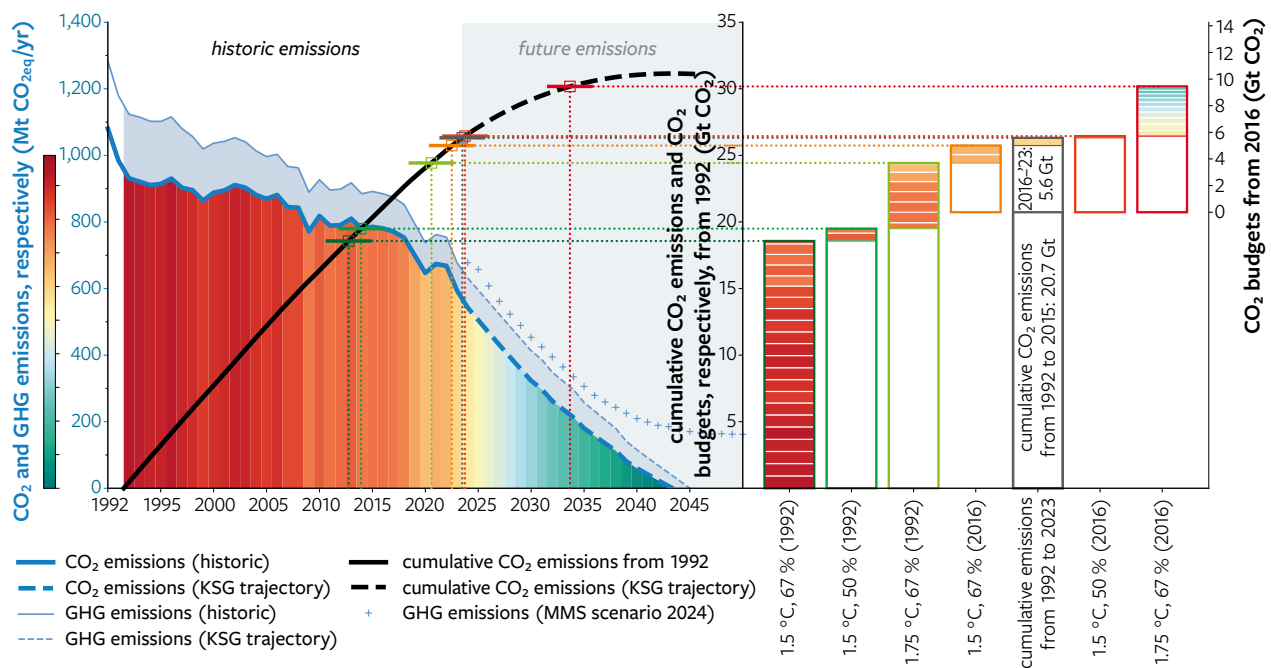
Under certain assumptions (see Appendix), a CO<sub>2</sub> reduction pathway can also be derived from the KSG (blue dashed line). If this were adhered to, the budget for 1.75 °C (67 %) would be exceeded around 2033. So if it

is argued that German climate policy corresponds to a 1.5 °C pathway, it would have to be made transparent on which assumptions and analytical results (e.g. contribution of negative CO<sub>2</sub> emissions) this statement is based. In addition, appropriate measures would have to be taken to ensure that these assumptions can be met. According to the SRU's calculations, the KSG pathway is above a pathway for 1.75 °C (67 %), but still well below 2 °C (SRU 2022, Question 13). Given the related challenges, meeting the statutory German climate targets would therefore be a considerable success, also by international standards. In the SRU's view, the remaining gap to the widely declared goal of limiting global warming to 1.5 °C must be quantified and discussed politically.

There are several ways to justify the significantly larger emissions budget for Germany which implicitly results

Figure 1

## CO<sub>2</sub> budgets and development of annual and cumulative emissions



The figure illustrates the relationship between historical and, respectively, future CO<sub>2</sub> emissions derived from the KSG (thick blue line and coloured stripes), cumulative CO<sub>2</sub> emissions (black line) and the various CO<sub>2</sub> budgets (bars). The dotted lines connecting the right and left parts of the figure indicate when the respective budgets were or will be exceeded according to the KSG pathway shown. As the depicted budgets relate to two different base years, two corresponding y-axes are shown on the right and the budgets with base year 2016 “float” at the level of the zero line of the corresponding right y-axis. By taking the historical cumulative emissions from 1992 up to and including 2015 (lower part of the black-framed bar) into account, the budgets with the different base years can be directly compared with each other. The budget bars are filled in according to the colour scale shown on the left so that the small bars stacked within them correspond in colour and height to the historical emissions that were or are still included in the respective budget. Also shown are the historical and future greenhouse gas (GHG) emissions according to the KSG pathway (thin blue line) as well as according to the “with measures scenario” (MMS) and “with further measures scenario” (MWMS) of the current projection report for Germany (small blue markers)<sup>1</sup>. All data presented on CO<sub>2</sub> and GHG emissions include emissions and sinks in the LULUCF sector.

SRU, own presentation; data sources: UBA 2024a; <sup>1</sup> UBA 2024b; KSG (for derivation of the emission pathway from the KSG, see appendix)

from the KSG reduction pathway. However, they are rarely made transparent in the public debate and are the subject of controversial scientific discussion, as some of them are currently only realisable in theoretical calculations. The majority of the IPCC's climate economic scenarios for mitigating climate change are based on economically optimised global decarbonisation pathways (IPCC 2022) which also use these methods to achieve climate targets at the lowest possible economic cost. The three approaches are as follows:

- Negative emissions: Firstly, it is often assumed that some of the excess CO<sub>2</sub> emitted today can be removed from the atmosphere in the future (carbon dioxide removal – CDR) (SRU 2022, Question 15). This allows to initially flatten the emissions reduction pathway. However, the processes required for this are currently only available to a limited extent and are energy-intensive and expensive. Costs and risks are shifted to future generations. Offsetting emissions through negative emissions should be primarily used to compensate unavoidable residual emissions, now and in the future.
- Emissions reductions abroad: Secondly, it is being discussed that part of Germany's reduction commitments could be realised in other regions of the world (SRU

2022, Question 16). This also leads to a less steep national reduction pathway, although there are currently no agreements or financial arrangements for taking over parts of the emissions budgets of other countries.

- Neutrality target years: Thirdly, it is implicitly assumed that all countries will reduce their emissions more or less in proportion to their current emissions aiming at a common global target year for greenhouse gas neutrality. However, this would imply a continuation of the current above-average emissions of high-emitting industrialised countries (“grandfathering”).

Even if such assumptions are considered plausible or necessary for economic and political reasons, an internationally fair, national CO<sub>2</sub> budget based on the SRU's calculation method would provide the necessary benchmark for a transparent assessment. If countries were to choose the argumentation that favours them for their national climate policy, all national contributions would add up to considerably more emissions than compatible with the available global CO<sub>2</sub> budget. This is currently still the case to a considerable extent (UNEP 2023). The increase in the level of ambition also envisaged in the adaptation process of the Paris Climate Agreement requires a move towards a fair budget.

### 3. Responsibility: What are the consequences of exceeding the 1.5 °C budget?

Exhausted CO<sub>2</sub> budgets raise the question of how politics and society should deal with missing the target. It is scientifically well documented that immense damage and losses are imminent if the temperature targets of the Paris Climate Agreement are not met (IPCC 2022; 2021a). All regions of the world will be massively affected by global warming, including Germany. Shifts in circulation patterns in the atmosphere and oceans have large-scale effects. Already today, countries and population groups with less economic power and influence, which themselves have contributed the least to climate change, are suffering serious consequences (UN 2023). Budget overruns should therefore above all be an opportunity to remind ourselves once again of the catastrophic effects of too hesitantly limiting global warming and to prioritise climate protection even more. This is challenging at the current time with a series of crises and wars capturing political attention and political popu-

lism is on the rise. Nevertheless, it remains true that today's generations' actions will be decisive for the consequences of climate change and further developments for decades and centuries. Impacts such as floods, fires or droughts, but especially the climate-related changes to the earth's ecosystems, will significantly shape and change the lives of all people (and all other living beings)—and endanger them in many ways. Once the fair national contribution compliant with the climate limit of 1.5 °C has been exceeded, it is therefore necessary to make even greater efforts within and outside Germany to minimise the likelihood of permanently exceeding this limit through global emissions.

The 1.5 °C limit remains the scientifically well-founded, relevant reference point against which exceedances must be measured. Regarding Germany's fair contribution to keeping global warming below this limit, the question of

political and moral responsibility for the damage and losses caused should therefore be given greater consideration in the debate on emission reductions. This is not only required by fundamental ethical principles of polluter responsibility. The political debate on the question of responsibility and liability for the consequences of exceeding the limit is also important in order to maintain the credibility of international climate policy. However, it is currently still poorly anchored in international law.

The SRU considers the following measures as necessary:

- o The extent to which targets have not been met must be made transparent with the CO<sub>2</sub> budget, which now shows exceedance budgets instead of remaining budgets.
- o For reasons of climate justice, Germany and the EU should recognise the damage and losses they have contributed to and credibly include the issue of compensation for affected countries in the discussion. In a further developed international law, states that fail to meet the Paris climate protection targets could also face increased liability risks. The extent to which states are responsible could be determined by the extent to which they have contributed to global warming to date, how much they have benefited and how solvent they are (polluter pays, beneficiary pays and ability to pay principle, see BAATZ 2016). One consequence of this would be that states would have a greater self-interest in keeping the target shortfall as low as possible in order to minimise the consequences of exceeding the target and the associated financial risks.

## 4. Context: CO<sub>2</sub> budgeting against the backdrop of current political debates

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Finally, a few selected links between a fair German CO<sub>2</sub> budget and climate policy discussions at federal state, national, EU and global level are addressed below.

The SRU has recommended a discussion about advantages and disadvantages of distributing the German CO<sub>2</sub> budget among the federal states (SRU 2022, Question 19). In order to achieve the national reduction target, the federal states and municipalities must also contribute to a reduction pathway that leads to net zero emissions in time. Although climate protection policy at federal level is sector-orientated, budgets at federal state level could additionally contribute to greater transparency. They allow to recognise and evaluate climate protection progress or deficits as well as the level of ambition of the respective federal state. In this respect, they can also exert pressure on sectoral management at federal level. However, the question of fair budget distribution remains open. Possible distribution keys have been scientifically analysed (ROPERS 2023). As suggested by the SRU, the federal states have also examined how they can distribute greenhouse gas reduction contributions methodically and fairly (UMK 2023). Advantages and disadvantages were identified for all distribution criteria, but no approach was recommended without reservation (ibid.). A combined approach was also discussed, consisting of 1) basically pursuing the same reduction rates in the sectors, 2) modifying these on the basis of state-specific reduction potentials and 3) using the budgets identified

by the SRU as a guide (ibid., p. 10). The SRU considers such an approach by the federal states to be sensible. At the very least, the cumulative emissions that result implicitly from the climate plans and laws of individual federal states should be explicitly reported. This would enhance the mandatory nature of compensations for temporary exceedances as required by the budget logic.

The numerical specification of the cumulative CO<sub>2</sub> budget, which follows from the KSG pathway, would also be an important supplementary component at federal level. Previously, the Council of Experts on Climate Change (ERK 2023a) assumed that the climate protection measures implemented, adopted and planned to date would lead to a “cumulative target achievement gap” compared to the KSG by 2030. According to the latest projection report of the German Environment Agency (UBA 2024b), the compliance of German greenhouse gas emissions in the period 2021 to 2030 with the KSG is possible. However, in a recent report (ERK 2024) commissioned by the Federal Government, the ERK concludes that this is not likely against the background of current developments and measures. Should a gap emerge, this would have to be compensated for retrospectively or climate neutrality would have to be achieved earlier provided that the maximum total amount of greenhouse gas emissions envisaged by the KSG for the period until climate neutrality is not to be exceeded. Furthermore, the ERK lacks the mandate to analyse and potentially

also to assess the appropriateness of the German targets, for example by comparing them with a fair national contribution to the international climate target. In the SRU's view, the ERK's mandate to assess the German government's climate policy is therefore incomplete and should be expanded accordingly.

The European Scientific Advisory Board on Climate Change (ESABCC) has also adopted the concept of an emissions budget for the EU (ESABCC 2023). However, the proposed greenhouse gas budget (11 to 14 Gt CO<sub>2eq</sub> between 2030 and 2050 or 52 to 55 Gt CO<sub>2eq</sub> from 2020) is not, according to the ESABCC's own statement, a budget derived from the global budget according to a distribution principle (*ibid.*; cf. CO<sub>2</sub> budget for the EU according to the SRU method, Table 1). Instead, it quantifies the cumulative emissions associated with an ambitious but technically and politically feasible reduction pathway. This envisages a 90 to 95 % reduction in greenhouse gas emissions by 2040 compared to 1990. The European Commission also refers to this ESABCC recommendation in its current proposal for an emissions reduction target of 90 % by 2040 compared to 1990 (European Commission 2024). The ESABCC (2023, p. 10 and 48) recognises that even with such a reduction pathway, there will still be a gap to a budget that can be described as fair. For this reason, additional climate protection measures outside the EU are recommended to be financed by the EU in order to fulfil the responsibility for a fair contribution to international climate protection (*ibid.*).

The SRU agrees with recommendations (see most recently the open letter from numerous organisations and scientists to the European Commission and the ESABCC of 8 January 2024, ALLESSON et al. 2024) that three categories of emission reduction targets should be clearly distinguished in regulatory terms and should be each underpinned by its own targets: 1) the reduction of gross greenhouse gas emissions, 2) the net uptake of CO<sub>2</sub> by terrestrial sinks (e.g. by forests, peatlands and agricultural soils) and 3) the additional permanent removal of CO<sub>2</sub> from the atmosphere through CDR processes. This increases transparency when offsetting reduction targets against planned future extractions of CO<sub>2</sub> from the atmosphere. It also supports the promotion, expansion and protection of terrestrial carbon sinks, some of which are only temporary in nature and are also susceptible to changes in management and environmental conditions. Finally, this would also allow the transparent quantification of the required potential for additional technical CO<sub>2</sub> storage in permanent reservoirs.

With the progress made so far in international climate protection the global warming will remain below 3 °C with medium probability if all measures are implemented (UNEP 2023). However, the sum of the measures is not sufficient to limit warming to well below 2 °C or even to a maximum of 1.5 °C, but at best to around 2.5 °C. In the final document of the first “Global Stocktake” at the United Nations Climate Change Conference COP28, the international community explicitly stated that the remaining global CO<sub>2</sub> budget compatible with the Paris Climate Agreement is now small and is being rapidly exhausted (UNFCCC 2023). This is also reflected in the figures for the remaining German CO<sub>2</sub> budget, regardless of the method of calculation.

# Appendix

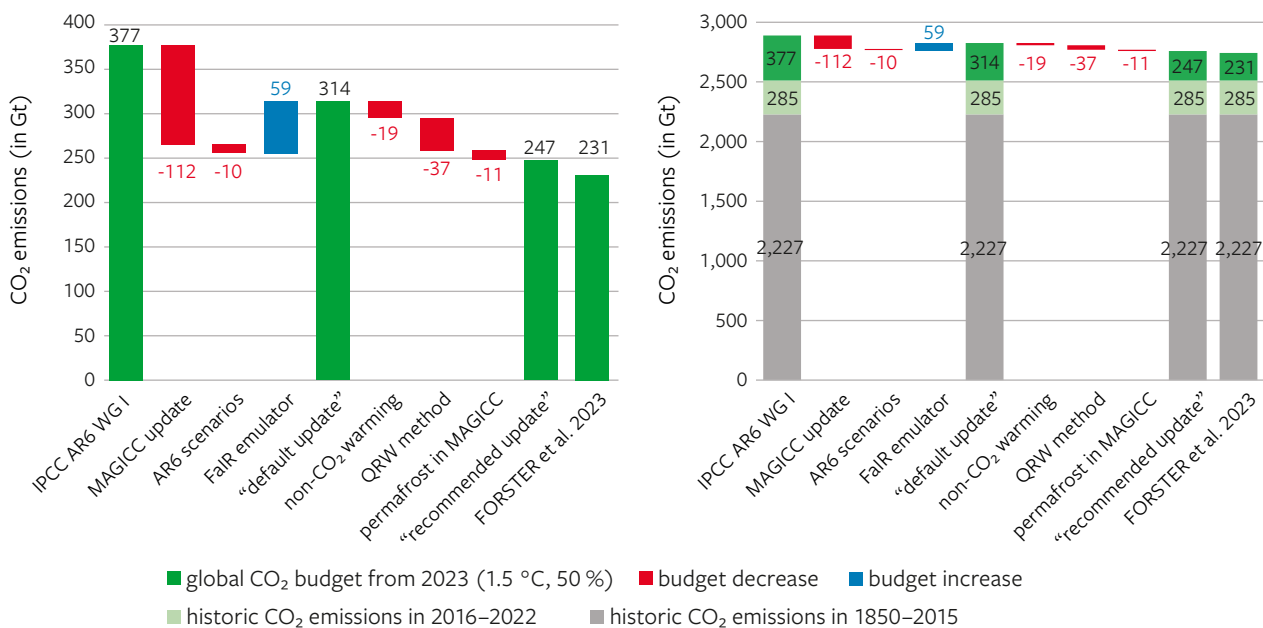
## Methodological updates in the calculation of global CO<sub>2</sub> budgets

For a better understanding, some aspects of the update of the remaining global CO<sub>2</sub> budget compared to the information in IPCC AR6 (IPCC 2021b) are explained below. The updates by FORSTER et al. (2023) and LAMBOLL et al. (2023) are methodologically compatible with the approach of IPCC AR6 (IPCC 2021b), i.e. they continue and advance it. However, the new studies take into account the emissions that have occurred since then and the increase in global warming. Moreover, the methodological approach is both updated and expanded in greater depth for individual components. For further details, please refer to the original publications. Some selected aspects:

- The MAGICC emulator, a type of simplified climate model used in the context of calculating the remaining global CO<sub>2</sub> budgets, was updated from version 7.5.1 to
- version 7.5.3 of the WG I report in IPCC AR6 to the WG III report. This newer MAGICC version was also used in the latest budget updates (FORSTER et al. 2023; LAMBOLL et al. 2023). With the update of this emulator, the (cooling) contribution of aerosols is estimated to be greater than before. Due to the decrease in aerosol input into the atmosphere in the course of global efforts to reduce emissions, this cooling effect will weaken in the future (more than previously considered) (FORSTER et al. 2023). This will significantly reduce the remaining global CO<sub>2</sub> budgets (see Fig. 2), as already pointed out in WG III's contribution to IPCC AR6 (LAMBOLL et al. 2023).
- The FaIR emulator, on the other hand, which is additionally used by LAMBOLL et al. (2023), leads to lower

• Figure 2

Global CO<sub>2</sub> budget from 2023 (left) and from 1850 (right)

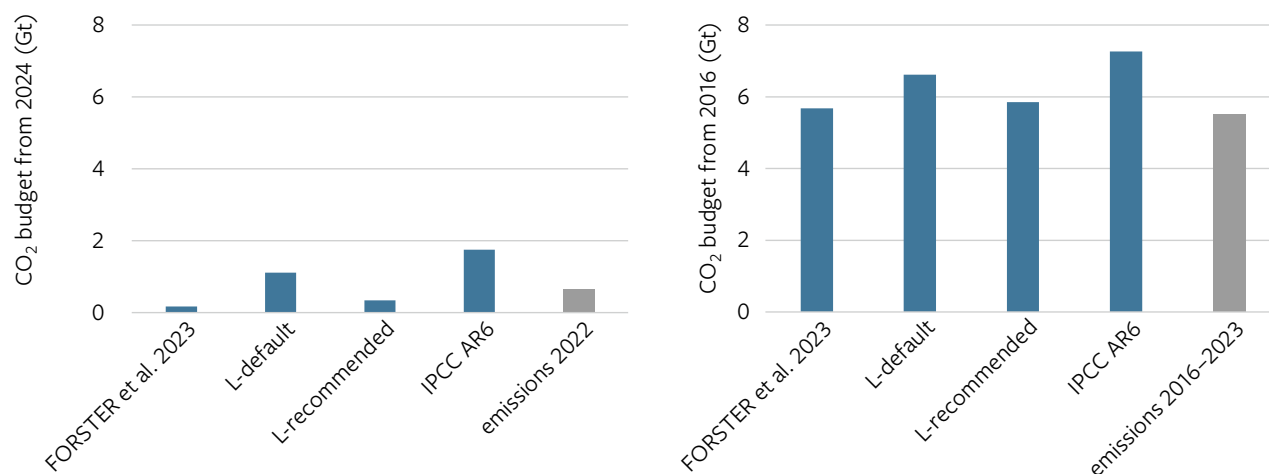


Global CO<sub>2</sub> budget for 1.5 °C (50 %) from 2023 (green bars) according to IPCC AR6 WG I (IPCC 2021b) (updated to 2023, i.e. global CO<sub>2</sub> emissions from 2020 to 2022 subtracted), LAMBOLL et al. (2023) ("default update" and "recommended update") and according to FORSTER et al. (2023) as well as negative and positive budget effects of the methodological changes (red and blue floating bars) in LAMBOLL et al. (2023). The base year of the budgets is 2023 on the left and 1850 on the right.

Sources: left: LAMBOLL et al. 2023, modified and supplemented with data from FORSTER et al. 2023; IPCC 2021b; right: SRU, own presentation; data sources: LAMBOLL et al. 2023; FORSTER et al. 2023; IPCC 2021b; FRIEDLINGSTEIN et al. 2023

### ◦ Figure 3

German CO<sub>2</sub> budget (1.5 °C, 50 %) from 2024 (left) and from 2016 (right)



Remaining CO<sub>2</sub> budget for 1.5 °C (50 %) for Germany (blue bars) from 2024 (left) and from 2016 (right) as well as a comparison of German CO<sub>2</sub> emissions (grey bars) in 2022 (left) and from 2016 to 2023 (right). “L-default” and “L-recomm.” stand for the “default update” and the “recommended update” from LAMBOLL et al. (2023). The remaining budget based on IPCC AR6 (IPCC 2021b) was adjusted to the base year 2024 by deducting CO<sub>2</sub> emissions in Germany in 2022 and 2023.

SRU, own presentation; data sources: LAMBOLL et al. 2023; IPCC 2021b; UBA 2024a; FORSTER et al. 2023

warming contributions from non-CO<sub>2</sub> greenhouse gases, which results in larger CO<sub>2</sub> budgets (FORSTER et al. 2023; see Fig. 2).

- Both update publications (FORSTER et al. 2023; LAMBOLL et al. 2023) also use the scenario database that was also taken as the basis for IPCC AR6 WG III. In contrast, the scenarios from the SR1.5 report were used in the budget calculations of IPCC AR6 WG I (IPCC 2018).
- In the “recommended update” by LAMBOLL et al. (2023), further methodological modifications are also made, which are regarded as an extension of the previous IPCC methodology (updated in the “default update”). For example, the greatest effect on the 1.5 °C budget (50 %) is the inclusion of warming caused by non-CO<sub>2</sub> greenhouse gases after CO<sub>2</sub> neutrality has been achieved.

- The changes in the remaining global CO<sub>2</sub> budget between the estimate in the last IPCC report (IPCC 2021b) and the two estimates prepared using an updated but consistent methodology (FORSTER et al. 2023; LAMBOLL et al. 2023) are relatively large in relation to the size of the remaining budgets (see green bars in Fig. 2, left). In part, however, these changes only appear so large because the remaining budget is now so small.
- For Germany, the differences are even more significant (see Fig. 3, left). This is due to the fact that the fair CO<sub>2</sub> budget for Germany as derived from SRU methodology has almost been exhausted. If we look at the budget that was available to Germany from 2016 (Fig. 3, right), the relative differences between the various studies are significantly smaller.

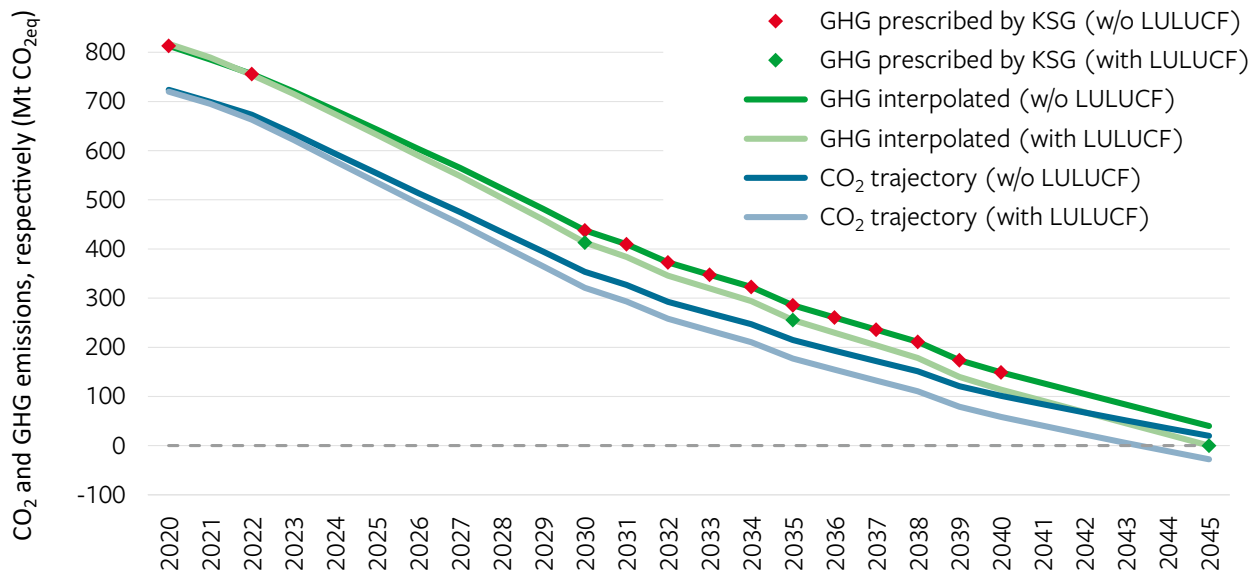
## Derivation of a CO<sub>2</sub> pathway from the KSG

As the KSG does not specify any separate maximum values for German CO<sub>2</sub> emissions, the CO<sub>2</sub> pathway shown in Figure 1, which corresponds to the KSG, is based on a number of assumptions: (a) the gaps in the KSG are filled by interpolation; (b) non-CO<sub>2</sub> emissions in the LULUCF sector remain constant at 7.7 Mt CO<sub>2eq</sub> annually; (c) in 2045, the share of CO<sub>2</sub> in the remaining gross greenhouse gas emissions (excluding LULUCF

in each case) is 50 %; (d) the CO<sub>2</sub> pathway (excluding LULUCF) is calculated as the average of two pathways: 1) linear decrease in the share of CO<sub>2</sub>—in greenhouse gas emissions and 2) linear decrease in the difference between greenhouse gas and CO<sub>2</sub> emissions (in each case excluding LULUCF). Figure 4 shows the targets prescribed by the KSG and the emission pathways derived by interpolation and on the basis of the assumptions.

### o Figure 4

Greenhouse gas pathway according to KSG and derived CO<sub>2</sub> pathway



The diagram shows the pathways for the future development of the maximum greenhouse gas (GHG) emissions compatible with the KSG as well as the CO<sub>2</sub> pathways derived from the KSG under the assumptions described above. Red or green markers: maximum values specifically specified by the KSG (without or with LULUCF); grey or green line: KSG pathway for total GHG supplemented by interpolation; blue-grey or blue line: derived CO<sub>2</sub> pathway.

SRU, own presentation; data sources: UBA 2024a; KSG

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(Copy deadline: October 2024)

You can download the SRU's publications at [www.umweltrat.de](http://www.umweltrat.de).  
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ISBN 978-3-947370-33-7

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Design: WERNERWERKE GbR, Berlin