Briefing

Cumulative CO_2 emissions in 1.5°C compatible pathways for Estonia

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This briefing calculates the cumulative CO_2 emissions that Estonia could emit if it is to align with the internationally agreed 1.5°C limit in the Paris Agreement. It produces emissions pathways for Estonia by downscaling global cost-effective pathways to the national level. The key findings are:

- In 1.5°C compatible pathways, Estonia's cumulative CO_2 emissions need to be limited to 160–200 $MtCO_2$ between 2020 and 2050, excluding land-use, land-use change and forestry (LULUCF).
- If Estonia can restore its LULUCF sink to the 2000–2020 average, total cumulative CO_2 emissions including LULUCF could be limited to 90–120 $MtCO_2$.
- Estonia's fair share of the global carbon budget may be smaller still, so domestic action should be supplemented by providing climate finance to less developed countries.
- Estonia would need to rapidly reduce CO_2 emissions and restore and expand the LULUCF sink, while also taking action to reduce non-CO_2 emissions in line with the best available science.

[1] This briefing was updated in March 2023 to improve the region mapping used to downscale global 1.5°C compatible pathways to Estonia.

Introduction

There is an approximately linear relationship between cumulative CO_2 emissions and global temperature rise (IPCC 2021). This gives rise to the concept of a 'carbon budget' – the amount of CO_2 that can be emitted to keep temperatures to a given level.

Working Group 1 (WGI) of the Intergovernmental Panel on Climate Change (IPCC) estimated that around 2,900 $GtCO_2$ can be emitted from 1850 onwards, if warming is to be limited to 1.5°C with a 50% probability. Of this, around 80% has already been emitted. Consequently, the remaining global carbon budget[2] is 500$GtCO_2$, as of the beginning of 2020 (IPCC 2021).

How should this remaining carbon budget be distributed across individual countries? A wide range of methods can be used to answer this question. Different methodologies provide different information on what 1.5°C compatible action looks like for a given country.

One method is to take the remaining carbon budget as estimated by IPCC WGI and use effort-sharing principles to distribute the remaining emissions. Distributing the remaining carbon budget based on equity principles provides important benchmarks in terms of what countries *should* do to contribute their fair share to global climate action (Fyson *et al* 2020). However, these equity-consistent budgets provide limited guidance on what the science says might be possible to implement domestically. This implementation component is of critical importance when considering policy development at the national level. In addition, there are a wide range of different possible equity principles that could be applied, which can substantially affect the resulting carbon budget (Höhne *et al* 2014).

A complementary methodology, therefore, is to estimate the cumulative CO_2 emissions for a given country in 1.5°C compatible pathways produced by downscaling global cost-effective pathways to the national level. These pathways are summarised in Working Group 3 (WGIII) of the IPCC. This gives information on technically feasible routes for a given country to align with 1.5°C. However, these pathways are not explicitly based on the remaining carbon budget as assessed in IPCC WGI. As such, we term these results produced by using these pathways "cumulative CO_2 emissions" rather than "carbon budgets". Importantly, there is strong agreement between the estimates of cumulative CO_2 emissions consistent with limiting warming to 1.5°C produced by IPCC WGIII, and the remaining carbon budgets for 1.5°C developed by WGI (Box 1).

[2] *This is defined as "the total net amount of CO_2 that could be released in the future by human activities while keeping global warming to a specific global warming level, such as 1.5°C, taking into account the warming contribution from non-CO_2 forcers as well" (Arias et al 2021)*

Box 1: The difference between carbon budgets and cumulative CO_2 estimates

IPCC WGI estimated the remaining carbon budget to limit warming to 1.5°C with a 50% likelihood as 500 $GtCO_2$ from 2020, with a range of around +/-220 $GtCO_2$ due to uncertainty in the level of reduction in non-CO_2 emissions. This estimate is based on a framework in which each potential factor in determining the carbon budget is assessed separately (IPCC 2021).

IPCC WGIII instead takes pathways produced by Integrated Assessment Models (IAMs). It then calculates the level of warming that results from these pathways (using climate model emulators), and the cumulative CO_2 emissions from 2020 until the time of net zero CO_2 emissions and hence peak warming (Riahi *et al* 2022).

IPCC WGIII found that, in pathways, which limit warming to 1.5°C with no or low overshoot, cumulative CO_2 emissions are around 510$GtCO_2$ from 2020 until the date of net zero CO_2 emissions, which is reached around 2050–2055. After net zero CO_2 emissions are reached, most pathways achieve net-negative CO_2 emissions, and thus 2020–2100 cumulative CO_2 emissions are lower than those between 2020 and the date of net zero.

The IPCC reviewed the differences between the remaining carbon budget (WGI) and cumulative CO_2 emissions (WGIII) for the same warming limits and found that they are consistent when accounting for the uncertainties involved.

This briefing uses the WGIII approach, calculating cumulative CO_2 emissions between 2020 and 2050 for Estonia in 1.5°C compatible pathways. These pathways limit cumulative emissions at a global level to around 500$GtCO_2$ between 2020 and the date of net zero CO_2 emissions, which is reached around 2050. They therefore remain consistent with the evidence provided in IPCC WGI. In line with the approach used in WGIII, we term our results "cumulative CO_2 emissions" rather than "carbon budgets".

For more details on the relationship between these two concepts, see Box 3.4 in Riahi *et al* (2022).

Estimating cumulative CO_2 emissions from existing model pathways gives us greater confidence in the techno-economic feasibility of the results at a national level. However, as global pathways produced by IAMs do not explicitly incorporate equity considerations, these 'model-based' cumulative CO_2 emissions may substantially exceed the equity-consistent budgets.

It is important to consider *both* equity-consistent carbon budgets and model-based domestic cumulative CO_2 emissions when determining 1.5°C compatible benchmarks.

The first is based on carbon budgets estimated using the WGI approach and uses equity principles to allocate this budget. This gives information on what *should* be done, without a clear narrative on how this can be achieved nationally or internationally.

The second is based on global pathways consistent with particular temperature goals and uses downscaling methods to allocate emissions to the national level. This gives a techno-economically feasible lower bound on what *can* be done domestically, but for wealthy countries will usually substantially exceed that country's "fair share" carbon budget. Any deficit between modelled domestic pathways and fair share allocations would need to be addressed, either by greater domestic emissions reductions, or by supporting emissions reductions abroad in less wealthy countries via climate finance, capacity building and technology transfer.

In this briefing, we estimate cumulative CO_2 emissions for Estonia between 2020 and 2050, based on 1.5°C compatible emission reduction pathways from the IPCC's latest assessment report (IPCC, 2022).

This approach finds that, in 1.5°C compatible pathways which represent the highest level of ambition for the EU27, Estonia's cumulative CO_2 emissions over the 2020–2050 period are 159–198MtCO_2. If LULUCF emissions can be restored to the 2000-2020 average sink of ~3MtCO_2/y, Estonia's cumulative CO_2 emissions over this period would be 83–122MtCO_2. Estonia will also need to reduce non-CO_2 emissions significantly to align with the 1.5°C temperature limit. Finally, appropriate provision of climate finance to less developed countries need to be an integral part of Estonia's efforts to address climate change (Climate Action Tracker 2021).

Analysis

We consider three pathways that feature in the IPCC's latest assessment report (IPCC, 2022). These pathways limit warming to 1.5°C with no or low overshoot at the global level and have limited deployment of CO_2 removal. This means they deploy less than 5GtCO_2/y of bioenergy with carbon capture and storage (BECCS) in 2050, and less than 3.6GtCO_2/y of afforestation/reforestation in the second half of the century (Fuss *et al* 2018). In addition, we filter to select pathways which demonstrate the steepest near-term greenhouse gas (GHG) emissions reductions for the EU27. In these pathways, EU27 emissions fall to 61–66% below 1990 levels by 2030 (excluding LULUCF)[3]. The selected pathways are summarised in Table 1.

We take the CO_2 emissions pathway for the European macro-region and downscale this to the country level, using an emissions intensity convergence method (van Vuuren *et al* 2007, Gidden *et al* 2019). In this method, the carbon intensity of each country (in CO_2/GDP) in the macro-region is calculated in 2019. Future carbon intensities are then projected by assuming convergence to the macro-region average by 2100. Combining these projected intensities with GDP projections for each country gives the resulting CO_2 emissions trajectory at a national level.

[3] For more information on the selection methodology and a detailed description of the pathways, see the report *"1.5°C pathways for the EU27: accelerating climate action to deliver the Paris Agreement"*.

Model	Scenario	Abbreviation	Description	Source
REMIND 2.1	R2p1_SSP1-PkBudg900	SSP1	This scenario uses the SSP1 socio-economic setup, representing a more sustainable future in which there is reduced consumption, greater inter- and intra-national equity, and continued progress in low-carbon technologies.	(Baumstark *et al* 2021)
REMIND-MAgPIE 2.1-4.2	SusDev_SDP-PkBudg1000	SusDev	This scenario has an explicit focus on achieving Sustainable Development Goals via sufficient and healthy nutrition, improved access to modern energy, and ambitious lifestyle shifts in industrialised countries.	(Soergel *et al* 2021)
REMIND-MAgPIE 2.1-4.2	DeepElec_SSP2 HighRE_Budg900	HighRE	This scenario displays highly ambitious near-term emissions reductions, underpinned by rapid renewables deployment and electrification of final energy demand.	(Luderer *et al* 2021)

Table 1: Description of scenarios used to estimate cumulative CO_2 emissions

Importantly, in this methodology, the carbon intensity of a given country (CO_2/GDP) undergoes a smooth transition from its value in the base year (2019) to the macro-region carbon intensity by 2100. Therefore, if the country has a high carbon intensity in the base year, it will have correspondingly larger future CO_2 emissions. Estonia currently has a high carbon intensity, with oil shale (a fossil mineral that can be burned directly or converted into oil) providing over 57% of primary energy in 2020 (Statistics Estonia 2022). In 2019, the carbon intensity of Estonia was more than twice the EU27 average. This leads to correspondingly larger cumulative CO_2 emissions. However, Estonia's high historical carbon intensity does not preclude the potential for rapid reductions in carbon intensity in the near future. Past performance does not dictate future possibilities. It may therefore be possible for the model-based cumulative CO_2 emissions derived by this analysis to be outperformed. A detailed country-specific analysis would be required to understand the potential for rapid emissions reductions in Estonia.

Future CO_2 emissions in Estonia are downscaled excluding land-use, land-use change and forestry (LULUCF) for several reasons. There are very high uncertainties in the LULUCF sector (Friedlingstein *et al* 2022) – more so than in other sectors – and there is a substantial discrepancy between the representation of anthropogenic LULUCF in IAMs and in national GHG inventories (Grassi *et al* 2021). Countries also use different accounting approaches to count LULUCF emissions and removals towards their targets. Where countries expect a growing LULUCF sink this can conceal insufficient emissions reductions (or even positive emissions trends) in other sectors.

Separate analysis is needed to assess the consistency of LULUCF mitigation efforts with the Paris Agreement. There is ongoing work to address the inconsistencies between IAMs and national GHG inventories and enable downscaling of LULUCF emissions to the national level. In this briefing, we provide an illustrative example of how LULUCF emissions could reduce cumulative CO_2 emissions in Estonia further, using data from historical GHG emissions inventories.

Results

Figure 1 shows CO_2 emissions in Estonia for the three selected pathways. CO_2 emissions (excluding LULUCF) fall 50–64% 2030 below 2019 levels, and fall 97–100% by 2050 relative to 2019 levels. CO_2 emissions represented 81% of Estonia's GHG emissions in 2020 (Estonian Government 2022). In these downscaled pathways, cumulative CO_2 emissions over 2020-2050 in Estonia are 158–198MtCO_2 (excluding LULUCF).

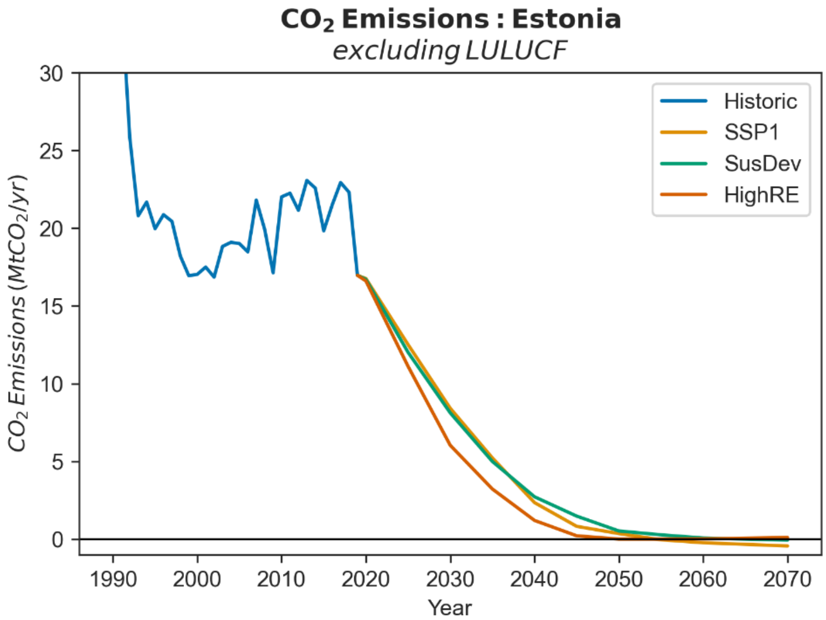

Figure 1: 1.5°C compatible CO_2 emissions in Estonia

Scenario	2020-2050 cumulative CO_2 emissions (excl. LULUCF)
HighRE	158MtCO_2
SSP1	198MtCO_2
SusDev	198MtCO_2

Table 2: Cumulative CO_2 emissions for Estonia in 1.5°C compatible pathways. Emissions are shown excluding LULUCF

It is not currently possible to downscale LULUCF emissions from global pathways to infer Estonia's future emissions. Estonia's LULUCF sink has been declining since 2010. This is due to a mix of intensive logging in recent years, reduced afforestation and the draining of peatlands. In 2020, the LULUCF sector became a net source of CO_2 (Estonian Government 2022). Reversing this trend, to create and sustain a significant LULUCF sink, would enable Estonia reach net zero CO_2 emissions before mid-century and further limit its contribution to future warming.

In the absence of a downscaled 1.5°C compatible LULUCF pathway for Estonia, we assume that the average LULUCF sink of ~3$MtCO_2$/y in the 2000–2020 period is achieved and sustained from 2030 onwards to estimate cumulative CO_2 emissions including LULUCF. In this scenario, Estonia would reach net zero CO_2 emissions by 2040 or earlier. Cumulative CO_2 emissions from LULUCF between 2020 and 2050 would be a sink of -76$MtCO_2$, resulting in total cumulative emissions (including LULUCF) for the three selected pathways in the range 88–122$MtCO_2$. Table 3 highlights 1.5°C compatible cumulative CO_2 emissions for Estonia when LULUCF is included[4].

Scenario	2020-2050 cumulative CO_2 emissions (incl. LULUCF)
HighRE	88$MtCO_2$
SSP1	122$MtCO_2$
SusDev	122$MtCO_2$

Table 3: Cumulative CO_2 emissions for Estonia in 1.5°C compatible pathways. Emissions are shown including LULUCF

Unsustainable practices in the LULUCF sector can have a substantial impact on total cumulative CO_2 emissions in Estonia (Anger-Kraavi *et al* 2020). Avoiding excessive logging, increasing reafforestation and afforestation, and addressing emissions from drained peatlands and peat mining are therefore key actions to return the LULUCF sector to a net sink of emissions in Estonia, rather than a source.

Conclusions

This note has calculated cumulative CO_2 emissions for Estonia between 2020 and 2050, by downscaling global emissions pathways consistent with limiting warming to 1.5°C with no or low overshoot. This has shown that, even excluding any potential LULUCF sink, Estonia could feasibly limit its cumulative CO_2 emissions to below 200$MtCO_2$ between 2020 and 2050. At 2021 emissions levels, Estonia would exceed this limit in under 17 years. Therefore, urgent action is needed to rapidly reduce CO_2 emissions by 2030 and reach net-zero CO_2 emissions around or before 2050.

[4] *These values are based on LULUCF emissions as reported in national GHG inventories. Further work would be needed to understand how using LULUCF emissions as reported in IAM pathways would affect these results.*

Returning the LULUCF sector to a net sink is a key step on the road to achieving carbon neutrality before mid-century, and can help Estonia further reduce its cumulative CO_2 emissions and contribution to future temperature rise.

In order to achieve the long-term temperature goal of the Paris Agreement set out in Article 2, Article 4.1 sets out the aim to achieve global net-zero GHG emissions in the second half of the century in accordance with the best available science. Although not assessed in this briefing, Estonia will need to reduce non-CO_2 emissions significantly to help achieve this goal and limit warming to 1.5°C (Ou *et al* 2021). Reducing short-lived non-CO_2 emissions such as methane can help limit near-term temperature rise (UNEP and CCAC 2021), while reducing N_2O emissions from agriculture can also help address wider planetary boundaries related to biogeochemical flows (Steffen *et al* 2015).

While at the global level, cumulative CO_2 emissions and remaining carbon budget estimates are strongly aligned (Box 1), they can differ strongly at the national level. This is because different allocation mechanisms are being used to distribute emissions to individual countries. The cumulative CO_2 emissions estimated here for Estonia are based on cost-effective pathways, and do not consider equity principles when allocating emissions to the national level. As such, these results should not be seen as an indication of Estonia's "fair share" carbon budget, which uses equity principles to distribute the remaining carbon budget estimated by IPCC WGI. To illustrate the difference between model-based cumulative CO_2 emissions and equity-consistent carbon budgets, we select one possible equity principle and create an illustrative equity-consistent carbon budget to compare with our results.

The equality principle proposes that all humans should have an equal claim to global collective goods, such as the remaining carbon budget. This leads to the concept of equal per-capita emissions footprints across the globe (a goal in stark contrast to the current inequality in global carbon footprints). This equality in per-capita footprints could be reached over a convergence period (e.g., by 2050), or immediately. If convergence is assumed to occur immediately, then the remaining carbon budget can be distributed based on current and future population trajectories. Estonia represented 0.017% of the global population in 2020, and this is projected to decline to 0.012% by 2050 (World Bank 2022). Estonia's per-capita share of the global carbon budget would therefore be 0.015% of the total (the 2020-2050 average).

Using the 500GtCO_2 global carbon budget estimated by IPCC WGI, Estonia's "fair share" budget would be as little as 73MtCO_2 under this illustrative equity approach. This is less than the cumulative CO_2 emissions estimated from global cost-effective pathways. This is only one approach, and alternative effort-sharing schemes could incorporate other equity principles such as Estonia's historical responsibility for climate change and capacity to reduce emissions or assume a convergence period for per-capita emissions, rather than immediate convergence of per-capita footprints. These would yield different carbon budgets, which are consistent with different equity principles.

However, this illustration highlights that the cumulative CO_2 emissions calculated in this analysis should be seen as the upper bound of 1.5°C-compatibility for Estonia. To align with 1.5°C in a manner that is robust to uncertainty in the future carbon budget and embodies principles of equity and justice, Estonia should consider outperforming these limits where possible, through taking measures beyond those considered in the pathways, such as greater levels of demand reduction for high-carbon goods and accelerated deployment of renewables. Where it is not possible for Estonia to achieve its 'fair share' of climate action through domestic action alone, Estonia should also increase the level of support given to developing countries to reduce their own emissions, via international climate finance, technological transfer and capacity building.

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