

Estimates of fair share carbon budgets for Switzerland

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This scientific report is based on the most recent and best available science. The authors are uninfluenced as to form or content by the exigencies of litigation.

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Alongside A/Prof Malte Meinshausen, he leads the Reduced Complexity Model Intercomparison Project (RCMIP). In the IPCC's Sixth Assessment Report, he led the writing of Cross-Chapter Box 7.1 on reduced complexity models used for scenario classification in AR6, was a Contributing Author to WG1 Chapters 1, 4, 5, 6, 7 and Technical Summary and WG3 Chapter 3 and Annex C. He completed his PhD at the Climate & Energy College within the University of Melbourne's School of Geography, Earth and Atmospheric Sciences in 2021, and his undergraduate Masters course in Physics at St. John's College, University of Oxford, where his Master's thesis was supervised by Prof Myles Allen. He is currently working on the next phase of RCMIP, taking MAGICC open source and developing more regionally detailed emulators.

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Table of contents:

1. Request from Verein KlimaSeniorinnen Schweiz and Greenpeace Switzerland.....	5
2. Background to effort-sharing approaches and fair share.....	7
3. European Scientific Advisory Board on Climate Change report on the EU's 2040 target.....	8
a. Introduction	8
b. Fair share budget analysis.....	8
c. Feasible domestic emissions pathways	10
d. Shortfall between domestic feasible emissions reductions and those required under a fair share budget.....	10
e. Recommendations based on the fair share and domestic feasibility analysis	11
4. Determining a fair share for Switzerland	13
a. Description of the global carbon budget	13
b. Update of the global carbon budget	13
c. Description of allocation methods for dividing the global carbon budget amongst countries	14
d. Switzerland's historical emissions.....	15
5. Results	17
a. Estimates of Switzerland's remaining 1.5°C carbon budget	17
b. Estimate of when Switzerland would need to reach net zero CO2 emissions, if it reduced its emissions on a straight-line trajectory	18
c. Estimates of Switzerland's projected GHG emissions assuming Switzerland's targets are met	19
6. Conclusion and commentary regarding the implications of Switzerland's carbon budget for its 2030 target.....	21

1. Request from Verein KlimaSeniorinnen Schweiz and Greenpeace Switzerland

This report is drafted at the request of Verein KlimaSeniorinnen Schweiz and Greenpeace Switzerland. On 20 September 2024, the authors of this report presented a study on estimates of fair share carbon budgets for Italy. On 20 November 2024, Verein KlimaSeniorinnen Schweiz and Greenpeace Switzerland requested a report for the Switzerland in line with the report that had previously been drafted for Italy. The specific request made to us was as follows:

The European Scientific Advisory Board on Climate Change (ESABCC) released its Scientific Advice for the determination of an EU-wide 2040 climate target (ESABCC Report) in June 2023. The ESABCC Report was used as a basis by the European Commission to recommend the European Union's (EU) 2040 emissions reduction target, which is in the process of being formally adopted. The ESABCC Report determines fair share budgets for the EU based on an assessment of effort-sharing approaches informed by relevant legal and ethical principles. The ESABCC identifies that, for some interpretations of fairness, the EU has already emitted more than its fair share of the emissions budget that leads to 1.5°C warming. In addition, the ESABCC identifies that the most ambitious emissions reductions modelled for the EU in the scientific literature result in cumulative emissions that are higher than the most lenient EU fair share budget. The ESABCC recommends that the EU should be looking to address this shortfall as part of its commitment to the Paris Agreement temperature goal.

In this report, we request that you cover the following issues:

- I. Background to effort sharing approaches and fair share;*
- II. An overview of the approach taken in the ESABCC Report with respect to calculating the EU's fair share, and how this influenced its recommendations for the EU's 2040 target;*
- III. Switzerland's fair share of the remaining global carbon budget to remain below 1.5°C with a 50% likelihood, for different interpretations of fairness, using the same methodological approach as the ESABCC Report and the underlying scientific study authored by Pelz et al. (2023);*
- IV. Estimate when Switzerland would run out of its fair share carbon budget based on a linear reduction of its emissions;*
- V. Project what Switzerland's annual and cumulative greenhouse gas (GHG) emissions will be, assuming Switzerland achieves the following targets: 50% reduction in 2030 (compared to 1990 levels), 75% reduction by 2040 (compared to 1990 levels), and net-zero by 2050*
- VI. In light of (IV) and (V), provide commentary on what the implications are in terms of the adequacy of Switzerland's existing 2030 target.*

In respect of request (III), we request that you provide results for territorial emissions using the following methodological approaches that were used in these reports, using the most lenient / generous parameters considered by the ESABCC or Pelz et al. in each case:

- 'Equality', as expressed through an equal per capita division of the global carbon budget, accounting from 2015;*

- **'Responsibility'**, as expressed through an equal per capita division of the global carbon budget, accounting from 1990;
- **'Capability'**, considering Switzerland's relative per-capita GDP, accounting from 2015; and
- **'Responsibility and Capability'**, considering Switzerland's relative per-capita GDP, accounting from 1990.

2. Background to effort-sharing approaches and fair share

The Paris Agreement sets the global common objective to hold “the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels”.

This temperature threshold requires limiting global anthropogenic emissions, including a cumulative amount of CO₂ emissions (referred to in this report as the **global carbon budget** or the **global CO₂ budget**). These carbon budgets are based on consideration of various likelihoods to stay below a given warming threshold, in light of physical uncertainties. To achieve this common goal, the Agreement requires each Party to submit Nationally Determined Contributions (NDC) that reflect “its highest possible ambition, reflecting equity and its common but differentiated responsibilities and respective capabilities (CBDR-RC), in the light of different national circumstances.” In the first submissions, Parties were invited to explain how their contributions are “fair and ambitious in the light of its national circumstances” (UNFCCC, 2018). In upcoming submissions, each Party is mandated to ‘provide the information necessary for clarity, transparency and understanding’ of increased ambition ‘reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances’.

The Intergovernmental Panel on Climate Change (IPCC) explains that “it is only in relation to such a ‘fair share’ that the adequacy of a state’s contribution can be assessed in the context of a global collective action problem” (IPCC, 2022). The quantification of a countries’ fair share of the global emissions reduction effort is needed to assess the adequacy of countries’ contribution to the common emissions objectives of the Paris Agreement. Both the recent Global Stocktake under the United Nations Framework Convention on Climate Change (UNFCCC) and the latest IPCC reports have recognised the collective insufficiency of current emissions pledges to hold the global temperature increase below 1.5°C without specifying which of the Parties’ NDCs are sufficient.¹

The IPCC has presented a range of emissions allocations methods categorized by the dimension of equity they represent (IPCC, 2014). Yet, it has not presented the numerical results of these studies, which suggest fair and Paris-aligned emissions levels for countries that can be compared to NDCs. In addition, only part of this literature aligns with international law (Rajamani et al., 2021) and represents countries’ “common but differentiated responsibilities and respective capabilities, in the light of different national circumstances”, as set out in Article 2 of the Paris Agreement. Independent scientific advisory bodies have leaned on this literature to discuss the ambition of possible emissions objectives of their governments.

¹ The IPCC does not specify which Parties’ NDCs are sufficient or not, because this is not within the IPCC’s mandate.

3. European Scientific Advisory Board on Climate Change report on the EU's 2040 target

a. Introduction

The ESABCC was established by the European Climate Law of 2021 as an independent scientific advisory body, mandated to provide the EU with scientific knowledge, expertise and advice relating to climate change.

In its report, the ESABCC conducts three separate analyses that provide the basis of its recommendations. Firstly, it provides results based on different perspectives on the EU's fair share of the remaining global carbon budget that is consistent with limiting global warming to 1.5°C (chapter 3). Secondly, it analyses emissions reduction pathways for the EU implementable within its borders that are consistent with global emission pathways that limit warming to 1.5°C (chapter 4). Thirdly, it analyses the shortfall between the feasible domestic reduction pathways and its fair share estimates (chapter 5). We will follow this structure in outlining the main findings of the ESABCC in its report below.

b. Fair share budget analysis

For the determination of EU fair share budgets in the ESABCC report, both legal and ethical perspectives are analysed and taken into account.

With regards to legal perspectives, the ESABCC finds relevant the legal responsibilities under the Paris Agreement to pursue the achievement of the temperature goal set out under Article 2, based on its highest possible ambition, CBDR-RC and fairness (also described above).² In addition, the ESABCC attached weight to emissions allocation based on various principles that are (amongst others) laid down in the European Climate Law, such as the polluter pays, precautionary and do no significant harm principles.³

Based on these legal principles, as well as ethical principles described in the literature on 'fair shares', the ESABCC presents remaining carbon budget allocation estimates that are directly informed by a study conducted by *Pelz et al.* Grandfathering and cost-effectiveness methodologies are excluded from the fair share calculations, as neither of these approaches are considered to be a 'standard of equity'.⁴

With regards to the results of the fair share calculations, the ESABCC concludes the following:

[...] from the start of 2020, the highest budgets (20-27 Gt CO₂, or seven to nine times the EU's CO₂ emissions in 2021) were associated with equal per capita allocation of emissions. Approaches based on the polluter pays principle (which is cited as a guiding principle in the European Climate Law) lead to lower budget estimates, such as those using historical emissions since 1850 or 1990. Several of these estimates are already negative. The most stringent budget

² ESABCC report, p. 26.

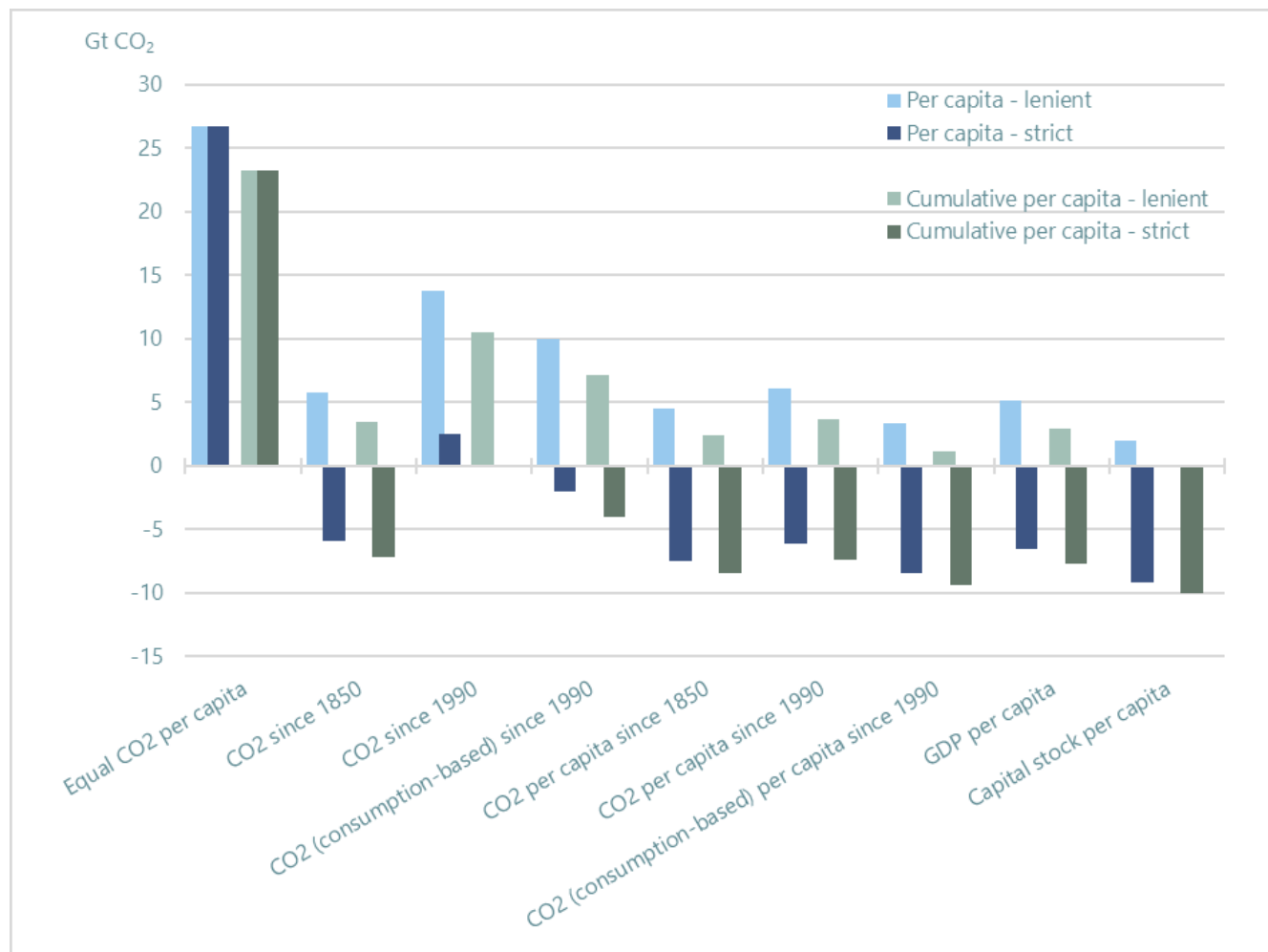
³ *ibid.*

⁴ p. 27.

estimates were found when the carbon budget was adjusted to reflect the ability to pay principle (interpreted as capital stock per capita).⁵

The results of the fair shares calculations (which are based on calculations undertaken in the study by Pelz et al.) are summarised in a figure in the report (reproduced below in Figure 1).

Figure 1 – Reproduction of Figure 3 of the ESABCC Report, showing estimates of the EU’s remaining fair share 1.5°C carbon budget from 2020, according to different principles and allocation methods. Negative budgets imply that the EU has already exhausted its fair share of the global emission budget.



⁵ p. 28.

c. Feasible domestic emissions pathways

The ESABCC also presented an analysis of emissions reductions pathways for achieving climate neutrality implementable in the EU territory and consistent at the global level with at least a 50% chance of limiting warming to 1.5°C at the end of the century with no or limited overshoot.⁶ Taking into account limitations with regards to the availability of negative emissions technology (in the report termed as ‘environmental risk levels’) and short-term technological scale-up, the ESABCC found that GHG emissions reduction levels of at least 88% and up to 92% (from 1990) could be achieved by 2040. A reduction of 95% could be achieved if technological scale-up challenges are overcome.⁷ The ESABCC noted that while reductions of 90-95% could be achieved taking the existing EU 55% GHG reduction target for 2030 as starting point, some of the emissions reduction scenarios show the feasibility of achieving higher emission reductions of up to 70% by 2030.⁸

The ESABCC noted that while the EU emissions pathways were derived from a global pathway to a 1.5°C warmer world, no explicit judgement was made about whether these scenarios’ allocation of emission reductions between the EU and the rest of the world should be considered fair.⁹ Conversely, in its fair share analysis, different fairness principles were used to estimate EU fair share carbon budgets but without explicit consideration of domestic feasibility.¹⁰ The fair share analysis was instead used to justify proposing the highest possible domestic ambition within the feasible range, recognising the need for complementary measures outside the EU.¹¹

d. Shortfall between domestic feasible emissions reductions and those required under a fair share budget

In order to make the estimates of the EU’s remaining carbon budget comparable to the implied cumulative emissions under domestic pathways, the ESABCC Report added estimated CO₂ LULUCF and non-CO₂ emissions, from the most ambitious scenario that it considered, to the fair share carbon budget (which, together, the ESABCC Report terms ‘**equity based fair share estimates**’). It does so by taking account of EU decarbonisation pathways, which assume CO₂ LULUCF and “non-CO₂ emissions from the most ambitious scenario”, in order to address fair-share considerations through the allocation of the carbon budget.¹² The EU’s GHG emissions allocation range for the 2020 to 2050 period was estimated to be between 40 and -85 gigatonnes (Gt) of CO₂ equivalent (CO₂e).¹³ As explained, the size of the negative budget value indicates that the EU may have already significantly exceeded its equity based fair share by the start of 2020. The ESABCC subsequently compares the range of fair share emissions allocation to the cumulative GHG emissions resulting from the most ambitious (95%) emission reduction pathway that that does not overly rely on negative emission technologies (defined as ‘environmental risk levels’ in the ESABCC Report). The ESABCC then concludes that even under the most ambitious domestic emissions pathway, EU domestic emissions would exceed the most lenient

⁶ p. 24.

⁷ p. 14.

⁸ p. 15.

⁹ p. 24.

¹⁰ *ibid.*

¹¹ p. 48.

¹² Table 10, p. 46.

¹³ p. 47.

interpretation of the EU’s equity based fair share estimates. The shortfall between the most ambitious domestic emission pathway (based on global, cost-optimal analysis) and the equity based fair share estimates range identified by ESABCC is shown in Table 1 below.

	95% emissions reduction pathway	Equity based fair shares	
		Highest estimate	Lowest estimate
Total GHG emissions between 2020-2050 (Gt CO ₂ e)	52	40	-85
Shortfall (Gt CO ₂ e)	N/A	12	137

Table 1 - Adapted from Table 11 of the ESABCC Report (page 47). The results on the shortfall (row two) are derived based on the difference between pathway and fair share emissions (row one).

e. Recommendations based on the fair share and domestic feasibility analysis

Given the shortfall between feasible domestic emissions pathways and even the most lenient equity based fair share estimates, the ESABCC recommends that the EU aims for the highest emission reduction level within its own territory, with a minimum reduction of 90% by 2040 (with 95% being the most ambitious option), and to address the shortfall between its territorial emissions and fair share budget through supporting emissions reductions outside of its territory.¹⁴

The following are citations from the report with some of the ESABCC's conclusions and recommendations in relation to addressing the shortfall (at page 15):

As the most ambitious reductions result in cumulative emissions that are higher than the most lenient equity-based fair share estimate (based on equal global per capita emissions), the Advisory Board considers that the EU should be looking to address this shortfall as part of its commitment to the Paris Agreement temperature goal. [...]

[...]

A fair contribution to climate change mitigation requires ambitious reductions in domestic emissions, complemented by measures outside the EU [...]

To deliver a contribution to achieving the Paris Agreement that is both fair and consistent with the physical science of climate change, the Advisory Board recommends that ambitious

¹⁴ p. 10, 15 & 48.

reductions in domestic emissions be complemented by measures outside the EU [...]. The EU must therefore ensure that it does the following.

- 1. **Aim for the highest level of ambition in domestic emission reductions and carbon dioxide removals**, while accounting for feasibility constraints, environmental risks and technological deployment challenges. The Advisory Board notes the importance of the EU communicating how it considers its contribution to be fair and ambitious, when submitting its post-2030 target as a nationally determined contribution under the Paris Agreement.*
- 2. **Contribute to direct emission reductions outside the EU**, in the light of the shortfall identified between the feasible pathways and fair share estimates.*
- 3. **Pursue sustainable net negative emissions after 2050**, as required under the European Climate Law, which would help manage temporary temperature overshoots, and support the international balancing of greenhouse gas emissions.*

4. Determining a fair share for Switzerland

a. Description of the global carbon budget

In its Sixth Assessment Report (**AR6**), the IPCC provides estimated values for the remaining global carbon budget, which correspond to the net quantity of CO₂ emissions that can be released over the century to the atmosphere from the start of 2020 while keeping global warming to 1.5°C. The exact value of the budget depends on several factors, including the pursued probability of keeping global temperature rise to within this limit, and the assumed path of non-CO₂ GHG emissions (which also contribute to warming).

The IPCC's estimates of the remaining carbon budget for 33%, 50% and 67% probabilities of limiting temperature rise to 1.5°C have been included in Table 2, below. The fair shares for the EU in the ESABCC Report are based on a remaining global carbon budget of 500 Gt CO₂ from the start of 2020, for a 50% chance of remaining below 1.5°C.

b. Update of the global carbon budget

In order to provide values based on best available science, this report bases its calculations on estimates of the remaining carbon budget from the following studies:

- I. A recent study by *Forster et al.* (2023), which provides an updated carbon budget using methods “as close as possible” to the IPCC in AR6, but with updated datasets, from 2023. The study's methodological proximity to the IPCC's work means that it is an authoritative piece of work. For example, this report was used as the basis of the most recent fair share assessment undertaken by the German Advisory Council on the Environment (SRU, 2024). A previous publication of the SRU was used as a basis by the German Constitutional Court in its ruling on the unconstitutionality of the German Climate Act.¹⁵
- II. A recent study by *Lamboll et al.* (2023), which provides the most up to date estimate of the remaining global carbon budget from the start of 2023. The study by *Lamboll et al.* uses updated data and an improved methodological approach to estimate the remaining carbon budget and represents the latest best available science.

Estimates of the remaining carbon budget for 33%, 50% and 67% probabilities of limiting temperature rise to 1.5°C from *Forster et al.* and *Lamboll et al.* have been included in Table 2, below. For reference and comparison, the IPCC's remaining carbon budget estimates from AR6, updated to account for global emissions that have taken place between 2020 and 2022 (the most recent year for which data is available) (the '**Updated AR6**' budget), have also been included in Table 2.

Both the studies by *Forster et al.* and *Lamboll et al.* use updated data sets compared to AR6. They also use improved methodological approaches to calculating the remaining carbon budget, as well as improved estimates of recent global temperature increase. As a result, estimates of the remaining

¹⁵ German Federal Constitutional Court, 2021, see: <https://www.bundesverfassungsgericht.de/SharedDocs/Pressemitteilungen/EN/2021/bvg21-031.html>

carbon budget in 2023 from these studies are considerably smaller than the ‘Updated AR6 budget’, which only takes into account global emissions since 2020 until the end of 2022 without the updated datasets and temperature estimates that are taken into account in the more recent studies. We therefore consider both *Forster et al.* and *Lamboll et al.* to represent the best available science, on the basis of which Switzerland's fair share budget calculations should be based.

Source	Budget from	Global carbon Budget (Gt CO ₂)		
		33%	50%	67%
<i>IPCC AR6</i>	<i>2020</i>	650	500	400
Updated AR6	2023	530	380	280
Forster et al.	2023	300	250	150
Lamboll et al.	2023	480	247	60

Table 2 – The remaining global carbon budget from 2023 onwards, as estimated using AR6 (updated to reflect emissions between 2020 and 2022), *Forster et al.* and *Lamboll et al.* The IPCC AR6 budget from 2020, which was used in the ESABCC Report, is also presented in italics for comparative purposes.

c. Description of allocation methods for dividing the global carbon budget amongst countries

The allocation methods in this report are drawn from the ESABCC Report. A separate report by *Pelz et al.* (2023) formed the basis of the ESABCC’s work on fair share allocations in its report. *Pelz et al.* provides further detail on allocation methods that are used but not presented in the ESABCC Report, as well as additional fair share emissions allocations using these methods.

Pelz et al. note that the choice for allocation methods and *their* operationalisation requires several value judgements aligned to desired foundational principles. These include deciding on parameters such as (i) the year at which the carbon budget is calculated (e.g., the year the Paris Agreement was signed) (ii) the starting year for allocation to express historic responsibility (e.g., 1990 or 1850), (iii) the proxy variable representing ability to pay (e.g., GDP per capita), and (iv) whether to base calculations on the population in the year that the budget is divided, or the cumulative population over the entire period from the starting year until net-zero CO₂. Some of these parameters must be transformed to an inverse range, for example to allocate proportionally lower budgets to countries with higher levels of capability. The value judgements necessary in this transformation (or penalty function) are illustrated through the presentation of ‘lenient’ and ‘strict’ results for each of the methodological approaches that it assesses.

The parameters selected in the ESABCC Report are described in the notes below Figure 3 of the report (at pages 28 - 29).

The ESABCC Report uses 2015 (the year that the Paris Agreement was signed) as the baseline year for calculating the EU's fair share of the remaining carbon budget, based on equity and capability approaches. The ESABCC Report, published in 2023, subtracts historical carbon dioxide from fossil fuels and industry (**CO₂ FFI**) emissions between 2015 and 2019, to present remaining fair share carbon budgets for the EU from 2020. This report updates the findings of the ESABCC Report by also taking into account historic emissions between 2020 and 2022 (the latest available year that global emissions data is available). This report presents remaining carbon budgets for Switzerland from 2023.

In respect of the remaining parameters, the plaintiffs have requested that these are selected to reflect the most lenient or generous results for the EU quantified by the ESABCC. This choice of parameterisation is not based on any particular value judgement. Stricter interpretations for the EU are justifiable and should not be discarded, but would require normative equity discussions outside the scope of this report (which simply seeks to compare Switzerland's pledge to emissions allocations consistent with the ESABCC methods). By selecting the parameters that provide the most generous quantifications submitted to the EU, this approach ensures that a breach of the allocations presented here would characterise a breach of any submitted parameterisation. As such, the baseline year for responsibility has been set to 1990, GDP per capita (as expressed in purchasing power parity, which is the basis used in the ESABCC Report) will be used to represent capability / ability to pay, and budgets will be distributed in per capita terms determined by the population at the year that Switzerland's national budget is calculated. In terms of the penalty function applied in *Pelz et al.*, the lenient approach identified in the ESABCC Report has been taken to provide a single result for each methodological approach.

In Figure 1, above, which presents the EU's fair share estimates shown in Figure 3 of the ESABCC Report, the methodological approaches that we use in this report correspond to the (i) 'Equal CO₂ per capita', (ii) 'CO₂ per capita since 1990' (although the methodological approach in *Pelz et al.* has been used - further information in this regard is available in Annex 1) and (iii) 'GDP per capita'. In addition, a fourth approach reflecting both capability and responsibility has been included, whereby 'GDP per capita' is calculated from 1990 - this approach has been included in *Pelz et al.* but is not presented in the ESABCC Report. A full overview of the parameters included in each methodological approach has been included in Annex 1.

The only methodological deviations from the approach taken in the ESABCC Report and *Pelz et al.* concerns the treatment of emissions from aviation and shipping. As these are not typically reflected in national emissions inventories due to emissions accounting norms, it is more robust from a methodological point of view to remove them before calculating national fair share carbon budgets.

d. Switzerland's historical emissions

Consistently with the ESABCC report, in this report we compared the remaining carbon budgets to Switzerland's CO₂ FFI emissions. In order to calculate Switzerland's latest remaining carbon budget in

line with the ESABCC report, Switzerland's past emissions must be taken into account at least from the year 2015. The latest year for which global official emissions data is reported is 2022. Between 1990 and 2022, Switzerland's territorial emissions from CO₂ were approximately 1.39 Gt CO₂. Between 2015 and 2022, Switzerland's territorial emissions from CO₂ were 0.30 Gt CO₂.

5. Results

a. Estimates of Switzerland's remaining 1.5°C carbon budget

The application of the allocation methods outlined above provide a range of estimates of Switzerland's carbon budget, presented in Table 3. Estimates of the remaining carbon budget are presented from the start of 2023.

For Switzerland, the 'equal per capita' allocation is the most lenient of all the allocation methods we consider. As indicated in the previous section, this allocation method does not take into account responsibility for historical emissions since 1990 or capability considerations, as expressed in the principle of CBDR-RC as laid down in the Paris Agreement.

From 2023, Switzerland's **remaining carbon budget is between -0.99 Gt CO₂ and 0.26 Gt CO₂** for the allocation approaches considered here. Across all methodologies, only the 'equal per capita' approach provides Switzerland with a positive remaining carbon budget that could last several years under current levels of CO₂ emissions (emissions from fossil fuel and industry (**CO₂-FFI**) were approximately 0.035 Gt CO₂ in 2022). While a small amount of budget (0.08 - 0.09 GtCO₂) remains under the 'responsibility' approach from the start of 2023, this would be exhausted by the end of 2025 if Switzerland's emissions remain approximately constant.. As such, **any estimate of Switzerland's fair share budget that reflects capability or responsibly would have already been exhausted, or will likely be exhausted in the near future.**

Remaining carbon budget from 2023 for Switzerland in Gt CO ₂				
Source	Equal per capita ('Equality')	CO ₂ per capita since 1990 ('Responsibility')	GDP per capita ('Capability')	GDP per capita since 1990 ('Responsibility and capability')
<i>Updated AR6</i>	0.41	0.26	-0.04	-0.94
Forster et al.	0.26	0.09	-0.09	-0.99
Lamboll et al.	0.25	0.08	-0.09	-0.99

Table 3 – Overview of Switzerland's remaining carbon budget, using the global carbon budgets from Forster et al. and Lamboll et al. as the basis for calculations. Budgets that have been exhausted by 2023 are presented in red. Estimates of Switzerland's carbon budget using the Updated AR6 carbon budget as the basis of calculations have been included for reference in grey.

b. Estimate of when Switzerland would need to reach net zero CO2 emissions, if it reduced its emissions on a straight-line trajectory

As is shown in Table 3, above, the allocation methods that take into account principles of ‘capability’ and ‘capability and responsibility’, indicate that Switzerland’s carbon budget has almost certainly already been exhausted. The year of budget depletion for these allocation methods, taking historical CO2-FFI emissions into account, are shown in Table 4. Switzerland would have had to reach net zero CO2 emissions in the years indicated below to remain within the respective budgets.

Source	Year by which Switzerland’s carbon budget was exhausted	
	GDP per capita ('Capability')	GDP per capita since 1990 ('Responsibility and capability')
Forster et al.	2020	1999
Lamboll et al.	2020	1999

Table 4 – Overview of the years by which the carbon budgets for Switzerland are exhausted for allocation methods that take into account principles of capability, or both capability and responsibility, for global budgets as reported in Forster et.al and Lamboll et.al.

The allocation methods that provide Switzerland with remaining budget are the ‘equal per capita’ and ‘responsibility’ approaches. Assuming Switzerland’s CO2-FFI emissions in 2023 and 2024 were at a similar level to those in 2022, its remaining budget under the ‘responsibility’ approach will be nearing depletion and would likely be exhausted before the end of 2025. When looking forward - the point that the carbon budget will be exceeded depends on assumptions about Switzerland’s CO2 pathway. In the absence of information concerning how Switzerland will reduce its non-fossil-fuel and non-CO2 emissions over time, the conclusions of this report relate solely to CO2-FFI, unless otherwise stated. Furthermore, addressing fair-shares of non-CO2 and land-use, land-use change and forestry (LULUCF) CO2 emissions is a separate matter that was not specifically considered in the ESABCC report.

If Switzerland were to reduce its CO2 emissions on a straight line basis from 2023, it would need to **reach net zero CO2 emissions by 2038** in order to remain within its ‘equal per capita’ carbon budget. Emissions would need to decline by approximately 0.002 GT CO2 per year, which implies an annual decline equivalent to approximately 6.4% of emissions in 2022 every year until net zero. This trajectory, alongside Switzerland’s historical CO2 emissions, has been included in Figure 2, below.

c. Estimates of Switzerland's projected GHG emissions assuming Switzerland's targets are met

Looking ahead, if Switzerland achieves GHG emissions reductions in line with its own national targets it will emit approximately 0.53 Gt CO₂e between 2023 and 2050. This figure is not directly comparable with Switzerland's CO₂ budget, as it reflects emissions of other GHGs, and more work would be needed to convert Switzerland's CO₂ budget into an indicative GHG budget as we have already noted. However, for context, in 2022, Switzerland's CO₂ emissions from FFI represented about 82% of its total GHG emissions.

For illustrative purposes, Figure 2 shows Switzerland's historical GHG emissions, which includes Switzerland's CO₂ FFI emissions, LULUCF CO₂ emissions and non-CO₂ emissions. Switzerland's projected GHG emissions between 2023 and 2050 have been included, which reflect Switzerland's targets. For ease of reference, these targets (which are outlined in the plaintiff's request) are:

1. At least a -50% reduction in greenhouse gas emissions by 2030 compared to 1990 (Climate and Innovation Act);
2. At least a -75% reduction in greenhouse gas emissions by 2040 compared to 1990 (Federal law on climate protection goals, innovation and strengthening energy security); and
3. Net zero by 2050 (Federal law on climate protection goals, innovation and strengthening energy security).

Given that Switzerland would need to reach net zero in 2038 to respect its carbon budget under the 'equal per capita' methodology, Switzerland's current emissions trajectory implies that its carbon budget would be overshoot considerably by 2038, as well by as the time it reaches net zero in 2050.

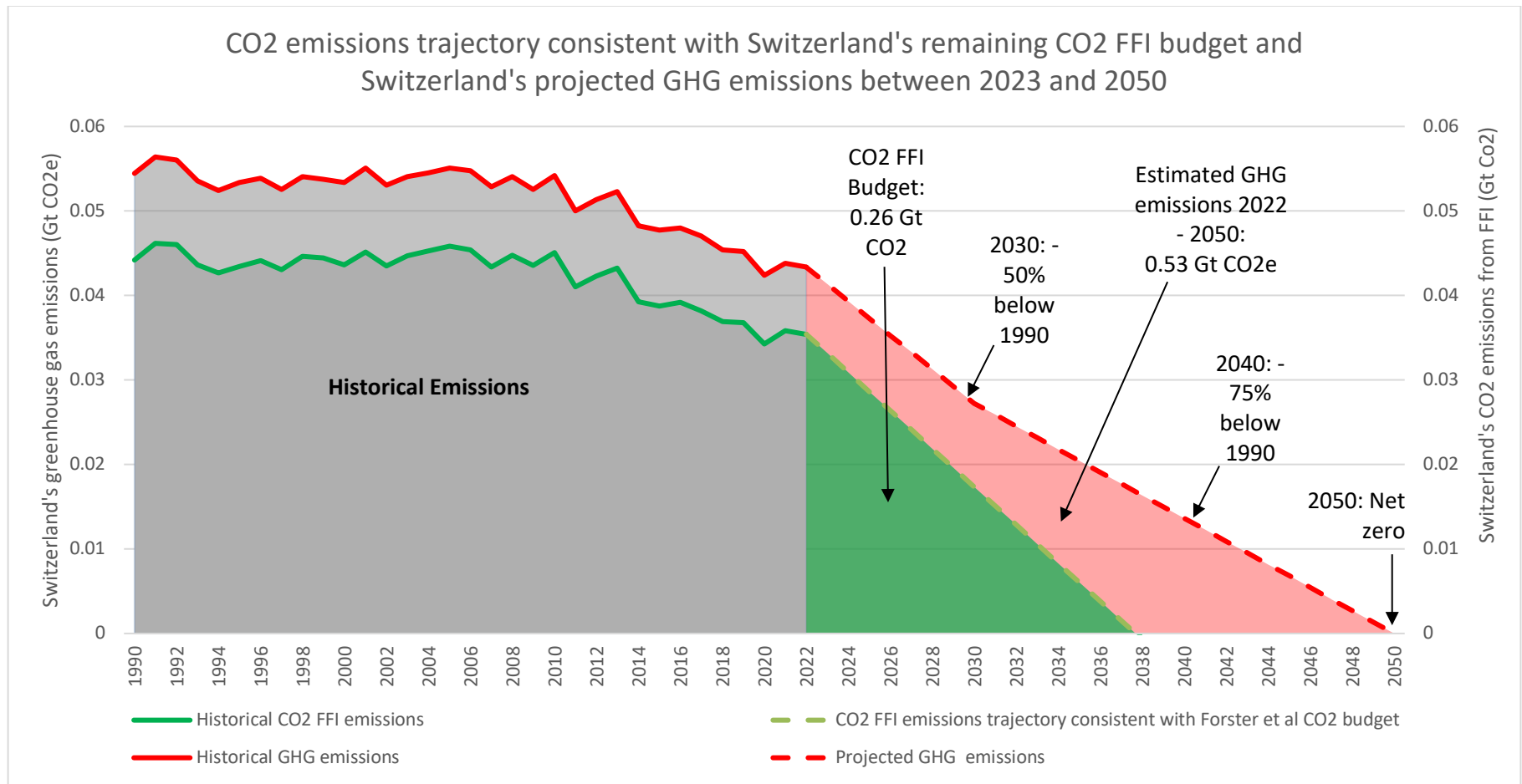


Figure 2 – Switzerland’s historical CO₂ emissions from Fossil Fuel and Industry (FFI) are represented by the green solid line. Switzerland’s estimated trajectory to reach net zero while remaining within its carbon budget (‘equal per capita’ approach, using the Forster et al. budget as a basis) is represented by the green dashed line. Assuming a budget of 0.26 Gt CO₂ available from the start of 2023, Switzerland would need to reach net zero CO₂ in 2038. For illustrative purposes, Switzerland’s historical greenhouse gas emissions are represented by the solid red line (in Gt CO₂e). Switzerland’s projected greenhouse gas emissions between 2023 and 2050, assuming it achieves emissions reductions in line with its targets, are represented by the red dashed line. Cumulative emissions over this timeframe are projected to be 0.53 Gt CO₂e. This report does not discuss possible assumptions for non-CO₂ emissions nor LULUCF CO₂ emissions, hence the two cumulative emissions numbers are not directly comparable in terms of fairness principles alone.

6. Conclusion and commentary regarding the implications of Switzerland's carbon budget for its 2030 target

This report has estimated fair share budgets for Switzerland based on the methodological approaches taken in the ESABCC report and the underlying scientific study authored by *Pelz et al. (2023)*, using the most up-to-date estimates of the remaining global carbon budget as a basis for calculations.

Estimates of Switzerland's carbon budget that are derived from allocation methods reflecting capability or a combination of responsibility and capability, as defined here, would have already been depleted by cumulative CO₂ emissions from fossil fuels and industry in the years 2020 and 1999, respectively. All CO₂ emissions since these years (i.e., since budget depletion) are in excess of Switzerland's carbon budget using these fair share approaches. Exceeding the fair share budgets either comes at the cost of the fair share budgets of other countries, or leads to overshoot of the globally available carbon budget.

While a small amount of budget remains under the 'responsibility' approach from the start of 2023, if emissions remained at a similar level as in 2022 then this will be exhausted before the end of 2025. Only the 'equal per capita' approach (the most lenient interpretation of an equitable fair share as defined in the ESABCC report) provides Switzerland with a non-negligible remaining carbon budget of 0.25 to 0.26 Gt CO₂ from the start of 2023. To remain within its 'equal per capita' budget on the basis of a straight line reduction, Switzerland would need to reach net zero CO₂-FFI emissions in 2038. This would require annual emissions reductions equivalent to approximately 6.4% of its CO₂-FFI emissions in 2022 every year until net zero. If Switzerland reduces its greenhouse gas emissions by 50% by 2030 (compared to 1990 levels) and is on track to meet its 75% emissions reduction target in 2040, Switzerland is likely to overshoot its 'equal per capita' carbon budget considerably by 2038 – and even more so by the time it reaches net zero in 2050.

Recalling the ESABCC's recommendations in its report, fair share carbon budgets do not necessarily need to be met entirely within a country's territory. The ESABCC's recommendation was that the EU, '*Aim for the highest level of ambition in domestic emission reductions and carbon dioxide removals*' as well as '*Contribute to direct emission reductions outside the EU, in the light of the shortfall identified between the feasible pathways and fair share estimates*'. Emissions reductions that are necessary to stay within fair share budgets thus do not entirely need to be achieved within the state's own territory. This is increasingly important in light of feasibility constraints rendering extreme reductions in territorial emissions difficult or impossible.

For the 'capability' and 'responsibility and capability' approaches, it is no longer possible to remain within the fair share budgets. As such, all additional domestic CO₂ emissions should be compensated through planned carbon dioxide removal (CDR) or emissions reductions or removals taking place abroad. Net-negative emissions may also help to compensate for the exceedance of Switzerland's fair share budget, but the timing of this matters. Unless these net-negative emissions are in the very near-term, it is more complex to assess whether this would allow for direct compensation or not.

As a further consideration, the remaining global carbon budget from 2023 for a 50% chance of remaining below 1.5°C is estimated to be 247-250 GT CO₂, which is equal to less than 7 years of current emissions levels (global CO₂ emissions from FFI in 2022 were 37.2 Gt CO₂). Delays in addressing any

exceedance of the global remaining carbon budget may lock the world into breaching the 1.5°C target. This overshoot may become permanent if feasibility limits mean that any temperature exceedance cannot be addressed in its entirety.

To reduce the risks of contributing to both temporary, or permanent, overshoot of the remaining carbon budget, any emissions in excess of Switzerland's fair share carbon budget would need to be compensated as soon as possible and in the near-term. Consequently:

- For the 'equal per capita' allocation:
 - o If Switzerland's CO₂-FFI emissions were to follow a straight line trajectory to net zero in 2038, it would need to be net zero from 2039 onwards.
 - o If Switzerland's annual CO₂-FFI emissions consistently exceed the annual CO₂-FFI emissions under the straight line trajectory, Switzerland would need to reach net zero CO₂-FFI emissions at the date that the budget is depleted, which (depending on the level of annual exceedance) could be considerably earlier than 2038. If it is not net zero at this time, it would need to set a net negative target to compensate for any overshoot of the budget.
- Under the budget allocated under the 'responsibility' approach, a net zero target would be required from the year the budget is depleted. If emissions in 2023, 2024 and 2025 were/are at a similar level to those in 2022, the budget will be depleted over the course of 2025 and a net zero target would need to be set from 2026 onwards.
- For the budgets allocated using the 'capability' and 'responsibility and capability' approaches, net negative targets would need to be set immediately for all allocations, until the total overshoot has been compensated.

Annex 1

Table 1 - Full description of the parameterisation each allocation approach

Fair share approach	Description of method / parameterisation
Equal per capita	An equal per capita allocation of the remaining carbon budget in the year 2015.
Responsibility	An equal per capita allocation of the remaining carbon budget in the year 1990.
Capability	A per capita allocation of the remaining carbon budget in the latest year of allocation, 2015, scaled in inverse proportion to GDP per capita in the year 2015, expressed in current purchasing power parity (2024).
Both Responsibility and Capability	A per capita allocation of the remaining carbon budget in the year 1990, scaled in inverse proportion to GDP per capita in the year 1990, expressed in current purchasing power parity (2024).

Annex 2 - Data and Methods

GDP Data:

- **GDP (Purchasing Power Parity, PPP):** A dataset from the World Bank's World Development Indicators is used, found in the API_NY.GDP.MKTP.PP.CD_DS2_en_csv_v2_1090665.csv file. This dataset includes GDP values adjusted for purchasing power parity, which accounts for the relative cost of living and inflation rates between countries.

Population Data:

- The historical population data comes from Our World in Data (OWID), specifically the population.csv file. This dataset includes population estimates for countries from 1990 to 2019. Source: <https://ourworldindata.org/grapher/population>.

Carbon Emissions Data:

- **Territorial CO2 Emissions:** The territorial fossil carbon emissions data is sourced from the Global Carbon Project, found in the National_Fossil_Carbon_Emissions_2023v1.0.xlsx file (sheet 2). This dataset includes country-level emissions from fossil fuel combustion and industrial processes. Source: <https://essd.copernicus.org/articles/15/5301/2023/>.
- **Data availability:** All underlying data for this report can be made available on request.

Data processing and analysis:

- **Coding script availability:** The full coding script used in this report to implement the parameterisation set out above can be made available on request.

Annex 3 - References

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