

## **VEREIN KLIMASENIORINNEN AND OTHERS v SWITZERLAND (53600/20) COMMUNICATION**

In accordance with Rule 9.2. of the Rules of the Committee of Ministers regarding the supervision of the execution of judgments and of terms of friendly settlements by Greenpeace International & Climate Litigation Network  
**June 2, 2026**

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### **1. Introduction**

1. Pursuant to Rule 9.2 of the Rules of the Committee of Ministers for the supervision of the execution of judgments and Article 46 § 1 of the Convention, the Climate Litigation Network and Greenpeace International (the NGOs) submit this joint Communication regarding the execution of *Verein KlimaSeniorinnen Schweiz and others v. Switzerland*.
2. In the context of the supervision of the execution of the judgment in *KlimaSeniorinnen*, the NGOs recall that Switzerland was invited to examine the establishment of an independent expert body and, in doing so, to draw on existing best practices from other Council of Europe member States.
3. Against this background, and with a view both to assisting Switzerland in identifying such best practices and to supporting the Committee of Ministers in its supervisory role, Greenpeace International commissioned and funded an independent expert report by

Dr. Alina Averchenkova on the practice of national advisory bodies across Council of Europe member States (“the Report”) (Annex I). The Report evaluates existing institutional models and identifies key elements of good practice in the design, mandate, independence, and functioning of such expert bodies.

4. In the present Communication, the NGOs present the principal findings of the Report and place them in the specific context of the *KlimaSeniorinnen* judgment and its effective implementation. In doing so, the NGOs seek to contribute constructively to ensuring the full and meaningful execution of the Court’s judgment. Crucially, the Report provides a framework not only for how Switzerland should design this mechanism, but also for how the Committee of Ministers can actively supervise both the initial setup of the body and the trajectory of its future work to ensure lasting compliance in line with Article 46 of the Convention.

## **2. Scientifically based conditions for an effective national climate body**

5. At its [1537th meeting](#) in September 2025, the Committee of Ministers examined Switzerland’s execution of the judgment for the second time. In its decision CM/Del/Dec(2025)1537/H46-372, the Committee of Ministers acknowledged the entry into force of the revised CO2 Act, closing the regulatory gap for the period 2025–2030, but observed that a regulatory framework alone is insufficient without effective implementation and regular updates. The Committee of Ministers took note that Switzerland, by a method of its choice, has quantified the future greenhouse gas emissions corresponding to the general measures and the target timeline put in place, but recalled “the paramount importance of ensuring the effective and efficient implementation of the objectives and measures adopted, and of ensuring in the future their updating as necessary”. It “underlined also that providing effective protection to individuals from the serious adverse effects of climate change is a legal obligation under the Convention and international law”, and invited Switzerland “to consider the opportunity of establishing an independent national body suited to the national political structure to monitor its climate policy, mandated *inter alia* to issue recommendations to the political authorities, drawing as appropriate on good practices of other member States”.
6. The accompanying [Notes](#) of the 1537th meeting detail this invitation further:

Ensuring full compliance with this legal obligation requires robust safeguards at the national level. Switzerland does not currently have an independent national body with a mandate to monitor and evaluate progress towards national

targets, issue recommendations for remedial measures, etc. The scientific bodies and platforms mentioned by the authorities, however relevant and important they may be, do not play this role. All stakeholders, including the UN Special Rapporteur, confirm this. Given the complexity of the issues at stake and the evolving nature of climate governance, the existence of such an independent national mechanism would significantly contribute to the implementation of the judgment. It would also facilitate the supervisory role of the Committee of Ministers, in accordance with the principle of subsidiarity – the Committee is not in a position to monitor Switzerland’s climate policy in detail for several decades, nor to settle disputes concerning the interpretation and application of the rules of climate science put forward by the interveners. This would also be in line with the ICJ Advisory Opinion, which emphasises that the mitigation and adaptation rules and measures in place must be accompanied by effective enforcement and monitoring mechanisms to ensure their implementation. The authorities could be invited to consider the opportunity of establishing such a body suited to the national political structure, drawing on existing good practices in other Member States where appropriate.

7. Despite the closure of the regulatory gap for the period of 2025–2030, the NGOs reiterate that Switzerland remains in a state of non-implementation of the judgment, particularly with respect to the requirement to quantify a fair-share, 1.5°C-aligned national carbon budget as a basis for its mitigation targets. As can be inferred from the Applicant’s previous Rule 9.2 submission of [March 2026](#), the Swiss authorities continue to rely on the 2022 Climate Act climate targets, which, while setting a net-zero goal for 2050, lack a 1.5°C-compatible, fair national CO<sub>2</sub> budget as the basis for the timeline for achieving climate neutrality (see also para. 16 of this Communication). Furthermore, recent data and statements from the Federal Office for the Environment (FOEN) in late 2025 suggest that Switzerland is already [set to miss its 2030 targets](#) by a significant margin, in particular also due to an over-reliance on foreign emissions reductions (Article 6 of the Paris Agreement) that are neither available nor verifiable at the scale required (paras. 6-10 [KlimaSeniorinnen Communication January 2026](#)).
8. This submission seeks to highlight key findings to guide the Committee – as well as Switzerland – in establishing an expert body based on best practices from other countries. In light of the above, the NGOs respectfully invite the Committee of Ministers to use the key conditions for a national body, as set out in the annexed Report and distilled from best practice, to examine Switzerland’s compliance.

9. The Committee of Ministers' decisions of September 2025, read together with the Notes on the Agenda, made clear that the establishment of an independent national mechanism mandated to, *inter alia*, monitor and evaluate progress and issue recommendations for remedial measures, would facilitate the Committee's supervisory role. While such a body could make a significant contribution to the implementation of the judgment, this would only be the case insofar as it enables Switzerland to fulfil the substantive requirements set out by the Court, including the quantification of a fair-share, 1.5°C-aligned national carbon budget,<sup>1</sup> and is itself established in accordance with the conditions identified in the Report and outlined below.
10. The Report establishes that independent climate advisory bodies have become a cornerstone of effective climate governance throughout Europe and globally. Such institutions provide the scientific rigour, long-term continuity, and accountability necessary to align national climate policy with international commitments and the best available science. They are specifically designed to bridge the structural gap between the short-term nature of democratic electoral cycles and the long-term planning horizon required to address the climate crisis over several decades. As the Report emphasises, however, the effectiveness of such a body is predicated on its genuine independence, which must be legally anchored in formal legislation rather than informal arrangements to protect the institution from political pressure and shifting government priorities (pp. 6-7).
11. The Report further notes (pp. 3, 11-12) that specific conditions are essential for enabling such bodies to be effective in fulfilling their objectives, which commonly include ensuring national climate change policy aligns with the latest scientific findings and international commitments, and holding governments to account for their implementation through independent scrutiny of progress.

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<sup>1</sup> See [DH-DD\(2025\)848: Rule 9.2 Communication from NGOs in Verein KlimaSeniorinnen Schweiz and Others v. Switzerland](#), paras 3-5 and [DH-DD\(2025\)101: Rule 9.2 Communication from NGOs in Verein KlimaSeniorinnen Schweiz and Others v. Switzerland](#) (paras 14-26). The Court set out in §550(a) the obligation to “adopt general measures specifying a target timeline for achieving carbon neutrality and the overall remaining carbon budget for the same time frame, or another equivalent method of quantification of future GHG emissions, in line with the overarching goal for national and/or global climate-change mitigation commitments”. This obligation, read together with the requirement that domestic measures be “updated with due diligence and based on best available evidence” (§550(d)), forms the substantive heart of States’ mitigation obligations under the Convention in relation to climate change. Crucially, the “regulatory obligation” identified by the Court (§572) requires States to quantify national GHG emissions limitations through a national carbon budget that is set: (1) in relation to the remaining global carbon budget consistent with limiting warming to 1.5°C; and (2) on the basis of a quantification of the State’s fair share of the remaining global budget.

12. The key institutional design features of an effective national climate body include:

1. **Independence and transparency:** personal, administrative, and financial independence secured through legally anchored procedures and operational arrangements enabling the body to define its own programme of work and exercise budgetary control;
2. **High-quality and broad multidisciplinary expertise** among members;
3. **High quality and breadth of expertise** among the members is necessary to ensure the body can effectively conduct credible analysis across multiple relevant disciplines.
4. **Clarity and breadth of mandate**, including the mandate of advising on targets, assessing progress, evaluating policy effectiveness, and supporting public engagement, ambition, fairness, and alignment with international commitments;
5. **Sufficient, stable and predictable funding** to ensure the body is adequately resourced.
6. **Accountability mechanisms**, including a duty for governments to respond to expert advice, justify any departures from that advice, and, in particularly effective models, a duty to act by taking additional measures where policies fall short of stated commitments.

(Report, pp.1, 11-12)

13. As regards the fourth design feature, the mandate to advise on targets, assessing progress, evaluating policy effectiveness, including alignment with international commitments, a [growing number of such bodies](#) explicitly assess whether national climate policies are compatible with international commitments, including the Paris Agreement, and in some cases directly evaluate the State’s “fair share” contribution to global mitigation efforts (p. 10). As stated in the Report, “[a]lignment with international commitments is increasingly incorporated in the scope of work by advisory bodies”. Independent climate advisory bodies in the UK, France, Sweden, and Finland, and at the EU level, examine the consistency of national and Union/regional action with the Paris Agreement. As noted in the Report, “[c]onsideration of ambition and fairness of national efforts in the global context are at the forefront of this work”(p. 2, see also and Table 3).

14. In this regard, the NGOs respectfully invite the Committee of Ministers to consider, in particular, Table 3 of the Report (p. 11), which provides comparative examples of independent advisory bodies and their mandates to ensure consistency with international commitments and the fairness of national efforts. These include the [UK](#)

[Climate Change Committee](#), the French [Haut Conseil pour le Climat](#), the [Irish Climate Change Advisory Council](#), the [Finnish Climate Change Panel](#), and the [EU Scientific Advisory Board on Climate Change](#) (“ESABCC”), which assess consistency with international climate commitments. For instance, the French Haut Conseil pour le Climat is responsible for evaluating government climate policy, assessing its alignment with France’s European and international commitments, and comparing France’s actions and commitments with those of other countries. Climate advisory bodies for the [UK](#) and [Finland](#) have assessed fairness considerations of national mitigation efforts in the global context, with the Finnish Climate Change Panel explicitly referring to the *KlimaSeniorinnen* judgment. The [ESABCC](#) has also quantified the EU’s (remaining) fair share carbon budget from 2020 according to different equity and allocation principles in the context of advising on the EU’s 2040 emissions reduction target.

15. This approach to international commitments is particularly relevant to the implementation of the Court’s judgment, given that the obligation under §550(a), read together with §572, necessarily requires the quantification of national emissions limitations in relation to both the remaining global carbon budget and the State’s equitable share thereof. Accordingly, where an independent expert advisory body is established to implement the judgment, its mandate must include assessing whether national climate policy is consistent with international commitments and reflects the State’s equitable share of global mitigation efforts, as is the practice in many Council of Europe Member States. The comparative practice shown in the Report and summarised above further supports the inclusion of such a mandate within any independent expert advisory body established in Switzerland. The NGOs would be pleased to provide further analysis of these comparative examples, should this be of assistance to the Committee of Ministers in its supervision of the execution process.
16. With a view to assessing how these comparative best practices could be translated into the Swiss national political structure, Greenpeace Switzerland has already commissioned two distinguished legal experts to prepare an independent study, which is currently underway, specifically to evaluate how an effective national climate advisory body could be established in Switzerland. The study examines the feasibility, legal basis, and institutional options for such a body in Switzerland, including possible models adapted to the Swiss constitutional and institutional framework. The findings of this work may be submitted in due course to the Committee of Ministers.
17. The NGOs respectfully request that the Committee of Ministers respond to Switzerland’s repeated assertion that its implementation efforts are stalled by a perceived lack of an established methodology to determine a national carbon budget.

In addition to being rejected by the Court (§570), climate advisory bodies such as the ESABCC have already explicitly and successfully assessed fair-share carbon budgets at the EU level, demonstrating that such methodologies are actively used and directly relevant for many Council of Europe member States. Scientifically, this capability is further cemented by a 2026 study published in *Nature Communications* by researchers at ETH Zurich (attached as Annex 2).<sup>2</sup> The ETH study provides an inventory-consistent framework for calculating national remaining carbon budgets across all standard equity-based allocation methods. Crucially, the study analyses Switzerland’s specific trajectory and, like the *Pelz et al* report, which the NGOs annexed to their [submissions of January 2025](#), demonstrates that none of the established allocation methods render a resulting carbon budget that aligns with the Swiss authorities’ calculations or its 2035 nationally determined contribution (NDC). The authors write “[t]his comparison reveals that Switzerland’s planned CO<sub>2</sub> emissions reductions are insufficient to remain within its fair share of the global RCB under almost all allocation methods considered. The RCB exceedance extends to more than 2 GtCO<sub>2</sub> (equivalent to around 60 times Switzerland’s domestic annual CO<sub>2</sub> emissions) with the largest overshoots found when considering capacity or historical consumption-based emissions”.<sup>3</sup> In this light, the NGOs emphasise that one of the most critical, immediate mandates of the national climate body must be to ensure that Switzerland’s climate targets are fully aligned with the Court’s judgment by explicitly quantifying a national remaining carbon budget.

### **3. The importance of continued Committee of Ministers supervision**

18. It is important to emphasise that although the establishment of an independent and effective national climate body would represent a tangible step towards implementing the *KlimaSeniorinnen* judgment, it would not, in itself, satisfy the substantive obligations outlined by the Court and articulated above.
19. If it meets the criteria for effectiveness outlined in this submission and in the expert report annexed to this submission, a national climate body would be able to provide Switzerland with advice on the best available science, scrutinise the ambition and fairness of domestic climate targets, assess progress towards meeting those targets, and promote greater accountability and transparency in policymaking.
20. However, even if the establishment of a national climate body were accompanied by mechanisms ensuring governmental accountability through duties to respond to its

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<sup>2</sup> Weber, K., Brunner, C. & Knutti, R. Tracking country-level mitigation progress using NGHGI-consistent carbon budgets. *Nat Commun* 17, 1494 (2026). <https://doi.org/10.1038/s41467-026-69078-9>

<sup>3</sup> *Ibid*, p.7

advice and to act upon it, this would not in and of itself discharge Switzerland's regulatory obligations set out in the judgment. The NGOs maintain that the Committee of Ministers should continue supervising the implementation of the *KlimaSeniorinnen* judgment. The supervision remains necessary until Switzerland adopts new emissions-reduction targets aligned with such a budget, and plans to achieve those reductions in a timely fashion and in line with its human rights obligations under the Convention. This is also in line with the national body's intended purpose, as expressed in the Notes of the Secretariat: "the existence of such an independent national mechanism would (...) facilitate the supervisory role of the Committee of Ministers, in accordance with the principle of subsidiarity". The national body must facilitate the Committee's supervisory role, not replace it.

21. In this context, the recently delivered judgment of the District Court of The Hague, dated 28 January 2026, in the [Bonaire climate case](#) is relevant. It applies the legal framework set out by the Court in *KlimaSeniorinnen* (paras. 10.7-10.24) and concludes that the Netherlands violates the Convention because it is failing to make an "equitable contribution" to the global emissions reduction effort to limit global warming to 1.5°C (para. 12.2). The establishment of a national climate body must in this respect be viewed as an important stepping stone towards this aim, but it remains important that the Committee of Ministers supervises the bottomline of the *KlimaSeniorinnen* judgment: that Switzerland's climate policies constitute an equitable contribution, or fair share, to limiting global warming to 1.5°C.
22. Accordingly, the NGOs respectfully submit that the Committee of Ministers should maintain active supervision over two distinct operational phases of this possible domestic implementation measure until the Court's judgment has been fully implemented. The Committee of Ministers should closely supervise the body's setup, ensuring that its formal legal basis, composition, and structural guardrails satisfy the effectiveness and independence criteria outlined in the Report and above. The mere creation of a body in name only, without robust legislative anchoring or adequate resource guarantees, would not provide an effective means of implementation. The Committee of Ministers should also supervise the body's long-term work. This means monitoring whether the body is genuinely empowered to carry out its mandate without political interference, whether it effectively quantifies and updates the fair-share carbon budget, and how the Swiss authorities respond to and integrate its scientific advice.

#### 4. Conclusion

23. To conclude, the NGOs respectfully submit that Switzerland continues to be under an obligation to comply with the substantive regulatory obligations identified by the Court in *KlimaSeniorinnen*, in particular the obligation to quantify national GHG emissions limitations through a fair-share, 1.5°C-aligned national carbon budget or equivalent method of quantification grounded in best available science. While the establishment of a national climate body would represent an important institutional step towards implementation, such a measure can only contribute meaningfully to execution if it is designed in accordance with best practices from other Council of Europe member States identified above and in the Report. Ultimately, the effective implementation of the *KlimaSeniorinnen* judgment and the effective protection of the human rights at issue depend on whether Switzerland in fact reduces its greenhouse gas emissions in a manner compatible with the 1.5°C temperature limit. Because the integrity of this mechanism relies entirely on its institutional structural integrity and its long-term operation, ongoing supervision by the Committee of Ministers over both its structural setup and its future work remains indispensable.

**VEREIN KLIMASENIORINNEN AND OTHERS v SWITZERLAND (53600/20)**

**ANNEX I**

To the Rule 9.2. Communication of Greenpeace International & Climate Litigation Network  
June 2, 2026

# National Climate Advisory Bodies: Lessons learnt on effective design

Policy report by Alina Averchenkova<sup>1</sup>

## Summary and Key Messages

Independent climate advisory bodies have become a cornerstone of effective climate governance across Europe and globally. They provide scientific advice, monitor progress, and strengthen accountability—functions essential for ensuring that national climate policies align with international commitments and best available science (IPCC, 2023). Switzerland, following the 2024 European Court of Human Rights (ECtHR) ruling in *Verein KlimaSeniorinnen Schweiz & Others v. Switzerland*, is now under heightened scrutiny to improve its climate governance architecture. The Committee of Ministers has invited Switzerland “to consider the opportunity of establishing an independent national body suited to the national political structure to monitor its climate policy, mandated *inter alia* to issue recommendations to the political authorities, drawing as appropriate on good practices of other member States” ([CM/Notes/1537/H46-37](#)).

This report synthesises lessons from existing climate advisory bodies, identifies design features that underpin their effectiveness, and outlines key recommendations to take into consideration in the design of such body to enable effective implementation of the ECtHR's judgement and CMDH's advice. It highlights the following design features as particularly important for the effectiveness of advisory bodies:

- **Independence and transparency** ensured through members appointment procedures and operational arrangements for work programme and budgeting is key for the effectiveness of climate advisory bodies. Such independence must be legally anchored through laws or regulations, rather than relying on informal arrangements.
- **High quality and breadth of expertise** among the members is necessary to ensure the body is able to effectively conduct credible analysis across multiple relevant disciplines.
- **Clarity and breadth of mandate** matters, bodies with authority to advise on targets and policies and to conduct independent assessment of progress exert greater influence.
- **Sufficient and predictable funding** shapes effectiveness, evidenced by the bodies supported by larger secretariats being able to conduct deeper analysis and engagement across a wider range of topics.
- **Statutory obligations for governments** to consider advice and to indicate the reasons for when it is not being followed improve effectiveness and accountability as examples of Ireland, New Zealand, the UK, France, Denmark, Sweden, and the EU demonstrate. Duty to act provision in Denmark further strengthens accountability by requiring the government to demonstrate how it will fill the gap between targets and planned policies if the advisory body finds inconsistency.

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<sup>1</sup> Dr. Alina Averchenkova is a Distinguished Policy Fellow at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science, where she leads research on governance and legislation.

- **Alignment with international commitments** is increasingly incorporated in the scope of work by advisory bodies. Independent climate advisory bodies in the UK, France, Sweden, and Finland, and at the EU level, help ensure consistency of national action with the Paris Agreement. Consideration of ambition and fairness of national efforts in the global context are at the forefront of this work.

## 1. Background and Global Trends

The ECtHR's 2024 *KlimaSeniorinnen* judgment found that Switzerland failed to take adequate measures to mitigate climate change, thereby violating Article 8 of the European Convention on Human Rights. The Committee of Ministers of the Council of Europe (CMDH) that is responsible for ensuring that respondent states take necessary measures to abide by the ECtHR's final judgments, has since recommended Switzerland *"to consider the opportunity of establishing an independent national body suited to the national political structure to monitor its climate policy, mandated inter alia to issue recommendations to the political authorities, drawing as appropriate on good practices of other member States"* ([CM/Notes/1537/H46-37](#)).

Across Europe and globally, independent advisory bodies have emerged as a key innovation in climate governance (Evans et al., 2024; Averchenkova & Chan, 2023; OECD, 2021). They help governments navigate complex scientific evidence, maintain long-term policy consistency and drive for ambition, and ensure accountability for climate commitments.

Many national climate laws now set up new expert advisory bodies or give this role to existing ones. Altogether, twenty-four European countries either already have a functioning climate advisory body or have passed laws to create one—though a few, like Spain and Estonia, haven't put these plans into practice yet (GRI LSE, forthcoming). At the EU level, the European Scientific Advisory Board on Climate Change (ESABCC) plays this role for regional climate policy. Out of the 46 member states of the Council of Europe, 29 have an expert advisory body on climate change, but they differ in their design and impact. Apart from Switzerland countries lacking such bodies are Albania, Bosnia and Herzegovina, Czechia, Italy, Kosovo, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Poland, Romania, San Marino, Serbia, and Turkey (ibid)<sup>2</sup>.

Beyond Europe, more countries are also setting up national climate advisory bodies. The International Climate Councils Network—a member-led network—now brings together 28 expert bodies that officially advise their governments on climate policy. These include councils in Australia, Brazil, Canada, Chile, South Africa, Nigeria, New Zealand, the Philippines, Guatemala, Mexico, and several others. Switzerland currently lacks such an institution.

## 2. Objectives of Independent Climate Advisory Bodies

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<sup>2</sup>This study doesn't include Armenia, Azerbaijan, Cyprus, or Georgia. Annex 1 gives more detail on the advisory bodies that do exist across Europe.

The primary objectives of climate advisory bodies are to ensure consistency of national climate change policy with the latest scientific findings and international commitments and to hold governments to account for their implementation, through independent scrutiny of progress made. Independent climate advisory bodies typically serve three core functions (Averchenkova et al., 2020; Evans et al., 2024):

**Expert Advise:** They provide independent, evidence-based advice on climate targets, pathways, and policy options, serving as a trusted knowledge broker.

- The UK government must consider recommendations made by the Committee on Climate Change on carbon budgets before it puts a proposal before Parliament.
- The German Expert Council is asked to verify the assumptions underlying the projected impact of measures proposed by sectoral ministries before a climate policy programme or a new 2050 plan is adopted.
- Sweden's Climate Policy Council must evaluate the analytical methods and models that provide the basis for policies.

**Monitoring and Accountability:** They assess progress toward national climate targets, scrutinise government reports, and highlight gaps in implementation, acting as a watchdog and often policy entrepreneur.

- Independent assessment of implementation with parliamentary oversight provides for a stronger accountability mechanism for climate change laws.
- In some countries the primary reporting requirements rest with the government, but the reports are scrutinised by the independent advisory bodies (e.g. in Sweden, Germany, Denmark and Ireland).
- Other countries delegate reporting on progress to the advisory bodies (e.g. France and the Netherlands). In the UK, the CCC issues a report on progress in implementation to which the government is required to respond by law. The UK government also produces its own annual report on emissions.

**Public Engagement and Debate:** They publish accessible reports and engage with stakeholders, elevating the quality of public debate.

- Denmark's climate change law mandates the creation of a Climate Dialogue forum as one of the tasks for its independent advisory body (Weaver et al., 2019).
- An assessment of the UK's CCC over the first 10 years of operation showed that its outputs have contributed to improving the quality of the political debate on climate change in the UK (Fankhauser et al., 2018).
- An evaluation of the work of the Finnish Climate Panel found that it had a significant impact on public and political debate (Weaver et al., 2019).

Many advisory bodies combine the first two functions, with some bodies encompassing all of them. For example, the Danish Council on Climate Change by law acts in all three roles. It provides evidence-based policy advice to the government and parliament, monitors and reports on government climate policy,

the national climate targets, and Denmark's EU obligations; and it also acts as a convener for the national policy debate. Denmark's Council is notable for having the convener function explicitly legislated through the mandate to create a Climate Dialogue forum.

New Zealand's Climate Change Commission (He Pou a Rangī) was set to provide the Government with advice, monitoring and reporting that supports transition to a climate-resilient, low emissions future. On the consultation side, the Commission's mandate is to hear New Zealanders' perspectives before making recommendations, and the Commission consults with the public regularly. However, its consultation mandate may be relaxed in the future based on the reforms to the climate change law proposed by the government in 2025, as discussed below.

The mandate of the UK's CCC encompasses the provision of independent advice on adaptation and mitigation, monitoring progress on reducing emissions and enhancing climate resilience, and conducting independent analysis into climate science. The UK CCC's stakeholder engagement function is substantial in practice in particular on sharing evidence and analysis, but it derives from the Committee's own interpretation of its broad ancillary powers and its governance framework — not from specific statutory language requiring public consultation or stakeholder engagement. In recent years the CCC has integrated deliberative participation methods into its work, starting with its engagement with the Climate Assembly UK (CAUK) in 2020, commissioned by six House of Commons select committees. The CCC used the recommendations from the CAUK to frame its Sixth Carbon Budget and has since integrated deliberative methods into its work on home decarbonisation and adaptation.

With the growing importance of public participation, the need to tackle climate disinformation and improve public awareness and buy-in into climate policies, the potential for climate advisory bodies to contribute as independent credible conveners is increasing. Having an explicit authority for the bodies to engage with the public and stakeholders and to act as conveners of relevant policy dialogues as part of their mandate would enable them to be more effective in this context.

### **3. Evidence of Impact**

Research across multiple countries shows that independent expert advisory bodies significantly improve climate governance by enhancing the transparency and legitimacy of policymaking, ensuring the credibility of climate targets and underlying policies, advancing their mainstreaming across policy areas, and strengthening their implementation (OECD, 2021; Evans et al., 2024; Averchenkova et al., 2024). They also enable more ambitious climate action by providing high-quality analytical expertise and maintaining a clear separation between evidence-based advice and political decision-making. They can also lend reinforcement to governments when there is political resistance to adopting targets or policy measures.

- **United Kingdom:** The UK's Climate Change Committee (CCC) has shaped national climate policy since 2008, influencing carbon budgets and the adoption of the net-zero target (Fankhauser et al., 2018).

- **Ireland:** The Climate Change Advisory Council (CCAC) has influenced carbon tax reforms and the phase-out of peat and coal subsidies (Tallon et al., 2020; Averchenkova et al., 2024).
- **New Zealand:** The Climate Change Commission (NZ CCC) has shaped national climate policy, and its advice has been upheld in court (Averchenkova et al., 2024). However, changes to the Climate Change response Act announced by the government at the end of 2025 may weaken the Commission's future impact due to, among other, weakening its advisory role on emissions plans, pushing back obligations to respond to Commission's advice by two years and other changes.<sup>3</sup>
- In **Ireland** and **New Zealand**, advisory bodies have also played a central role in fostering engagement with politically sensitive or emerging policy issues—for example, advancing the debate on reducing agricultural emissions in ways that would be difficult to achieve from within government (Averchenkova et al., 2024).
- **Germany:** The Council of Experts on Climate Change (ERK) provides rigorous scientific validation but has limited influence due to the absence of a statutory requirement for government response (Averchenkova et al., 2024).

Box 1 outlines examples of impacts of climate advisory bodies. However, the extent to which advisory bodies shape policymaking varies considerably depending on their design. Section 4 below discusses key design considerations for ensuring effectiveness of the bodies based on the experience to date and Annex 1 provides an overview of design features for a selection of nine prominent bodies.

### Box 1: Impact of advisory bodies in Ireland, Germany and New Zealand

**The UK's Committee on Climate Change (UK CCC)**—the first body of its kind—has, since its establishment in 2008, made a significant contribution to national climate policy. It has helped maintain focus on ambitious long-term objectives through the carbon budget framework, improved the quality of political debate, and influenced a range of sectoral policies, including new legislation on energy, infrastructure, housing, and water (Averchenkova et al., 2021a; Barreira and Ruiz-Bautista, 2020). Its analysis is regularly used in the UK Parliament to support arguments for stronger accountability and more ambitious climate action across all major political parties (Fankhauser et al., 2018).

**Ireland's Climate Change Advisory Council (CCAC)** provides evidence-based advice on carbon budgets, engages in dialogue with sectoral ministries, and conducts assessments of gaps in policy and progress. An independent review of the CCAC's first five years (Tallon et al., 2020) concluded that the Council “has been successful in establishing itself as an authoritative voice in the national climate debate” and that “its frank and rigorously evidence-based annual analysis of Ireland's disturbing record on mitigation has been a defence against even further slippage” (p. 3). The report highlights several concrete impacts, including the use of

<sup>3</sup> Examples related to the impact of the New Zealand's Climate Change Commission below refer to the period up to March 2024 prior to these reforms and are based on the study of the impact of climate laws by Averchenkova et al., 2024.

CCAC analysis to support increases in the national carbon tax and to justify ending government subsidies for peat and coal burning.

**New Zealand's Climate Change Commission (NZ CCC)** has taken an active and prominent role in shaping the national climate policy debate. Its institutional authority—and the weight of its advice in government decision-making—has already been tested in court. In a notable case, the government was challenged for rejecting the Commission's recommendations without carrying out its own alternative analysis or proposing a different course of action. The case concluded with the government agreeing to follow the CCC's advice in the future, which further strengthened perceptions of the Commission's standing and influence.

**Germany's Council of Experts on Climate Change (ERK)** is widely regarded as an independent and authoritative voice that consolidates scientific knowledge, pushes for greater ambition, holds policymakers to account, and stimulates more rigorous debate on missed emission targets. However, its impact is more limited than that of its counterparts in Ireland and New Zealand. This is largely due to the absence of a requirement for the government to formally respond to its advice, as well as the Council's relatively narrow mandate, which focuses primarily on validating the assumptions behind government-proposed measures. As a result, some stakeholders in Germany have called for expanding the Council's mandate to include the ability to make explicit recommendations on how government policy could be improved, and for introducing an obligation for the government to justify itself when it chooses not to follow the Council's advice (Averchenkova et al., 2024).

Across these cases, the most impactful bodies share three features: strong mandates, independence, and mechanisms requiring government response (Averchenkova, A., & Lázaro-Touza, L., 2020; Averchenkova et al., 2024).

#### **4. Design Considerations for Effective Advisory Bodies**

To be effective, climate advisory bodies must be independent and have an appropriate status, a clear and broad statutory mandates, adequate resources and capacity, and sufficient powers to hold Government to account, including a statutory requirement obliging governments to consider and respond to their advice.

##### **a. Independence**

Robust institutional design and genuine independence help protect advisory bodies from politicisation and undue influence (Seibicke, 2025). International practice shows that independence of a climate advisory body, and the extent to which this independence is recognised by stakeholders, is a fundamental determinant of its effectiveness. Independence requires legal safeguards for appointments, autonomy over work programmes, and an independent secretariat and budget (Averchenkova et al., 2020).

- **Appointment of members**

Effective climate advisory bodies use transparent, merit-based appointment processes, include multidisciplinary expertise, and avoid ex-officio political

appointments (Weaver et al., 2019). Appointment procedures that are opaque, politicised, or dominated by vested interests risk undermining the credibility of the institution and diminishing the weight accorded to its advice (see Box 2 and Annex 1). Robust safeguards for independence should be embedded within the appointment framework and ideally be anchored in law. Recruitment processes should be open, transparent, and based on clearly defined merit criteria. Selection should prioritise professional expertise and integrity, and avoid mechanisms that allow for undue political influence, such as direct ministerial appointment without oversight or automatic ex-officio membership. Transparent procedures—such as public calls for applications, independent selection panels, and published criteria—enhance both the actual and perceived impartiality of the body.

### **Box 2. Risks associated with weaker safeguards for independence**

In Ireland, the inclusion of several ex-officio members in the Climate Change Advisory Council, including a representative of the agricultural sector, has been criticised for constraining the Council's ability to recommend more ambitious mitigation measures in areas where vested interests are strong. In New Zealand, concerns were raised that the nomination of a significant proportion of members by a single political party risked undermining the perceived neutrality of the Climate Change Commission, notwithstanding the professional qualifications of the appointees. In both cases, the issue was not the competence of individual members but the perception that the advisory body was insufficiently insulated from political or sectoral influence.

Source: Averchenkova et al., 2024.

#### **• Budget and administrative independence**

Stable, multi-year, and non-discretionary funding is essential to safeguard institutional autonomy and ensure that governments cannot influence the body's work programme, staffing, or analytical outputs through financial pressure. Provisions on funding independence across leading climate advisory bodies emphasise stable, statutory, and ring-fenced budgets that cannot be altered at political discretion (see Annex 1).

Effective bodies have multi-year funding, control over internal resource allocation, and transparent financial reporting. They are prohibited from accepting private or sectoral funding, ensuring that their analysis remains impartial. These safeguards collectively protect the body from political or stakeholder influence and are recognised as essential for credibility and long-term effectiveness.

- UK CCC – funding is provided through the sponsoring departments but is protected by statute and cannot be altered without parliamentary scrutiny.
- New Zealand CCC – receives a multi-year appropriation, reducing annual political interference.
- France's High Council on Climate (HCC), known in French as the Haut Conseil pour le climat, has a dedicated line within the Prime Minister's budget;
- Denmark's Klimarådet has an independent budget allocation administered through the Ministry but not controlled by it.

## b. High quality and breadth of expertise

Climate policy spans multitude of disciplines and hence a broad range of expertise among members is essential to the effectiveness and legitimacy of climate advisory bodies. Multidisciplinary membership ensures that recommendations are scientifically robust, economically sound, technologically feasible, and socially informed; it also strengthens independence and stakeholder trust.

When no single sector or discipline dominates, the risk of capture is reduced, and the body's independence is easier to defend. Diverse expertise improves deliberation, helps identify unintended consequences, and supports integrated assessments of mitigation, adaptation, and equity.

While initially the first advisory bodies were primarily composed of scientists and economists, there has been a shift over the past two decades towards greater representation of social sciences (see Table 1 for the key disciplines currently represented in the climate advisory bodies across Europe).

- In Ireland, the reforms to the advisory body through an amended climate legislation in 2021 improved gender balance and diversity of expertise, including not only climate scientists and economists that typically dominated climate advisory bodies in the early days, but also behavioural scientists. Since 2021, the CCAC has expanded and has a stronger secretariat with increased capacity.
- The composition of the UK CCC has moved from a tight cluster of economists, financiers, and physical scientists in the earlier years toward a wider mix that now includes energy engineering, transport, international climate governance, climate-health research, and natural capital economics. It also includes a behavioural scientist with expertise in the psychology of decision-making, language, and cognition.
- Denmark's Council on Climate Change has historically included members with expertise in political science and economics alongside natural scientists. The Danish Climate Act specifies that the Council must reflect a broad range of expertise, and in practice this has included social scientists working on energy transitions and political economy.
- Sweden's Climate Policy Council has included political scientists and researchers working on governance, societal transitions, and behavioural dimensions of climate.

**Table 1: Prevalent disciplines in national climate advisory bodies in Europe**

<b>Discipline</b>	<b>Why It Matters</b>
Climate science / atmospheric physics	Scientific basis for mitigation pathways
Economics (environmental, energy, macro)	Costs, benefits, and policy design
Engineering (energy, transport, industrial)	Feasibility of technological transitions
Environmental science & ecology	Biodiversity, land use, and impacts
Law	Alignment with legal obligations
Social sciences (behaviour, sociology, political science, health)	Addresses public acceptance and societal change
Agriculture & land-use science	Emissions from land, food systems
Risk & disaster	Adaptation and resilience planning

Source: Author.

**c. Clarity and breadth of mandate**

The breadth of an advisory body's mandate determines what it can examine, whom it can engage, and what connections it can draw across policy domains. Where that scope is too narrow or lacks statutory protection, the body may be unable to address the full dimensions of the problem — and whatever role it does have can be further curtailed at the discretion of successive governments (Seibicke, 2025).

A strong mandate should include advising on targets, assessing progress, evaluating policy effectiveness, and supporting public engagement (OECD, 2021). See Table 2 and Annex 1 for details on mandates of existing advisory bodies in Europe. The most impactful advisory bodies have their mandates embedded into climate legislation, which provides stronger protection against political change over time. Inclusion in the mandate of an independent expert review of the compatibility of national measures with emissions pathways and targets or carbon budgets alongside duty to act

**Table 2: Institutional Mandate Comparison in Selected Advisory Bodies**

Mandate element	Advisory bodies that include the element
Advice on Targets	IE, NZ, UK, FR, EU, DK, SE, FI
Progress Assessment	All bodies except emerging ones
Gov't Response to the Advice Required	IE, NZ, UK, FR, EU, DK, SE

Source: Author.

**d. Government accountability**

One of the central problems that climate advisory bodies are designed to address is a mismatch between the long-term timescale of the climate crisis and short-termism of democratic politics with four-five-year electoral cycles. Without accountability mechanisms, there is a structural incentive for governments to accept ambitious long-term targets while delaying or diluting the policies needed to meet them. An advisory body that is not backed up by a mechanism that ensures that advice is heard, responded to, and publicly accounted for cannot effectively address this challenge. In practice two types of accountability mechanisms emerged in relation to advisory bodies—a 'duty to respond' to the advice, and a 'duty to act' in case the advisory body identifies insufficient action by the government to meet the targets.

Integration of a requirements on governments to respond to the advice or the recommendations of the advisory body seeks to minimise the risk of advice being ignored by politicians. A duty to respond requires the government to publicly engage with findings, explain its position, and create a record against which Parliament, courts, and civil society can hold it to account. National governments are already required by law to respond to input from their independent expert councils in Denmark, France, Ireland, and the UK (Evans et al., 2024). Similar

provisions have been introduced in Spain and Slovenia, where the bodies have not yet been operationalised at the time of writing.

- In the UK and Ireland, if the governments diverge from the carbon budget proposals by the advisory bodies, they must clearly state the reasons for doing so. Successive governments have accepted all six recommended carbon budgets and amended the 2050 target to net zero in line with the UK CCC advice.
- In Denmark and France, the governments are required to respond to the recommendations of their advisory bodies on climate policy formulation.
- In Germany, the lack of the requirement for the government to respond to the advice of the expert advisory body has been seen as detrimental to the body's impact on policy making and accountability, particularly compared to the impacts of similar bodies in Ireland and New Zealand where climate laws require a response from the government (Averchenkova et al., 2024).

A stronger safeguard for government's accountability is integrated in the Danish Climate Act 2020, which introduced 'the duty to act' requiring government to propose additional measures when the Denmark's Council on Climate Change finds that current policies risk falling short of target. The Council is tasked with assessing whether the government's climate efforts make it probable that the climate targets will be reached. The Minister in charge of climate action must make their own assessment, and if the answer is that targets are not probably going to be met, the Minister must present new initiatives (Articles 4(2), 7(3),7(4)).

In Denmark the Parliament scrutinises the Council's assessment, the Minister's response, and the adequacy of any proposed additional measures, and may actively demand that the government go further than what it has proposed. In contrast in the UK the government must respond to the CCC's annual progress reports and lay those responses before Parliament, but there is no mechanism for Parliament to assess that response or require additional measures. Parliamentary scrutiny of the government's climate performance happens through the ordinary work of select committees and debate, not through a dedicated statutory process.

Duty to respond makes the gap between ambition and delivery visible; while duty to act ensures that visibility triggers an obligation to close it, enhancing effectiveness of the advisory body.

## **5. Ensuring Consistency with International Commitments and Fair Share**

A growing number of advisory bodies explicitly assess whether national climate policies align with international commitments, including the Paris Agreement (IPCC, 2023). Some bodies explicitly focus on consideration of 'the fair share' in the global efforts (see Table 3). This aspect is particularly relevant to the implementation of the ECtHR's judgment and should be considered for inclusion into the mandate of an independent expert advisory body in Switzerland.

**Table 3: Consistency with international commitments and fairness of efforts**

<b>United Kingdom</b>	The CCC evaluates whether UK carbon budgets align with global temperature goals and assesses the UK's fair share.
<b>France</b>	The HCC assesses France's contribution to global mitigation.
<b>Ireland</b>	The CCAC ensures that Ireland's carbon budgets align with EU climate law and the Paris Agreement.
<b>Finland</b>	The Finnish Climate Change Panel evaluates whether Finland's long-term strategy aligns with global pathways.
<b>EU ESABCC</b>	The ESABCC provides EU-wide assessments of fair share and international consistency (ESABCC, 2023).

Source: Author.

## 6. Operation of advisory bodies in the federal decentralised systems

Countries with federal decentralised systems of governance take a variety of approaches to the role of national advisory bodies vis-à-vis devolved administrations. The UK Climate Change Act 2008 establishes the CCC as an advisor to all four national authorities and builds advice to the devolved administrations into the CCC mandate. Each devolved administration has then passed its own climate legislation that assigns the CCC specific advisory functions within its own framework. For example, Scotland through its own legislation sets a statutory role for the CCC. The Scottish Government requests regular advice, including an annual Scottish progress report on reducing emissions, advice on emissions reduction targets and regular independent assessments of adaptation programmes.

However, other countries with decentralised systems either have separate advisory bodies at each level of government (as in Australia, where New South Wales has its own Net Zero Commission alongside the federal Climate Change Authority) or have no formal advisory architecture at the sub-national level.

## 7. Key recommendations for the design of a climate advisory body

Independent climate advisory bodies address a fundamental challenge in democratic governance: mismatch between electoral cycles that incentivise short-term thinking and the sustained action and foresight planning over the decades required to address climate challenge. Well-designed bodies help by showing the gap between political commitment and implementation visible, requiring governments to justify departures from expert advice, and in the strongest models that include duty to act demanding additional action when policies fall short. Anchored in legislation with clear mandates, protected independence, and formal accountability mechanisms, climate advisory bodies help embed climate obligations in the institutional fabric of the state and to ensure the obligations continue across changes of government. They are based on a principle that extends beyond climate policy: that governance systems must safeguard the interests of present and future generations against short-term political pressures.

Establishing an independent climate advisory body in Switzerland in line with best European and international practice would strengthen its climate governance and enable stronger compliance with the ECtHR judgment. Drawing on best practices from across Europe, such a body could help enhance transparency, accountability, and public trust.

Design of such a body should ensure independence; high quality and breadth of expertise among the members; sufficient and predictable funding; and an obligation to respond for governments. Its mandate should be clear and broad at least to cover advice on targets and policies, and independent assessments of implementation; and a requirement to consider alignment with international commitments when providing advice on emission reduction targets.

Specific criteria to ensure effectiveness of climate advisory body include:

- **Personal, administrative and financial independence** through legally anchored procedures and operational arrangements ensuring that:
  - (i) members are selected through transparent procedures (e.g. through public calls, independent selection panels, and published criteria) and in their personal capacity based on professional expertise and academic qualifications, expressly avoiding political representation and proportionality;
  - (ii) the body has full authority to define its own programme of work and budgetary control to conduct its own analysis and commission external studies to enable it to fulfil its functions based on its best independent judgement;
  - (iii) the body is not vulnerable to political cycles and can maintain institutional knowledge (e.g. through being a permanent institution with staggered terms and ringfenced budgets).
- **High quality and breadth of expertise** among the members covering natural science, economics and social sciences, to ensure the body is able to effectively conduct credible analysis across multiple relevant disciplines.
- **Clarity and breadth of mandate**, with a strong mandate including advising on targets, assessing progress, evaluating policy effectiveness, and supporting public engagement. Including consideration of ambition and fairness of national efforts in the global context and alignment of targets with international commitments in the scope of work helps ensure consistency of national action with the Paris Agreement.
- **Accountability for governments** through duty to respond to the advice and duty to act (like in the case of Denmark) help improve effectiveness. Examples of Ireland, New Zealand, the UK, France, Denmark, Sweden, and the EU demonstrate that statutory requirements for the governments to consider advice and to indicate the reasons for when it is not being followed, enhance accountability. Parliamentary oversight in this context further helps strengthen governmental accountability.
- **Sufficient and predictable funding** to ensure the body is well resourced to conduct deeper analysis and engagement across a wider range of topics.

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## Annex 1: Design features of selected independent climate advisory bodies

Feature	United Kingdom CCC	Germany ERK	Ireland CCAC	France HCC	Denmark Klimarådet	Sweden Klimatpolitiska Rådet	Finland Ilmastopaneeli	EU ESABCC	New Zealand CCC
<b>Members</b>	~8 core members; multidisciplinary experts	5 experts; gender balance required	13 members; mix of experts and ex-officio	13 independent experts	8 independent experts	8 independent experts	~15 academic experts	15 independent scientists	9 members + Māori advisory body
<b>Secretariat Size</b>	~40–45 staff	~15 staff	~20 staff	~15–20 staff	~10–12 staff	~10 staff	~5–7 staff	~25 staff	~35 staff
<b>Annual Budget</b>	~£6–7 million	~€3–4 million	~€4–5 million	~€3–4 million	~€2–3 million	~€2–3 million	~€1–2 million	~€5–6 million	~NZ\$10–12 million
<b>Appointment of members</b>	Joint appointment by UK nations	Federal Government	Government on Minister's nomination	Appointed by government; independent selection committee	Appointed by Minister for Climate	Appointed by Government	Appointed by Government; academic institutions nominate	Appointed by EU institutions via scientific panel	Governor-General on Minister's recommendation
<b>Advice on Targets</b>	Yes – recommends carbon budgets	No	Yes – proposes carbon budgets	Yes – evaluates alignment with budgets	Yes – advises on national targets	Yes – advises on targets and pathways	Yes – advises on long-term strategy	Yes – recommends EU-wide targets	Yes – advises on emissions budgets
<b>Progress Assessment</b>	Annual progress reports	Annual sectoral review	Annual review	Annual review	Annual assessment	Annual assessment	Annual assessment	Annual EU-wide assessment	Annual monitoring
<b>Policy Advice</b>	Advises on mitigation pathways	Validates assumptions	Advises on climate action plan	Advises on policy coherence	Advises on policy design	Advises on policy gaps	Advises on policy effectiveness	Advises on EU policy	Advises on policies
<b>Duty for the Government to respond to the advice</b>	Yes	No	Yes	Yes	Yes	Yes	No (recommendations influential but not binding)	Yes	Yes
<b>Approach to International Commitments</b>	Paris alignment + UK fair share	EU; no explicit Paris assessment	Paris + EU alignment	Paris alignment + global contribution	Paris alignment	Paris alignment + Swedish climate law	Evaluates Paris alignment + equity considerations	EU-wide Paris alignment	Explicit Paris alignment

Source: Author.

**VEREIN KLIMASENIORINNEN AND OTHERS v SWITZERLAND (53600/20)**

**ANNEX II**

To the Rule 9.2. Communication of Greenpeace International & Climate Litigation Network  
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# Tracking country-level mitigation progress using NGHGI-consistent carbon budgets

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The remaining carbon budget (RCB) of countries provides a benchmark for evaluating national mitigation efforts and was central to a recent European Court of Human Rights' ruling. However, estimates of national RCBs are inconsistent with CO<sub>2</sub> accounting in national greenhouse gas inventories (NGHGIs). Here, we align RCBs with NGHGI accounting standards. For 2024, NGHGI alignment reduces the 1.5 °C (50%) global RCB by ~100 GtCO<sub>2</sub> (~50%) and the 2 °C (66%) RCB by ~200 GtCO<sub>2</sub> (~20%). Thus, we estimate the 1.5 °C (50%) NGHGI-consistent global RCB to be depleted by 2027. We provide NGHGI-consistent national RCBs for common allocation methods and most countries. Following Paris Agreement equity principles, we find that by 2025, 64–85 countries could have exceeded their fair-share RCB for 1.5 °C (50%). While national RCBs depend on normative choices and are unlikely to directly drive negotiations, our framework enables more methodologically robust RCB calculations to track country-level mitigation progress.

The success of global climate targets, such as those outlined in the Paris Agreement<sup>1</sup>, depends on the mitigation efforts of individual countries. National remaining carbon budgets (national RCBs) are a conceptual tool for informing and assessing national climate policy<sup>2,3</sup>. They represent a country's share<sup>4,5</sup> of the global RCB – the maximum net CO<sub>2</sub> emissions permissible before exceeding a specific temperature threshold with a given probability<sup>6,7</sup> – under certain assumptions and value judgments. Irrespective of whether RCBs drive global policy and mitigation efforts (see discussion) or simply track expected national progress, they are simple metrics to use. Once calculated, national RCBs can be compared with future CO<sub>2</sub> emissions expected from national climate targets to infer the target's compatibility with Paris Agreement temperature limits. This comparison, however, is methodologically challenging because the definition of anthropogenic CO<sub>2</sub> emissions embedded in national climate targets differs from the definition used in global RCB calculations<sup>8,9</sup>. This mismatch must be taken into account to ensure consistent quantification of RCBs for accurate assessments of national climate policy. Conceptually, this mismatch cannot be entirely eliminated, because the scientific foundation of the global RCB is undermined when using the reporting guidelines<sup>9,10</sup> used in national greenhouse gas inventories (NGHGIs), as additional global warming does not stop when reaching net zero CO<sub>2</sub> emissions<sup>11</sup>.

Determining a country's share of the global RCB involves three steps: (1) defining the global RCB available, (2) selecting a framework for the distribution of the global RCB to all countries (i.e., the allocation principle), and (3) operationalizing and applying the allocation principle with available data (i.e., the specific allocation method). Although there exists an extensive literature on sharing the global RCB (steps 2 and 3)<sup>4,12–20</sup>, there are common methodological inconsistencies in step one – the definition of the distributable global RCB – that are not considered (e.g.,<sup>14,20–22</sup>) or addressed non-transparently (e.g.,<sup>23</sup>).

Methodological inconsistencies arise due to differences in how anthropogenic CO<sub>2</sub> emissions are accounted for in scientific modeling conventions versus the reporting guidelines used in NGHGIs. Global RCB values in IPCC reports<sup>7</sup> (IPCC-based RCBs) or other scientific assessments<sup>24,25</sup> are derived under scientific modeling conventions. In contrast, it is the NGHGIs and their accounting conventions that form the basis for most emission reduction targets in nationally determined contributions (NDCs) and national climate strategies<sup>22,26</sup>.

Scientific modeling conventions and NGHGI accounting differ in their definitions of anthropogenic CO<sub>2</sub> emissions in two ways: The first difference occurs in the definition of land-use, land-use change, and forestry (LULUCF) CO<sub>2</sub> emissions, where scientific modeling conventions and NGHGIs implicitly attribute different parts of atmosphere-

land CO<sub>2</sub> fluxes to human influence<sup>11,27–29</sup>. In scientific modeling conventions that underpin the IPCC assessments, indirect CO<sub>2</sub> fluxes – the fluxes driven by human-caused changes to the environment, such as elevated atmospheric CO<sub>2</sub> levels, higher temperatures, and changes in nutrient supply – are not counted as anthropogenic CO<sub>2</sub> fluxes, but are considered to be part of the natural land sink<sup>11</sup>. These indirect effects, also termed “passive”, have so far led to a strong net uptake of atmospheric CO<sub>2</sub><sup>30</sup>. NGHGI accounting<sup>9,10</sup>, however, relies largely on observational data, making it typically difficult to fully separate passive CO<sub>2</sub> fluxes from CO<sub>2</sub> fluxes due to direct anthropogenic influence (e.g., de-, re-, and afforestation or forest management). For practical reasons, NGHGI accounting uses land that is classified by countries as “managed” as an indicator for the land where anthropogenic CO<sub>2</sub> fluxes occur<sup>27,28</sup>. Part of what is considered the natural CO<sub>2</sub> sink by modelers is incidentally included as an anthropogenic CO<sub>2</sub> sink in NGHGIs, as countries largest in area tend to classify most (if not all) land as managed, and isolation of passive CO<sub>2</sub> fluxes remains imperfect in NGHGI accounting<sup>29</sup>. This results in a fundamental mismatch of 5–7 GtCO<sub>2</sub> per year, corresponding to 12–17% of 2023’s global total anthropogenic CO<sub>2</sub> emissions<sup>30,31</sup>. This gap continues to evolve depending on the climate scenario<sup>3,32</sup> and the land classification by countries. This difference in methodology also explains why IPCC reports<sup>7</sup> and assessments of the Global Carbon Project<sup>30</sup> find that the LULUCF sector is a net source of CO<sub>2</sub> emissions, while NGHGIs consistently report it as a net sink<sup>8,27–29,32</sup>.

Crucially, under scientific modeling conventions, the concept of reaching net zero CO<sub>2</sub> to stop global temperature rise works just because passive CO<sub>2</sub> fluxes are classified to be natural (non-anthropogenic)<sup>11</sup>. After reaching net zero CO<sub>2</sub> emissions, continued passive CO<sub>2</sub> uptake by the land and oceans leads to decreasing atmospheric CO<sub>2</sub> concentrations that are necessary to counterbalance continued warming after forcing stabilization<sup>33</sup>. On the contrary, under NGHGI accounting of anthropogenic LULUCF CO<sub>2</sub> emissions, achieving net zero anthropogenic CO<sub>2</sub> emissions does not halt global temperature rise, as demonstrated by Allen et al.<sup>11</sup>. Most of the passive CO<sub>2</sub> uptake occurring on managed land is regarded as anthropogenic CO<sub>2</sub> removal in NGHGIs<sup>29</sup> and can therefore be potentially used to compensate for anthropogenic CO<sub>2</sub> emissions<sup>11</sup>. Thus, after reaching global net zero CO<sub>2</sub> from a NGHGI accounting perspective, the IPCC-based RCB continues to deplete. Limiting warming to a set temperature threshold requires continuous net negative CO<sub>2</sub> emissions in NGHGI accounting – this makes the concept of a RCB fundamentally incompatible with NGHGI accounting. Correcting the size of the available global RCB to fit NGHGI accounting conventions therefore requires assumptions about future emission pathways<sup>8</sup>.

The second difference relates to CO<sub>2</sub> emissions from international aviation and shipping (bunker fuels). Under the United Nations Framework Convention on Climate Change (UNFCCC), their mitigation is coordinated in cooperation with the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO)<sup>34</sup>. NGHGIs still report CO<sub>2</sub> emissions from bunker fuels but exclude them from national totals<sup>9,35</sup>. Similarly, bunker fuel emissions are most often excluded from national climate targets. Exceptions include intra-EU aviation emissions<sup>36</sup>, Switzerland’s net zero target<sup>37</sup>, and the UK climate target<sup>38</sup>.

A meaningful assessment of national climate targets and ambitions requires national RCBs derived from a global RCB that is aligned with NGHGI accounting conventions. This fact is, however, usually not explicitly considered or not communicated (e.g.,<sup>17,18,39–41</sup>). Political and societal implications of this shortcoming arose in the ruling of the European Court of Human Rights (ECtHR) in the case of *Verein KlimaSeniorinnen Schweiz and Others v. Switzerland*<sup>42</sup>. The (lacking) quantification of a national RCB represented a central point in the court’s argumentation (e.g., paragraphs 322–325, 360, 569–573<sup>42</sup>), but awareness of raised methodological mismatches was missing.

Determining a country’s share of the global RCB remains a delicate task because perceived emission reduction responsibilities are not purely scientific but involve political and ethical dimensions<sup>3,43,44</sup>. While the Paris Agreement sets global temperature limits, the contributions of individual countries remain voluntary, submitted as NDCs<sup>22</sup> to the UNFCCC. The UNFCCC and the Paris Agreement establish guiding principles for equity<sup>1,45,46</sup>, which can act as guardrails for translating a global RCB into national RCBs.

In this study, we propose a correction of the distributable global RCB that improves the consistency with NGHGI accounting, and thereby strengthens the robustness of national RCBs regardless of the chosen allocation principle when used to evaluate country-level mitigation progress. To simplify such a procedure, we provide a dataset of NGHGI-consistent national RCBs for a wide range of allocation methods and for all 197 Parties to the UNFCCC. Previous studies have sometimes excluded CO<sub>2</sub> emissions from the LULUCF sector and bunker fuels when allocating emissions or carbon budgets<sup>12,46,47</sup>, and accordingly made adjustments to distributable emissions. However, these studies did not address the conceptual mismatch between scientific modeling conventions and NGHGIs. While the implications of differences in the attribution of passive CO<sub>2</sub> fluxes in the LULUCF sector have been documented<sup>8,32</sup>, and a correction has been included once before in the context of a national RCB<sup>48</sup>, to our knowledge, the two necessary corrections have so far not been applied systematically to global and national RCBs. We aim to fill a gap in the scientific literature concerning an up-to-date, methodologically more robust quantification of national RCBs that combines global scope, temporal coverage, and a broad range of allocation methods. Here, we quantify the effect of the proposed correction and also examine the variation in the updated national RCBs that arises from different normative choices.

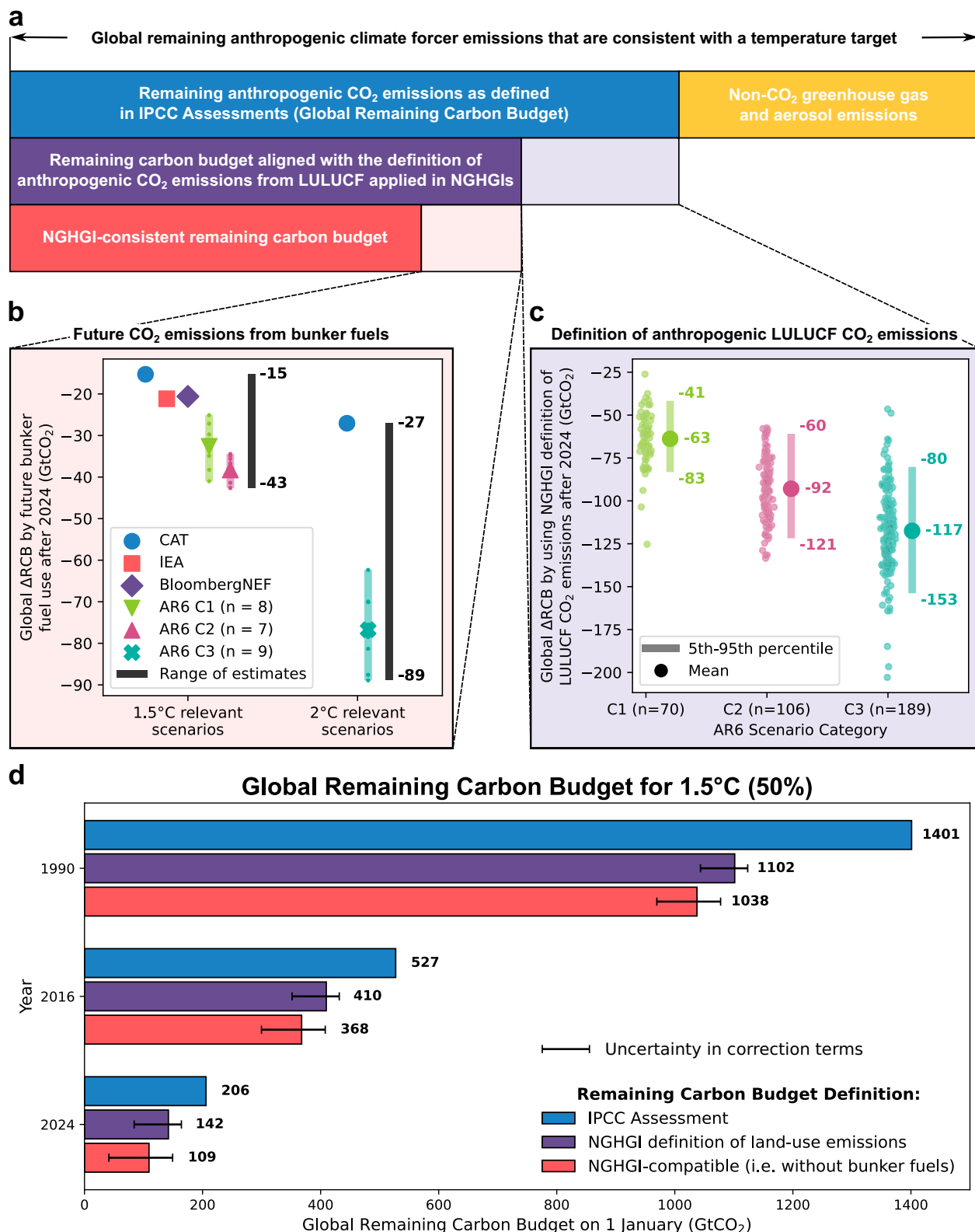
## Results

### The global NGHGI-consistent RCB

To convert the IPCC-based RCBs into NGHGI-consistent RCBs, we apply two independent absolute correction terms (Fig. 1): The first correction, the attribution of passive CO<sub>2</sub> fluxes in the LULUCF sector, strongly depends on the specific climate scenario (Fig. 1c) and the future amount and type of land classified as managed by countries. The methodological discrepancy between scientific modeling conventions and NGHGI accounting is projected to decline until global net zero CO<sub>2</sub> emissions (according to the definition in scientific modeling) are reached and switches sign afterward<sup>8</sup> (Supplementary Fig. 1). Using data from Gidden et al.<sup>8</sup>, we estimate that in 2024, the adjustment reduces the global RCB by 63 (41–121) GtCO<sub>2</sub> for 1.5 °C (50%) and 117 (80–153) GtCO<sub>2</sub> for 2 °C (66%) scenarios. Values in parentheses are the 5th (of C1 and C3 scenarios, respectively) and 95th percentile (of C2 and C3 scenarios, respectively) of the estimated correction terms, spanning several tens of GtCO<sub>2</sub> of scenario uncertainty.

The second correction accounts for excluding bunker fuel CO<sub>2</sub> emissions in NGHGIs. This further reduces the NGHGI-consistent global RCB (Fig. 1b): For 2024, we estimate a reduction of 33 (15–43) GtCO<sub>2</sub> for 1.5 °C and 77 (27–89) GtCO<sub>2</sub> for 2 °C scenarios, respectively. Future CO<sub>2</sub> emissions from bunker fuels also depend on scenario characteristics and data source (Fig. 1b), with AR6 scenarios projecting slightly higher values than other assessments.

Consequently, we estimate a 2024 NGHGI-consistent RCB of 109 GtCO<sub>2</sub> (41–149 GtCO<sub>2</sub> considering the spread in correction terms) and 709 (660–796) GtCO<sub>2</sub> for limiting warming to 1.5 °C (50%) and 2 °C (66%), respectively (red bars in Fig. 1a, d and Supplementary Fig. 3). For 1.5 °C (50%), this corresponds to a 47% (27–80%) reduction due to NGHGI alignment, equivalent to twice the anthropogenic CO<sub>2</sub> emissions in 2024<sup>30</sup>. For 2 °C (66%), we find a 21% (12–27%) reduction due to NGHGI alignment in 2024. For both temperature limits, the majority of this reduction stems from the difference in the definition of



anthropogenic LULUCF CO<sub>2</sub> emissions. The absolute difference between RCB definitions increases when going back in time (Fig. 1d), because of past differences in the reported anthropogenic LULUCF CO<sub>2</sub> emissions and accumulating CO<sub>2</sub> emissions from bunker fuels. When the Paris Agreement was adopted, the 1.5 °C NGHGI-consistent global RCB was 368 GtCO<sub>2</sub> – 30% lower than the IPCC-based RCB of 527 GtCO<sub>2</sub>.

**Allocation of the NGHGI-consistent budget to countries**

Using NGHGI-consistent global RCBs, we derive national RCBs from 1990 to 2022/2023 for a wide range of allocation principles and countries and make this dataset of NGHGI-consistent national RCBs available (see data availability section). The Paris Agreement refers to “the principle of equity and common but differentiated responsibilities and respective capabilities, in the light of different national

**Fig. 1 | Conversion of the IPCC-based to a NGHGI-consistent global RCB.**

a Schematic representation of the framework suggested to convert cumulative anthropogenic CO<sub>2</sub> emissions consistent with staying below a certain temperature limit (the global RCB), as defined in IPCC reports, to a NGHGI-consistent global RCB. Two correction terms are applied to the IPCC-based global RCB: The future CO<sub>2</sub> emissions from bunker fuels (b) and a change in the definition of anthropogenic LULUCF CO<sub>2</sub> emissions (c). Bar sizes in (a) are indicative and not necessarily proportional to actual values. b The range of bunker fuel emissions in different scenarios from 1 January 2024 to the year of net zero CO<sub>2</sub>. c The change in the 2024 global RCB by adopting the definitions of anthropogenic LULUCF CO<sub>2</sub>

emissions employed in NGHGIs (obtained from Gidden et al.<sup>8</sup>). C1, C2, and C3 denote IPCC AR6 scenarios with different maximum temperatures in (b) and (c): C1: Below 1.5 °C (50%) with no or limited overshoot; C2: Below 1.5 °C (50%) with high overshoot; C3: Below 2 °C (66%). d Comparison of alternative definitions of the global 1.5 °C-compatible RCB (50%) for 1990, 2016 (around the time of Paris Agreement adoption), and 2024 (the last year global data is available for this study). Error bars reflect uncertainty in correction terms. The lower (upper) bound is derived from the maximum (minimum) of assessed future bunker fuel emissions and the 95th percentile of C2 scenarios (5th percentile of C1 scenarios) for the assessed mismatch in future LULUCF CO<sub>2</sub> emissions.

circumstances”<sup>41</sup>. This terminology goes back to the UNFCCC Earth Summit in Rio de Janeiro 1992<sup>45</sup>, but does not define metrics for allocation. The Paris Agreement formulation has generally been interpreted in simple words as “all countries should contribute, but those who have emitted more in the past and have capacity (e.g., financial, technical) should contribute more”.

For illustration, we consider already established allocations based on equal-per-capita (EPC), cumulative equal-per-capita (cEPC), different weighting of economic capacity (CAP)<sup>17,18</sup>, Bretschger burden sharing (Bretschger)<sup>15</sup>, grandfathering, (cumulative) equal-per-capita with historical responsibility<sup>4,47</sup> for territorial or consumption-based emissions (cEPC+Terr / EPC+Terr, or cEPC+Cons / EPC+Cons, respectively), and capacity with historical responsibility (CAPRES). Years contained in allocation labels refer to the starting year of historical responsibility or aggregation (in the case of cumulative indicators). The scaling factor  $\sigma$  acts as a variable weight for economic capacity, as detailed in Equations (11)–(18) in the Methods. We do not attempt to judge the different allocation assumptions and their implications in this work, but rather to correct them for consistency with the NGHGI methodology and provide them to any potential user. Many other allocation criteria have been proposed and are possible, while here we provide a number of allocation principles commonly found in the literature.

We illustrate the diversity in allocation principles and methods by presenting results for four countries selected for their distinct economic profiles and emission trajectories: China, the USA, Switzerland, and Nigeria. Figure 2 shows their per-capita 1.5 °C-compatible RCBs for 2022 (analogous figures for other countries are provided with the dataset). Across most countries, allocated national RCBs vary considerably depending on the chosen allocation principle – particularly based on whether (and if so, since when) historical responsibility is accounted for. While alignment with NGHGI accounting substantially changes the size of the national RCB for some allocation principles – e.g., China’s 2022 EPC-based RCB is reduced by 39%, or its 2022 CAPRES1990 ( $\sigma=1$ )-based RCB is almost completely depleted – in terms of magnitude, the choice between the different allocation principles often has a larger effect on the resulting national RCB (see Supplementary Fig. 4 and 5 for the effect of the correction on national RCBs).

The upper ten allocations in Fig. 2 (EPC to CAP1950 ( $\sigma=1$ )) disregard historical responsibility, distributing the NGHGI-consistent global RCB among countries without adjustments for past emissions. This always yields positive budgets (as long as the global RCB is still positive), but the size is dependent on the year the allocation is performed: Even if a country’s relative share were to remain constant over time, the global RCB decreases with time (Fig. 1d). Thus, these estimates can be misleading, in particular as certain underlying principles (e.g., grandfathering and Bretschger burden sharing) are considered ethically problematic and are not aligned with UNFCCC equity principles<sup>43,46</sup>.

Allocation methods incorporating historical responsibility (e.g., EPC+Terr, EPC+Cons, and CAPRES) can result in negative RCBs for high cumulative emitters such as the USA, Canada, or Qatar, indicating exceedance of a country’s fair-share CO<sub>2</sub> emissions under the

respective allocation principle. There is no agreement on the start of historical responsibility, and previous studies define different or a range of starting years<sup>19,47,49</sup>. Unsurprisingly, this choice matters for the size of national RCBs – evident in Fig. 2 for China, the USA, and Switzerland. Including model-based anthropogenic LULUCF CO<sub>2</sub> emissions in calculations of historical responsibility – rather than fossil CO<sub>2</sub> emissions alone – leads to a decrease in calculated RCBs for countries recently associated with high LULUCF CO<sub>2</sub> emissions, such as those located in South America, Sub-Saharan Africa, and Southeast Asia (Supplementary Fig. 6).

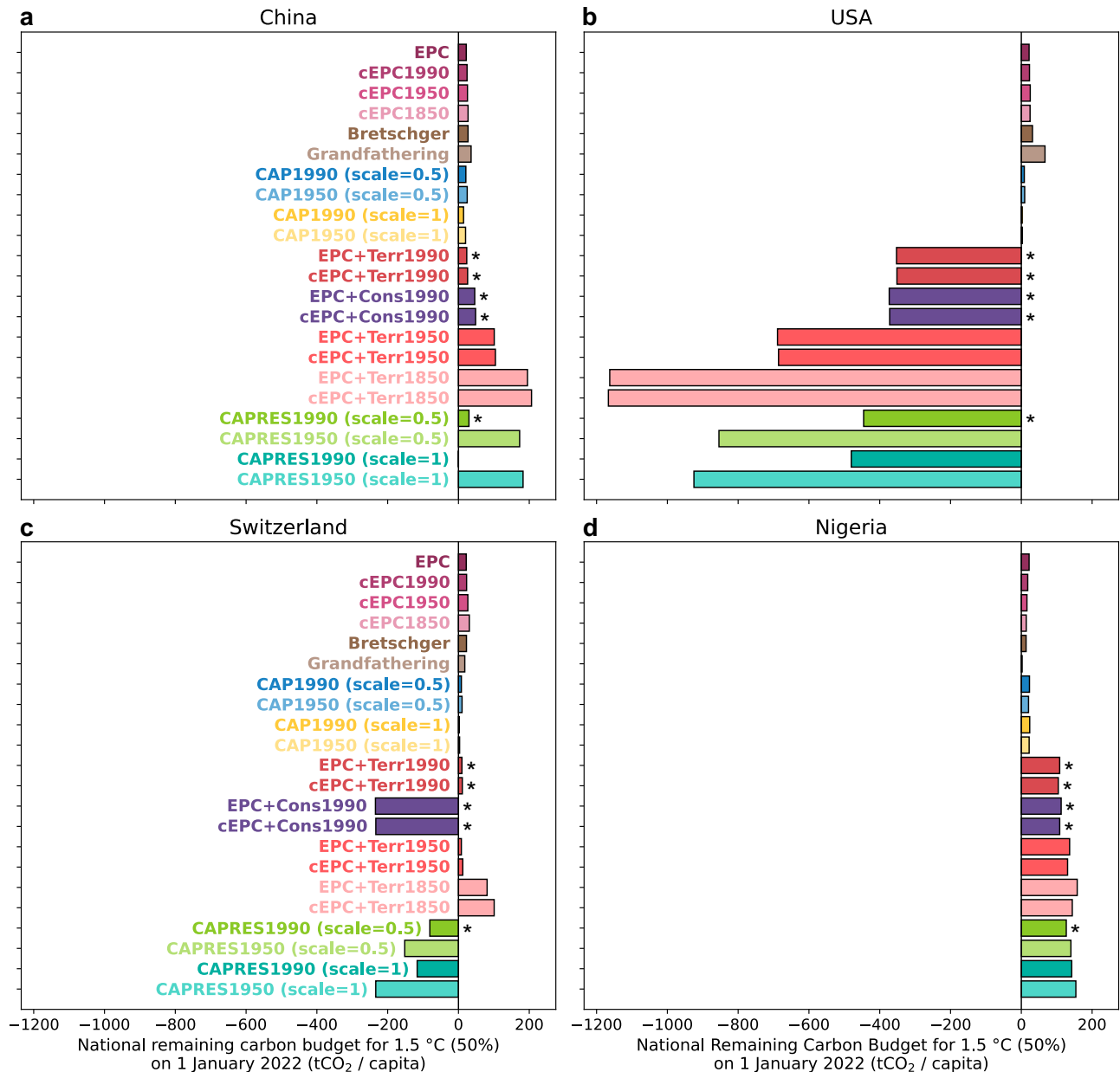
Nuances in implementation details, such as the weighting of economic capacity (by the scaling factor  $\sigma$ , Equations (17), (18), and (23)) and the choice between territorial and consumption-based CO<sub>2</sub> emissions, further influence national RCBs. For countries like Switzerland, Singapore, or Sweden, the consumption-based RCB is substantially lower than their territorial RCB. Among the selected countries, the sensitivity to changes in capacity weighting is evident for the USA and China. China’s 2022 RCB stays positive, except under strong weighting of economic capacity from 1990 onward. Meanwhile, we find that Nigeria’s RCB remains positive and largely unaffected by the allocation method – here, the most important determining factor is whether historical responsibility is being considered.

In brief, the selection of countries in Fig. 2 highlights the widely recognized strong dependence of national RCBs on both normative allocation choices and implementation details<sup>13,16,17,21,43,50</sup>. Here we find that for 2022 these tend to dominate over the correction applied and the sensitivity to the chosen temperature target (see Supplementary Fig. 7 for comparison with Fig. 2).

**Time-dependent national RCBs and exceedance of Paris agreement temperature limits**

Calculating the NGHGI-consistent global RCB back in time (Eq. (3)) allows us to examine the time evolution of national RCBs and provide insights into how national and regional contributions to carbon budget depletion have changed over the past decades. We assess how selected national and regional RCBs have evolved since 1990, focusing on five allocation principles that interpret UNFCCC equity principles and account for historical responsibility and economic capacity since 1990 (denoted as “fair-share” allocations and marked with an asterisk in Fig. 2): EPC+Terr1990, cEPC+Terr1990, EPC+Cons1990, cEPC+Cons1990, and CAPRES1990 (scale=0.5). Figure 3 shows the time series of the full range of fair-share per-capita RCBs for China, the USA, Switzerland, and Nigeria, as well as aggregated geographical regions.

National RCB depletion over time differs widely (Fig. 3a, b): The US 1.5 °C-compatible RCB turned negative already around 2000 and continues to decline faster than the global average, China’s RCB depletes more rapidly than the global average since around 2010, and Switzerland’s RCB spans positive to negative values depending on the chosen allocation method over a long period of time. On a global scale, there are only three out of eight geographical regions – Africa, Asia, and Central America – that have not yet exceeded their fair share of the 1.5 °C (50%) RCB in 2022, with Europe, North America, Oceania, and South America already surpassing it when the Paris Agreement was



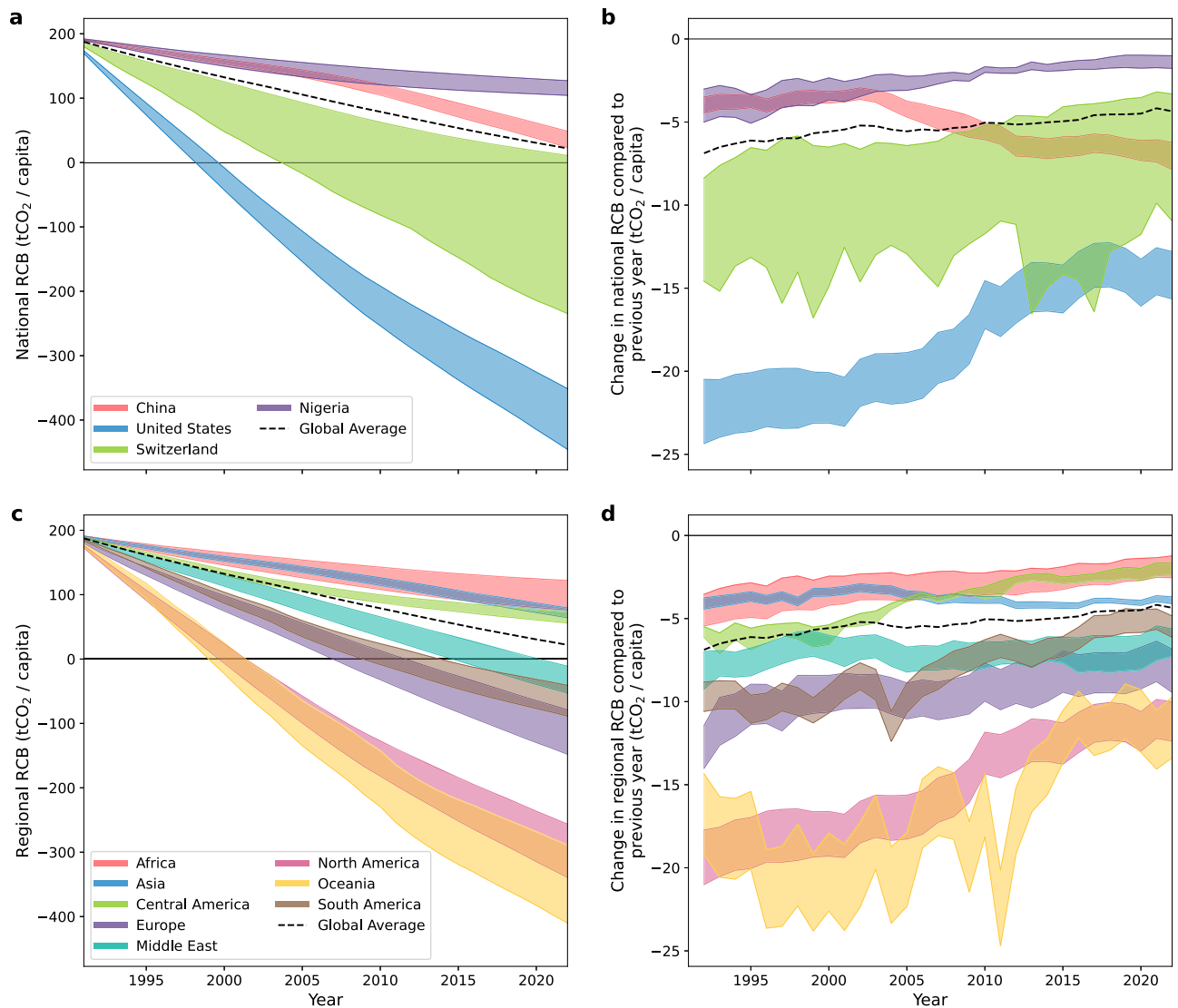
**Fig. 2 | Illustration of national RCBs from different allocation methods for four countries.** Per-capita 1.5 °C (50%) RCBs for China (a), the USA (b), Switzerland (c), and Nigeria (d) as of 1 January 2022, computed for a range of allocation methods. EPC denotes equal-per-capita allocations; Bretschger refers to Bretschger burden sharing; CAP stands for capacity-based allocations; EPC+Terr (EPC+Cons) considers

historical responsibility for territorial (consumption-based) emissions, and CAPRES takes capacity and historical responsibility into account. More details on the naming of allocation methods and their implementation are found in the Methods section *Distribution of the NGHGI-consistent global RCB*. Allocation methods marked with an asterisk (\*) are selected for subsequent parts of our analysis.

adopted (Fig. 3c). The depletion in per-capita RCB slows down globally and across most regions, which is an encouraging development (Fig. 3d). However, regions with lower per-capita RCBs still deplete their RCBs at a faster rate. This rate of depletion decreases over time, which is also evident in alternative country aggregations (Supplementary Fig. 8). Put simply, when measured with RCBs, every year the world is still getting more unequal, but less quickly.

On a national level, among the 197 countries that are parties to the UNFCCC<sup>51</sup>, 57–79 countries (29–40% of all) had exceeded their fair-share RCB for limiting warming to 1.5 °C (50%) by the start of 2022 (Fig. 4). These countries collectively represent 1.6–2.3 billion people (20–29% of global population) and 46–56% of global GDP. The number of countries overshooting their fair-share RCB has been steadily rising, and extrapolated trends project this number to have reached 64–85

(32–43%) by 2025 (see map in Supplementary Fig. 9) and reach 79–97 (40–49%) by 2035. We find a similar result for 2 °C (66%): 37–57 countries out of 197 (covering 1.2–1.6 billion people and 37–47% of global GDP) had already surpassed their fair share of CO<sub>2</sub> emissions by 2022 when using NGHGI-consistent RCBs (Supplementary Fig. 10 and Supplementary Tables 1–3). Thus, many countries effectively face an accruing carbon debt<sup>47</sup> and the notion of a “remaining carbon budget” becomes increasingly misleading, particularly for countries in the high human development index group<sup>52</sup> (Supplementary Fig. 11). Without alignment to NGHGIs, exceedance shifts to later years, as indicated in gray in Fig. 4 and Supplementary Fig. 10: For example, when considering IPCC-based RCBs in 2022, the number of countries exceeding their 2 °C (66%)-compatible RCB, the population they represent and their share of global GDP are reduced to 29–48 (compared to 37–57)



**Fig. 3 | Temporal evolution of NGHGI-consistent national and regional RCBs for 1.5 °C (50%).** **a** National per-capita RCBs of China, the USA, Switzerland, and Nigeria since 1990 under a selection of fair-share allocation methods. **b** Corresponding changes in national per-capita RCBs relative to the previous year. **c** Per-capita RCBs

for eight geographical regions. **d** Corresponding changes in regional per-capita RCBs relative to the previous year. The colored areas indicate the full range of the five selected allocation approaches.

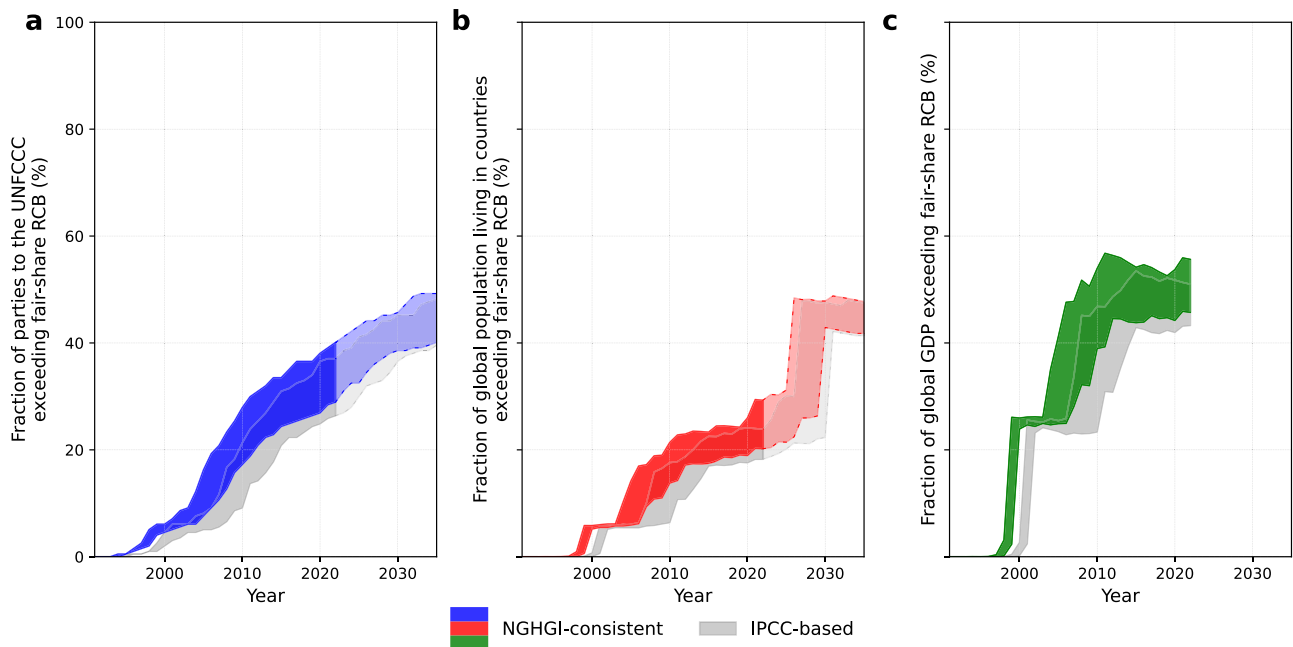
countries, covering 0.9–1.4 billion people, and 30–43% of global GDP, respectively.

### The case of Switzerland's RCB and NDC

We analyze Switzerland's RCB more in depth, due to its central role in the proceedings at the European Court of Human Rights (ECtHR) in the case of *Verein KlimaSeniorinnen and Others v. Switzerland*<sup>42</sup>, which could be a precedent for similar cases, especially after a recently published Advisory Opinion on the Obligations of States in respect of Climate Change<sup>53</sup> of the International Court of Justice (ICJ). In the mentioned case, Switzerland's government contended that "there was no established methodology to determine a country's carbon budget" (paragraph 570<sup>42</sup> and re-iterated during the proceedings of the Advisory Opinion of the ICJ<sup>54</sup>). Simultaneously, the court mandated that Switzerland needed to "adopt general measures specifying a target timeline for achieving carbon neutrality and the overall remaining carbon budget for the same time frame" (paragraph 550<sup>42</sup>). In brief, the ECtHR ultimately judged the absence of an attempt to quantify the national RCB to be a violation of Article 8 of the European Convention of Human Rights (paragraph 572<sup>42</sup>), which relates to the "Right to

respect for private and family life"<sup>55</sup>. With the framework outlined in this study, we can provide a scientifically robust estimate of Switzerland's RCB, despite the (perceived) lack of prior standardization for carbon budget calculations. We also assess Switzerland's RCB in the context of its NDC submitted in 2025<sup>56</sup>.

We first present a revised estimate of Switzerland's 1.5 °C (67%) RCB for 2020 under the equal-per-capita (EPC) allocation principle. This allocation principle was chosen and applied in the ruling of the ECtHR and yielded a RCB estimate of 0.44 GtCO<sub>2</sub> for Switzerland, which was later compared to Switzerland's NGHGI-based national climate strategy (paragraph 569<sup>42</sup>). Using the global RCB estimate given in the IPCC AR6<sup>7</sup> based on scientific modeling conventions, we obtain essentially the same value of 0.44 GtCO<sub>2</sub> (top bar in Fig. 5). However, Switzerland's RCB reduces to 0.30 GtCO<sub>2</sub> when aligning the global RCB with NGHGI accounting conventions, hence, making it comparable to Switzerland's national emission reduction targets embodied in its NDC (second bar in Fig. 5). Applying the global RCB update from Lamboll et al.<sup>24</sup> further reduces this estimate to 0.06 GtCO<sub>2</sub>. While these revisions do not qualitatively alter the court's argumentation, the assessment of whether Switzerland's emission



**Fig. 4 | Exceedance of national fair-share RCBs globally over time.** Fraction of UNFCCC countries exceeding their 1.5 °C (50%) compatible fair-share RCB over time (a), alongside the share of global population (b), and GDP (c) they represent. The colored areas in a, b, and c indicate the range arising from the five selected allocation methods used to calculate national RCBs, each resulting in distinct

timings of countries exceeding their fair-share of the global RCB. The gray shading corresponds to the results, if derived from an IPCC-based global RCB instead. Extrapolation to 2035 for UNFCCC parties and population is based on a quadratic extension, as described in the Methods section *Global Analysis*.

reduction targets are sufficient is changing. The originally communicated value of Switzerland's RCB (0.44 GtCO<sub>2</sub>) is slightly larger than Switzerland's post-2020 cumulative CO<sub>2</sub> emissions, implied by its updated NDC<sup>56</sup> (vertical line in Fig. 5). Yet, both NGHGI-consistent RCB estimates are lower (by a factor of seven when considering the RCB update). Thus, Switzerland's proposed emission reductions result in higher cumulative CO<sub>2</sub> emissions than the RCB allocated to Switzerland using an equal-per-capita approach, adding detail to the court's argumentation.

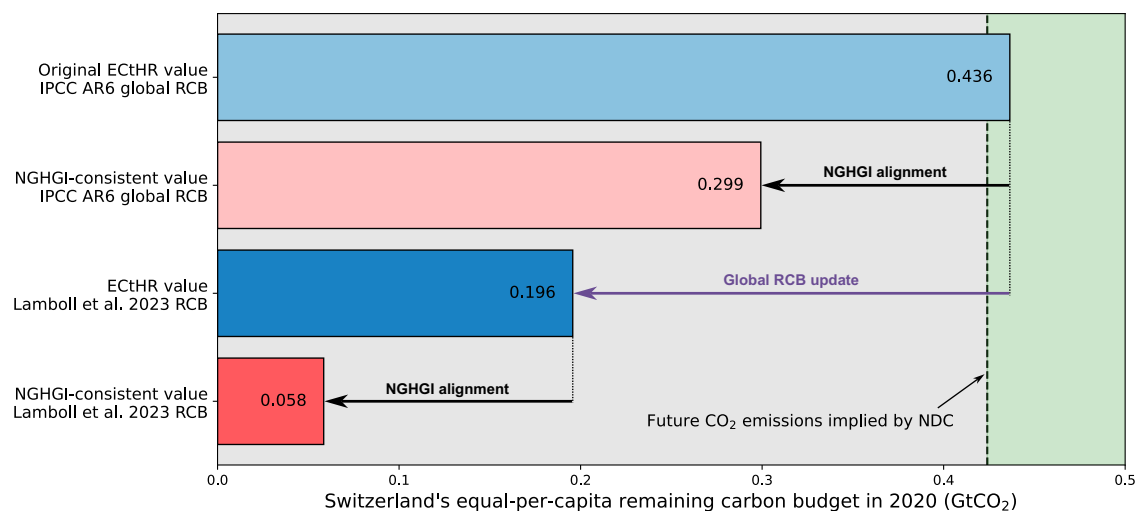
For a more comprehensive assessment of Switzerland's CO<sub>2</sub> emissions reduction ambitions, we use RCBs derived from a range of allocation methods. We compare Switzerland's NGHGI-consistent 1.5 °C (50%) RCBs at the time of the Paris Agreement adoption to the cumulative CO<sub>2</sub> emissions implied by its NDC (allocation at the start of 2016). This comparison reveals that Switzerland's planned CO<sub>2</sub> emissions reductions are insufficient to remain within its fair share of the global RCB under almost all allocation methods considered (Fig. 6). The RCB exceedance extends to more than 2 GtCO<sub>2</sub> (equivalent to around 60 times Switzerland's domestic annual CO<sub>2</sub> emissions<sup>30</sup>) with the largest overshoots found when considering capacity or historical consumption-based emissions. The only allocation methods that provide Switzerland with a larger RCB than its NDC-consistent cumulative CO<sub>2</sub> emissions are those that consider historical responsibility for CO<sub>2</sub> emissions since 1850. This exception arises because Switzerland's historical LULUCF CO<sub>2</sub> emissions since 1850 were below the global average, leading to the buildup of a net CO<sub>2</sub> credit between 1850 and 1950. However, when historical responsibility is limited to fossil CO<sub>2</sub> emissions, Switzerland exceeds its national RCB under all assessed allocation methods (Supplementary Fig. 12). Despite the absence of one universally established allocation method, all methods considered here lead to the same conclusion: Switzerland's past and planned CO<sub>2</sub> emissions are incompatible with the global 1.5 °C limit. The magnitude of the RCB overshoot increases under allocations aligned with UNFCCC equity principles and referenced in section 4.6 of Switzerland's updated NDC<sup>56</sup>. When accepting a more relaxed interpretation

of the Paris Agreement of limiting warming to 2 °C (66%), Switzerland's planned contribution is sufficient under EPC allocation and inclusion of responsibility for territorial emissions, but not when considering capacity or responsibility for consumption-based emissions (Supplementary Fig. 13 and 14). Similar assessments for other countries are possible with the data we provide with this study.

## Discussion

In this study, we introduce the concept of a global NGHGI-consistent RCB for methodologically robust national RCB calculations and present a simple two-step correction framework to adjust IPCC-based RCB estimates. The RCB distributable to countries is lower than the IPCC-based RCB and not considering alignment with NGHGIs leads to a systematic overestimation of national RCBs, skewing assessments of national mitigation efforts. The necessary correction terms bear considerable uncertainty due to scenario dependence. They are likely to be underestimated (Supplementary Note 1) and the NGHGI-consistent global RCB thus still remains overestimated. Consequently, under our current assumptions, we estimate that permissible country-reported CO<sub>2</sub> emissions compatible with the 1.5 °C limit, when aggregated globally, have either already been exhausted or will reach zero by 2027 – slightly earlier than estimated in the most recent NDC synthesis report<sup>22</sup>. The 2024 NGHGI-consistent 2 °C (66%) compatible global RCB amounts to approximately 700 GtCO<sub>2</sub>, equivalent to just 21 years of country-reported CO<sub>2</sub> emissions from 2022<sup>30,57</sup>, emphasizing the need for rapid global decarbonization to stay within the Paris Agreement temperature limits.

Besides uncertainties in applied correction terms, NGHGI-consistent RCB estimates inherently contain geophysical and scenario-related uncertainties from IPCC-based RCB estimates<sup>2,6,24</sup>, particularly regarding future non-CO<sub>2</sub> emission pathways<sup>6,58</sup>. Less stringent non-CO<sub>2</sub> GHG mitigation could further reduce global RCB estimates by approximately 220 GtCO<sub>2</sub><sup>7</sup>, implying depletion of the 1.5 °C (50%) NGHGI-consistent global RCB already around 2021. While integrating non-CO<sub>2</sub> GHGs into a broader global warming budget<sup>49</sup>



**Fig. 5 | The correction of Switzerland's equal-per-capita RCB in 2020 provided in the ruling of the ECtHR.** The original value of 0.44 GtCO<sub>2</sub> is reduced through alignment with the NGHGI accounting conventions (black arrows) and the updated global RCB estimate (purple arrow). The green area on the right indicates where

Switzerland's equal-per-capita RCB is larger than the future CO<sub>2</sub> emissions implied in Switzerland's second NDC, while within the grey part, the future emissions exceed the RCB.

would offer a more comprehensive picture of climate responsibility, such an approach adds conceptual and methodological complexities. Given the conceptual simplicity, robust scientific foundation, and longstanding acceptance of carbon budgets<sup>59–62</sup>, we focus here on CO<sub>2</sub> for introducing NGHGI-consistent RCBs.

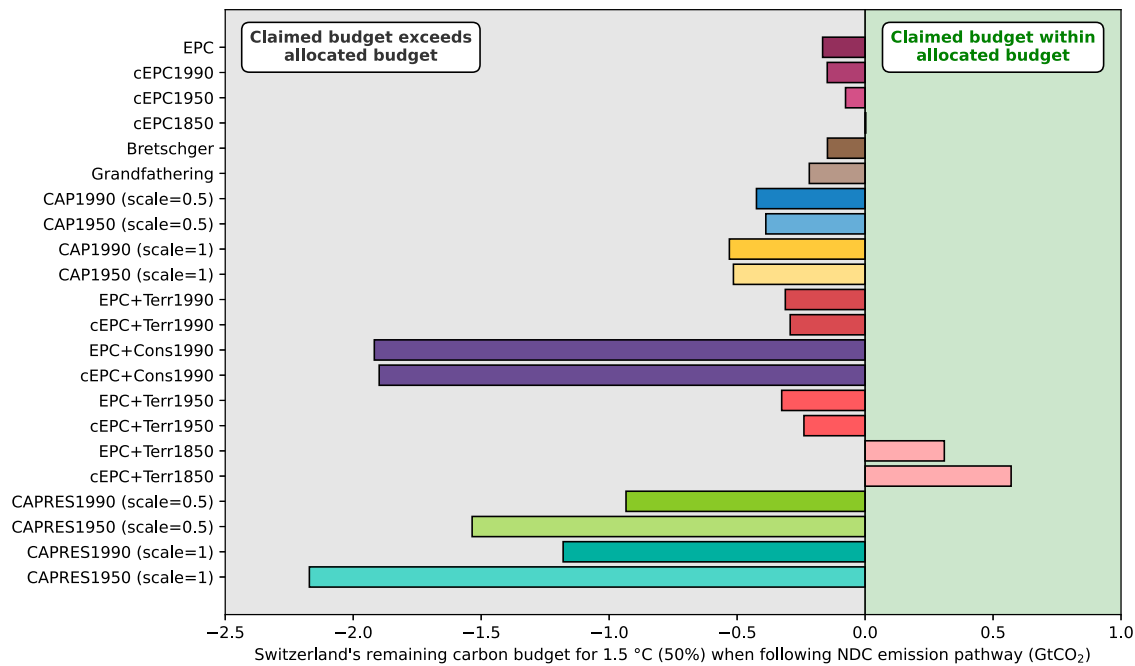
Additional uncertainties in time-dependent NGHGI-consistent RCBs (particularly pre-2000) are due to accumulated errors in fossil CO<sub>2</sub> emissions data ( $1\sigma \approx 5\%$ <sup>30</sup>) and incompleteness of used NGHGI-reported LULUCF CO<sub>2</sub> emissions, resulting in a maximum added uncertainty of approximately 50 GtCO<sub>2</sub> ( $= 1\sigma$ ) around 1990. National RCBs that consider historical responsibility are particularly affected by uncertainty in bookkeeping LULUCF CO<sub>2</sub> emissions<sup>30</sup>. By default, we include territorial LULUCF CO<sub>2</sub> emissions when calculating national carbon debts or credits (Eq. (19)–(23)). For better transparency in mitigation efforts, one might want to separate the contributions of fossil and LULUCF CO<sub>2</sub> emissions, so we provide national RCBs considering historical responsibility for only fossil CO<sub>2</sub> in the dataset, too (see Supplementary Fig. 15–17).

We see it as the role of the existing fair-share literature (e.g.,<sup>43,46</sup>) to inform decision-makers and courts about suitable allocation approaches. Therefore, in calculating national RCBs, we aimed to remain agnostic regarding allocation methods and provide RCBs derived from diverse equity principles. Whereas our selection is inevitably incomplete, it is sufficient to show how national RCBs are sensitive to both the underlying equity principles and their operationalization. However, this sensitivity should not obscure the need for accurate accounting and the methodological corrections we propose. Reasoning with a single allocation method paints an incomplete or misleading picture for many countries. Thus, we argue that argumentations involving national RCBs and a nuanced assessment of country-level climate targets generally require RCBs derived not only transparently and consistently but also using multiple allocation methods that are consistent with UNFCCC equity principles<sup>1,46</sup>.

For part of our analysis, we do make an implicit value judgment in selecting five allocation methods, particularly in defining the start year of historical responsibility as 1990. This choice underestimates the carbon debt of historically high CO<sub>2</sub> emitters but reflects the choices made in previous literature<sup>4,17–19,47</sup> and is consistent with the time when international scientific climate change assessment and global negotiations started. Even with this conservative choice, we find that at the

time of the Paris Agreement negotiations (end of 2015), 49–69 countries had already exceeded their 1.5 °C-compatible fair share of the global NGHGI-consistent RCB – compared to 44–62 (a bias of around 10%) when using an IPCC-based RCB. This can be interpreted as an (at that time) implicit approval of a requirement for future net negative emissions, which are the primary avenue for addressing the accrued carbon debt and the pronounced asymmetry between countries with a high and those with a low to middle human development index<sup>19,49</sup> (Supplementary Fig. 11). Even when the global RCB for 1.5 °C or 2 °C is depleted, the quantification of national RCBs remains informative, e.g., to estimate the size of a national carbon debt and the resulting required cumulative amount of net negative CO<sub>2</sub> emissions for any internationally agreed temperature limits<sup>47,63</sup>. When historical responsibility is taken into account, many national RCBs are already negative today and increasingly so once the global RCB is depleted. Conversely, certain countries may keep positive budgets long after a global RCB is depleted. It is worth highlighting that under an overshoot of a global RCB, care needs to be taken when applying existing allocation methods, as interpretations of distributional approaches change when moving from a positive to a negative quantity to distribute (Supplementary Note 2). However, there is no change in the notion that countries with minimal or negative RCBs need not only to adopt and implement emission reduction strategies with the highest possible ambition<sup>1,64</sup>, but also aim for net negative CO<sub>2</sub> emissions after they reach net zero CO<sub>2</sub> emissions.

Finally, we argue that the distribution of a global RCB to countries is not the driver of national climate policy. The concept of a global RCB has been instrumental in recognizing the need for global and country-level net zero targets. However, attempts to agree on universal allocation methods for the global RCB at the Conferences of the Parties (COPs) have not been successful, as countries are reluctant to let other entities prescribe or restrict their national policies. National RCBs inherently depend on value judgments, making agreement difficult. Deliberately selecting a single allocation method can, in an extreme case, misrepresent a country's "fair" share of the RCB. Thus, arguing with national RCBs might even prove obstructive in global negotiations. Still, assumptions around RCB calculations require harmonization. Carbon budgets (sometimes within GHG budgets) appear in policy discussions<sup>23,65–67</sup>, the assessment of NDCs<sup>22</sup>, and may be required to be quantified in future legal deliberations (as implied by



**Fig. 6 | Comparison of Switzerland's 1.5 °C (50%) RCB to Switzerland's cumulative CO<sub>2</sub> emissions implied by its second NDC.** We show the difference between Switzerland's derived RCBs – calculated by various allocation methods – and Switzerland's future CO<sub>2</sub> emissions – implied by its second NDC. RCBs are

calculated for the start of 2016, which approximately coincides with the Paris Agreement adoption. Positive values suggest an allocated RCB larger than the post-2015 CO<sub>2</sub> emissions implied by Switzerland's NDC (green area to the right), while negative values indicate Switzerland overshooting its RCB (gray area to the left).

the ECtHR<sup>42</sup> and strengthened by the ICJ<sup>53</sup>). Given the cumulative nature of CO<sub>2</sub>-induced warming, they are a simple and robust quantity for assessing mitigation targets in relation to fair shares, tracing efforts, a comparison between nations<sup>3,68</sup>, and quantifying a country's responsibility to global CO<sub>2</sub> removal efforts<sup>47</sup>. These applications underscore the importance of transparent and NGHGI-consistent national RCB calculations, which we seek to facilitate with this study. We stress once more that net zero CO<sub>2</sub> emissions are not sufficient for halting warming when using NGHGI accounting conventions for anthropogenic CO<sub>2</sub><sup>11</sup>. Hence, recognition of the existence of different RCB definitions (IPCC-based and NGHGI-consistent) is essential to prevent misconceptions when designing climate strategies and accurately assessing the compatibility of national with global climate targets, such as in NDC synthesis reports and future legal cases.

## Methods

### Calculating a NGHGI-consistent global RCB

By default, we consider global RCB estimates for 1.5 °C (50%) and 2 °C (66%) calculated for the 1 January 2023 by Lamboll et al. (RCB<sub>glob</sub><sup>Lamboll et al.</sup>)<sup>24</sup>. While a RCB only accounts for CO<sub>2</sub> emissions, each global temperature limit is associated with a specific amount of future CO<sub>2</sub> and non-CO<sub>2</sub> climate forcer emissions, derived from an assessed set of future scenarios<sup>58</sup>. Non-CO<sub>2</sub> GHG and aerosol emissions are expected to contribute to net warming (yellow bar in Fig. 1a), with their emission pathways implicitly affecting the size of the global IPCC-based RCB (blue bar in Fig. 1a). As we focus on consistent CO<sub>2</sub> accounting, we use IPCC-based RCB values as they are published and do not further examine assumptions behind future non-CO<sub>2</sub> pathways (see discussion). We calculate IPCC-consistent (also termed IPCC-based) global RCBs (RCB<sub>glob</sub><sup>IPCC</sup>) for the 1 January 1990–2024 with total global fossil CO<sub>2</sub> emissions ( $E_{CO_2}^{foss}$ ) taken from the Global Carbon Budget 2024 (GCB2024)<sup>30</sup>. To account for the definition of anthropogenic LULUCF CO<sub>2</sub> emissions used by IPCC Assessment Reports (ARs) we further add the mean of LULUCF CO<sub>2</sub> emissions estimated by four bookkeeping models (BMs, variable:  $E_{CO_2}^{LULUCF, BM_b}$ ,  $b \in [1, 4]$ ) also

provided by the GCB2024<sup>30</sup>.

$$RCB_{glob}^{IPCC}(t) = RCB_{glob}^{Lamboll et al.}(2023) + \begin{cases} \sum_{t'=2023}^{t-1} \left( -E_{CO_2}^{foss}(t') - \frac{1}{4} \sum_{b=1}^4 \left( E_{CO_2}^{LULUCF, BM_b}(t') \right) \right) & \text{if } t > 2023 \\ \sum_{t'=t}^{2022} \left( E_{CO_2}^{foss}(t') + \frac{1}{4} \sum_{b=1}^4 \left( E_{CO_2}^{LULUCF, BM_b}(t') \right) \right) & \text{if } t < 2023 \end{cases} \quad (1)$$

To make the global RCB consistent with the NGHGI accounting conventions, we first adjust the global RCB by using the results of the reanalysis performed by Gidden et al.<sup>8</sup>. They quantified the reduction in the global RCB by adopting the definition of anthropogenic LULUCF CO<sub>2</sub> emissions implied by the NGHGI accounting conventions from 2020 onward for 1.5 °C (50%) and 2 °C (66%) scenarios from the AR6 scenario database<sup>69</sup> – this is why we limit our analysis to the RCB for 1.5 °C (50%) and 2 °C (66%). The reduction in global RCB is given by the integrated difference between the estimate of model-based and NGHGI-based anthropogenic LULUCF emissions until net zero CO<sub>2</sub> is reached from a model-based perspective and depends on the characteristics of the specific scenario (individual dots in Fig. 1c). The reanalysis by Gidden et al.<sup>8</sup> appears to underestimate the past difference between the (positive) model-based and (negative) NGHGI-based emissions (Supplementary Fig. 2). We therefore adjust their calculated values with data on the difference between mean CO<sub>2</sub> emissions from GCB2024 BMs and global NGHGI-reported values<sup>57</sup> from 2020 to 2023, slightly increasing the reduction in the global RCB. This form of adjustment is, however, not possible for the future difference, likely leading to an underestimation of the correction. We use the mean of all reanalyzed C1 (C3) scenarios from the AR6 scenario database<sup>69</sup> for the correction of the 1.5 °C (2 °C) IPCC-based RCB (correction term  $\Delta E_{CO_2}^{2023 \rightarrow \text{net zero CO}_2} = E_{CO_2}^{LULUCF, IPCC} - E_{CO_2}^{LULUCF, NGHGI}$  in Eq. (2)).

To estimate the range of future CO<sub>2</sub> emissions from bunker fuels we take scenarios from the AR6 scenario database<sup>69</sup>, Climate Action

Tracker (CAT) assessments<sup>70,71</sup>, historical and scenario data from the International Energy Agency (IEA)<sup>72–74</sup>, publicly available scenario data from BloombergNEF<sup>75</sup>, and historical bunker fuel CO<sub>2</sub> emissions from the GCB2024<sup>30</sup>. In the AR6 scenario database, global CO<sub>2</sub> emissions from international aviation and shipping are described by the variables `Emissions[CO2|Energy|Demand|Transportation|Aviation` and `Emissions[CO2|Energy|Demand|Transportation|Maritime`, provided by 8, 7, and 9 scenarios in the C1, C2, and C3 categories, respectively. The IEA Net Zero Scenario<sup>74</sup> and the two BloombergNEF scenarios (Net Zero and Economic Transition) provide data on CO<sub>2</sub> emissions from aviation and shipping, separately, but do not discriminate between domestic and international transport. According to IEA data<sup>73</sup>, international aviation historically contributed between 58% and 62% of total aviation CO<sub>2</sub> emissions. We therefore use a factor of 0.6 to scale provided CO<sub>2</sub> emissions from aviation, assuming a near-constant split until net zero CO<sub>2</sub> emissions are reached. For shipping, we assume that CO<sub>2</sub> emissions are dominated by international transport and use voyage-based data provided by CAT<sup>70</sup>, leading to good agreement with the other datasets specifying international shipping and total bunker fuel CO<sub>2</sub> emissions in the historical period (Supplementary Fig. 18 and 19). Bunker fuel CO<sub>2</sub> emissions are summed from 2023 until the year net zero CO<sub>2</sub> is reached to obtain a further correction to the global RCB as of 1 January 2023. In the case of the CAT assessments, we assume net zero CO<sub>2</sub> emissions are reached in 2050 (2065) for the 1.5 °C (2 °C) compatible pathways, following the timing of net zero CO<sub>2</sub> emissions found in the other scenarios considered.

The cumulative future CO<sub>2</sub> emissions from bunker fuels ( $\Delta E_{\text{CO}_2, \text{bunker fuels}}^{2023 \rightarrow \text{net zero CO}_2}$ ) are subtracted from the global RCB estimate, already corrected for the difference in the definition of anthropogenic LULUCF CO<sub>2</sub> emissions between IPCC ARs and NGHGs. Given the spread in the correction terms associated with future bunker fuel emissions, and the designedly optimistic values in CAT assessments, we use the mean value of the C1 scenarios for correcting the RCB for 1.5 °C (50%) and the mean value of the C3 scenarios for the 2 °C (66%) global RCB. The full range of estimates is however considered in the illustration of the uncertainty. This way, we obtain a global RCB ( $\text{RCB}_{\text{glob}}^{\text{NGHGI}}$ ) that is consistent with the definitions applied in NGHGs. The conversion of RCBs to the definitions applied in NGHGs is conceptually shown in Fig. 1a and can be expressed as follows:

$$\text{RCB}_{\text{glob}}^{\text{NGHGI}}(2023) = \text{RCB}_{\text{glob}}^{\text{IPCC}}(2023) - \Delta E_{\text{CO}_2, \text{LULUCF}_{\text{IPCC}} - \text{LULUCF}_{\text{NGHGI}}}^{2023 \rightarrow \text{net zero CO}_2} - \Delta E_{\text{CO}_2, \text{bunker fuels}}^{2023 \rightarrow \text{net zero CO}_2} \quad (2)$$

To calculate the NGHGI-consistent global RCB back (forward) to 1 January 1990 (2024), we consider an updated version of the dataset<sup>57</sup> provided by Grassi et al.<sup>31</sup> (available on request) for globally aggregated LULUCF CO<sub>2</sub> fluxes reported in NGHGs ( $E_{\text{CO}_2}^{\text{LULUCF, NGHGI}}$ ), and bunker fuel CO<sub>2</sub> emissions from the GCB2024 ( $E_{\text{CO}_2}^{\text{bunker fuels}}$ )<sup>30</sup>.

$$\text{RCB}_{\text{glob}}^{\text{NGHGI}}(t) = \text{RCB}_{\text{glob}}^{\text{NGHGI}}(2023) + \begin{cases} \sum_{t'=2023}^{t-1} (-E_{\text{CO}_2}^{\text{foss}}(t') + E_{\text{CO}_2}^{\text{bunker fuels}}(t') - E_{\text{CO}_2}^{\text{LULUCF, NGHGI}}(t')) & \text{if } t > 2023 \\ \sum_{t'=t}^{2022} (E_{\text{CO}_2}^{\text{foss}}(t') - E_{\text{CO}_2}^{\text{bunker fuels}}(t') + E_{\text{CO}_2}^{\text{LULUCF, NGHGI}}(t')) & \text{if } t < 2023 \end{cases} \quad (3)$$

### Allocation of the NGHGI-consistent budget to countries

The NGHGI-consistent global RCB is distributed among countries according to different allocation principles, based on past population data from Our World in Data (1850–2023)<sup>76</sup> and supplementary Swiss population data<sup>77</sup>, fossil territorial (1850–2023) and consumption-based (1990–2021, see Supplementary Note 3), as well as LULUCF CO<sub>2</sub>

emissions from the GCB2024<sup>30</sup> and GDP-per-capita data (1950–2022) from the Maddison Project Database<sup>78</sup> estimated using purchasing power parity (using GDP based on market exchange rates was shown to lead to negligible changes in allocations<sup>49</sup>).

The number of countries represented in the datasets varies. National RCBs are calculated for the biggest subset of countries represented in the datasets used, even if some entities are not formally part of the UNFCCC. In addition to the 197 countries that are parties to the UNFCCC, the population dataset includes data for 41 entities that are either only partially recognized countries, disputed territories, or overseas sub-national territories, often with a certain degree of autonomy, which account for around 0.5% of the global population in 2023 (see Section 6 in Supplementary Information for a complete list). The different allocation principles applied are the following, with the number of national RCBs given in parentheses: (cumulative) equal-per-capita (238); Bretschger burden sharing, grandfathering, (cumulative) equal-per-capita with historical responsibility for territorial emissions (all 197), (cumulative) equal-per-capita with historical responsibility for consumption-based emissions (118); capacity and capacity with historical responsibility (both 165).

The mathematical implementation of the different allocation principles is given in the following, where we use:

$i \dots$  Country index

$\text{Pop}_i(t) \dots$  Population (4)

$\text{GDP}_i^{\text{per-capita}}(t) \cdot \text{Pop}_i(t) = \text{GDP}_i(t) \dots$  Gross domestic product

$\sum_{t'=y}^t \text{Pop}_i(t') = \text{cPop}_i^y(t) \dots$  Cumulative population since year  $y$  (5)

$\sum_{t'=y}^t \text{GDP}_i(t') = \text{cGDP}_i^y(t) \dots$  Cumulative GDP since year  $y$  (6)

$E_{\text{CO}_2, i}^{\text{foss}}(t) + \frac{1}{4} \sum_{b=1}^4 (E_{\text{CO}_2}^{\text{LULUCF, BM}_b}(t)) = E_{\text{CO}_2, i}^{\text{terr}}(t) \dots$  Territorial CO<sub>2</sub> emissions (7)

$\sum_{t'=y}^t E_{\text{CO}_2, i}^{\text{terr}}(t') = \text{cE}_{\text{CO}_2, i}^{\text{terr}, y}(t) \dots$  Cumulative territorial CO<sub>2</sub> emissions since year  $y$  (8)

$E_{\text{CO}_2, i}^{\text{foss, cons}}(t) + \frac{1}{4} \sum_{b=1}^4 (E_{\text{CO}_2}^{\text{LULUCF, BM}_b}(t)) = E_{\text{CO}_2, i}^{\text{cons}}(t) \dots$  Consumption based CO<sub>2</sub> emissions (9)

$\sum_{t'=y}^t E_{\text{CO}_2, i}^{\text{cons}}(t') = \text{cE}_{\text{CO}_2, i}^{\text{cons}, y}(t) \dots$  Cumulative consumption based CO<sub>2</sub> emissions since year  $y$  (10)

**Equal-per-capita (EPC):** The allocation of the global RCB depends on the current share of the global population.

$$\text{RCB}_i^{\text{EPC}}(t) = \text{RCB}_{\text{glob}}^{\text{NGHGI}}(t) \cdot \text{Pop}_i(t) \quad (11)$$

**Cumulative equal-per-capita (cEPC):** The allocation of the global RCB depends on the share of the cumulative population since a year  $y$ .

$$\text{RCB}_i^{\text{cEPC}, y}(t) = \text{RCB}_{\text{glob}}^{\text{NGHGI}}(t) \cdot \text{cPop}_i^y(t) \quad (12)$$

**Bretschger burden sharing:** The fraction of the global RCB allocated to a country depends on a scaled version of the CO<sub>2</sub>

emissions per person<sup>15</sup>. This represents a variation of the grandfathering principle and, like it, lacks a basis in international environmental law<sup>46</sup>. However, this approach was used to establish exceedance of a national RCB<sup>48</sup>. For allocation of the budget on the 1 January, we take the emissions from the previous year.

$$RCB_i^{Bretschger}(t) = RCB_{glob}^{NGHGI}(t) \cdot \frac{m_i(t-1) \cdot F_i(t-1)}{\sum_i (m_i(t-1) \cdot F_i(t-1))} \quad (13)$$

with

$$m_i(t) = \frac{Pop_i(t)}{\sum_i Pop_i(t)} \quad (14)$$

$$F_i(t) = \left( \frac{E_{CO_2,i}^{terr}(t)}{Pop_i(t)} \right)^{0.25} \quad (15)$$

**Grandfathering:** The global RCB is distributed according to the fraction of emissions in the year before. Grandfathering is considered to contrast it with other allocation principles. We stress that grandfathering is argued to have no ethical basis in international environmental law<sup>43,46</sup>.

$$RCB_i^{GF}(t) = RCB_{glob}^{NGHGI}(t) \cdot \frac{E_{CO_2,i}^{terr}(t-1)}{\sum_i E_{CO_2,i}^{terr}(t-1)} \quad (16)$$

**Capacity (CAPy ( $\sigma = \sigma^*$ )):** The allocation of the global RCB is proportional to the factor  $\phi_{CAP,i}^{y,\sigma^*}$ , which depends on a scaled version of the cumulative GDP per capita, with the strength of the scaling encapsulated in the scaling factor  $\sigma^{17,18}$ .

$$RCB_i^{CAPy(\sigma=\sigma^*)}(t) = RCB_{glob}^{NGHGI}(t) \cdot \frac{\phi_{CAP,i}^{y,\sigma^*}(t)}{\sum_i \phi_{CAP,i}^{y,\sigma^*}(t)} \quad (17)$$

with

$$\phi_{CAP,i}^{y,\sigma^*}(t) = \left( \frac{cGDP_i^y(t-1)}{cPop_i^y(t-1)} \right)^{-\sigma} \cdot cPop_i^y(t-1) \quad (18)$$

The choice of  $\sigma$  is normative. Following Pelz et al.<sup>17,18</sup> use  $\sigma = 0.5$  as a default, but do calculations with  $\sigma = 1$  as well.

For the allocation principles and methods so far, historical responsibility can be accounted for by calculating a country's fair share for a past point in time and subtracting the CO<sub>2</sub> emissions that occurred since then. The allocation principles and methods described next take historical responsibility explicitly into account.

**Equal-per-capita with historical responsibility for territorial / consumption-based emissions (EPC+Terry / EPC+Consy):**<sup>4,79</sup>

$$RCB_i^{EPC+Terry}(t) = RCB_i^{EPC}(t) - \sum_{t'=y}^{t-1} \left( E_{CO_2,i}^{terr}(t') - \frac{\sum_i E_{CO_2,i}^{terr}(t')}{\sum_i Pop_i(t')} \cdot Pop_i(t') \right) \quad (19)$$

$$RCB_i^{EPC+Consy}(t) = RCB_i^{EPC}(t) - \sum_{t'=y}^{t-1} \left( E_{CO_2,i}^{cons}(t') - \frac{\sum_i E_{CO_2,i}^{cons}(t')}{\sum_i Pop_i(t')} \cdot Pop_i(t') \right) \quad (20)$$

We note that we do not fully account for consumption-based LULUCF CO<sub>2</sub> emissions. Deforestation can be driven by exports<sup>80</sup>, but consumption-based LULUCF CO<sub>2</sub> emissions have not been systematically quantified to the best of our knowledge.

**Cumulative equal-per-capita with historical responsibility for territorial / consumption-based emissions (cEPC+Terry / cEPC+Consy):**<sup>47</sup>

$$RCB_i^{cEPC+Terry}(t) = RCB_i^{cEPC}(t) - \left( cE_{CO_2,i}^{terr,y}(t-1) - \frac{cPop_i^y(t-1)}{\sum_i cPop_i^y(t-1)} \cdot \sum_i cE_{CO_2,i}^{terr,y}(t-1) \right) \quad (21)$$

$$RCB_i^{cEPC+Consy}(t) = RCB_i^{cEPC}(t) - \left( cE_{CO_2,i}^{cons,y}(t-1) - \frac{cPop_i^y(t-1)}{\sum_i cPop_i^y(t-1)} \cdot \sum_i cE_{CO_2,i}^{cons,y}(t-1) \right) \quad (22)$$

**Capacity with historical responsibility (CAPRESy ( $\sigma = \sigma^*$ )):** This allocation principle compares the capacity-based fair-share emissions with actual territorial emissions for each year since the start year of historical responsibility  $y$ .

$$RCB_i^{CAPRESy(\sigma=\sigma^*)}(t) = RCB_i^{cEPCy}(t) - \sum_{t'=y}^{t-1} \left( E_{CO_2,i}^{terr}(t') - \frac{\phi_{CAP,i}^{y,\sigma^*}(t')}{\sum_i \phi_{CAP,i}^{y,\sigma^*}(t')} \cdot \sum_i E_{CO_2,i}^{terr}(t') \right) \quad (23)$$

### Global analysis

For global analyses we consider only five allocation methods that take historical responsibility since 1990 into account (EPC+Terr1990, EPC+Cons1990, cEPC+Terr1990, cEPC+Cons1990, CAPRES1990 ( $\sigma=0.5$ )). We denote the associated national RCBs as “fair-share” RCBs. However, we note that our choice contains an implicit value judgment and may underestimate the full historical responsibility of certain high income countries that disproportionately contributed to global CO<sub>2</sub> emissions between 1850 and 1990. Projections until 2035 for national RCB ranges are based on a linear extrapolation of the year-to-year change in the minimum and maximum national RCBs from 2013–2022 (equivalent to a quadratic extrapolation). The same is done for 2000–2022 for sensitivity analysis (Supplementary Tables 1–3). Countries are geographically aggregated, as in the GCB2024<sup>30</sup>. For extrapolation, SSP2 population projections are used and taken from the Wittgenstein Center Population and Human Capital Projections<sup>81</sup>.

### Switzerland's remaining carbon budget

Future (cumulative) CO<sub>2</sub> emissions for Switzerland are derived from its updated 2025 NDC<sup>36</sup> and the *ZERO Basis* scenario from the Energy Perspectives 2050+<sup>82</sup>. In this scenario, Switzerland's net GHG emissions (aggregated according to GWPI00 from the IPCC AR5) reach zero in 2050 and net zero CO<sub>2</sub> is reached in 2045 (Supplementary Fig. 20). This scenario is consistent with a GHG emission budget of 106.8 MtCO<sub>2</sub>-eq for 2031–2035, and reductions in GHG emissions compared to 1990 of 50% reduction in 2030, of 59% over 2031–2035, and of 65% (slightly more than the minimum 64% stated in the NDC) for 2031–2040.

Switzerland's equal-per-capita RCB in 2020 is calculated according to Eq. (11). For recalculating the value communicated in the ruling of the ECtHR, we use the 1.5 °C (67%) global RCB for 1 January 2020 from the IPCC AR6 WG1 Table 5.8<sup>7</sup> of 400 GtCO<sub>2</sub>. From Table 2 in the Supplementary information of Lamboll et al.<sup>24</sup> we obtain an updated 1.5 °C (66%) RCB estimate for 1 January 2023 of 60 GtCO<sub>2</sub> and use Eq. (1) to calculate the value for 1 January 2020 yielding 274 GtCO<sub>2</sub>. We calculate the NGHGI-consistent values using the available correction

terms for 1.5 °C (50%) (Eq. (2)), which we judge to be very close to the necessary correction for 1.5 °C (66%).

### Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

### Data availability

All data used and generated during this study have been deposited at <https://doi.org/10.5281/zenodo.17426185>.

### Code availability

All code used to analyze the data and generate the figures of the main text and Supplementary Information is available at <https://doi.org/10.5281/zenodo.17426185>.

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## Author contributions

C.B. and R.K. initiated and supervised the research. K.W. performed the analysis, created the figures and wrote the first draft. All authors contributed to the continuous discussion of results, further analyses, and editing of the manuscript.

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