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Belgium's national emission pathway in the context of the global remaining carbon budget

JOERI ROGELJ
Grantham Institute – Climate Change and Environment
Imperial College London, Exhibition Road, South Kensington, London SW7 2AZ, UK

Highlights

- This Science Brief assesses the implications of the scientific evidence on carbon budgets presented in the latest assessment of the Intergovernmental Panel on Climate Change for national carbon budgets and emissions reductions in Belgium.
- Based on the best available science, the global remaining carbon budget for limiting global warming to 1.5°C amounts to 400 billion tons of carbon dioxide emissions ($GtCO_2$).
- The implications of this global remaining carbon budget for Belgium can be explored by using equity and fairness principles to determine a fair national carbon budget share.
- A variety of principles was applied ranging from approaches that are considered inherently unfair (a grandfathering approach) to approaches that have been proposed by developing country experts.
- Based on this wide range of distribution keys, the minimum emissions reduction for Belgium that puts their national trajectory in line with limiting global warming to 1.5°C and on track to reach net zero greenhouse gas emissions by mid-century is -69% in 2030 relative to 1990 levels.
- If Belgium's net zero greenhouse gas target would be advanced from 2050 to 2042, the corresponding emissions reductions in 2030 would amount to -61% relative to 1990 levels.

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Introduction and context

Human activities are causing the climate change that we are observing and experiencing today (*1*, *2*). Changes in heat extremes, droughts and extreme precipitation across the globe can now be attributed to the greenhouse gas emissions that result from human activities and our global economy (*2*, *3*). Some of these changes, such as increases in heatwaves, can be halted when greenhouse gas emissions are strongly reduced, while others, such as sea-level rise can be slowed but will ultimately continue to worsen for centuries to millennia (*2*–*5*).

Informed by the best available science in the assessments of the Intergovernmental Panel on Climate Change (IPCC), Parties to the United Nations Framework Convention on Climate Change (UNFCCC) decided in 2015 at their 21st Conference of the Parties (COP21) in Paris 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, recognizing that this would significantly reduce the risks and impacts of climate change"* (*6*). In 2021, at COP26 in Glasgow, countries further strengthened this commitment by *"[resolving] to pursue efforts to limit the temperature increase to 1.5 °C"* (*7*). They also *"[recognize] that limiting global warming to 1.5 °C requires rapid, deep and sustained reductions in global greenhouse gas emissions, including reducing global carbon dioxide emissions by 45 per cent by 2030 relative to the 2010 level and to net zero around mid-century as well as deep reductions in other greenhouse gases"* (*7*).

These international decisions have clear implications for global and national emissions. This science brief provides an updated overview of the latest scientific understanding of emissions reduction requirements in line with limiting warming in line with the international climate goals of the Paris Agreement and the Glasgow Climate Pact. It also updates implications for emissions reductions for Belgium as they were initially discussed in ref. (*8*), in light of the most recent Sixth Assessment Report (AR6) of the IPCC (*9*, *10*) and most recent national greenhouse gas inventories.

The remaining carbon budget for limiting warming to 1.5°C

For over a decade now, it has been firmly established that global warming is close to linearly proportional to the total amount of carbon dioxide (CO_2) emissions ever emitted in the atmosphere by human activities, also referred to as anthropogenic CO_2 emissions (*2*, *4*, *11*–*21*). The IPCC's best estimate is that each 1000 billion tonnes of anthropogenic CO_2 ($GtCO_2$) emissions cause 0.45°C of global warming (*2*, *21*).

That same assessment highlights that from a physical science perspective, global cumulative CO_2 emissions have to be capped to keep human-induced warming from increasing further, and reaching net zero anthropogenic CO_2 emissions is therefore a requirement (*2*, *21*–*23*). Reductions in other anthropogenic greenhouse gases such as methane (CH_4) or nitrous oxide (N_2O) are also required to limit their contributions to future warming.

This proportionality between anthropogenic CO_2 emissions and the overall global warming, together with the understanding that no continued further warming is expected once global anthropogenic CO_2 emissions reach net zero levels, implies that requirements for limiting global warming to a specific level can be quantified by means of a global carbon budget (*4*, *21*, *24*). These factors lead the IPCC to define the term 'remaining carbon budget' as *"the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers [such as other greenhouse gases (methane, nitrous-oxide, fluorinated gases) and some air pollutants], […] expressed from a recent specified date [such as the start of the year 2015 or 2020]"* (25).

The IPCC AR6 provides the most recent and most authoritative estimates of the remaining carbon budget for limiting warming to a specific temperature level (such as 1.5°C or 2°C) with a specified probability (such as 50%, 66%, or higher probability) (*2*, *4*, *21*). The latter probabilities are the result of appropriately accounting for assessed scientific uncertainties and their quantifications. In addition, estimates assume that also other, non-CO_2 greenhouse gases are strongly reduced.

To limit global warming to 1.5°C relative to preindustrial levels (approximated by the 1850–1900 period) with a 50-50 probability, the remaining carbon budget was assessed to amount to 500 $GtCO_2$ anthropogenic CO_2 emissions, starting from 2020. If global cumulative CO_2 emissions from 2020 until net zero are kept to within these 500 $GtCO_2$ there is a 1-in-2 chance that global warming is kept to 1.5°C, and a 1-in-2 chance that it ends up above. This 500 $GtCO_2$ figure is consistent with the corresponding estimate of 580 $GtCO_2$, starting from 2018, from the IPCC Special Report on Global Warming of 1.5°C (SR1.5) (*18*, *19*), when accounting for the about 80 $GtCO_2$ of carbon dioxide that were emitted globally in the period 2018 – 2019 (*26*), and the updated assessment of Earth system feedbacks included in IPCC AR6.

Considering a higher likelihood that global warming is effectively kept below 1.5°C, implies that the remaining carbon budget is further reduced from the above-mentioned 500 $GtCO_2$ value. For instance, for having a 66% or 83% chance that global warming is kept to 1.5°C, the remaining carbon budgets were estimated at 400 and 300 $GtCO_2$, respectively (Table 1).

To further inform the Paris Agreement long-term temperature goal of holding global warming well below 2°C while pursuing to limit it to 1.5°C, the above-mentioned remaining carbon budget estimates can be considered in the context of what they achieve for limiting warming to other, higher temperature limits. Also here, the latest IPCC assessment report provides key information (*2*, *4*, *21*). For example, while keeping emissions to within a remaining carbon budget of 500 $GtCO_2$ results in limiting global warming to 1.5°C with 50% probability, it also implies that 1.7°C of global warming is avoided with about 85% probability, and 1.8°C of global warming with a greater than 90% probability (Table 1, and additional calculations).

Any of these remaining carbon budget estimates require also non-CO_2 greenhouse gas emissions to be strongly limited and reduced over the next decades, and particularly methane. Uncertainty about how deeply and how successfully methane emissions can be reduced over the next decades, combined with the challenges associated with their mitigation (*27*), means that remaining carbon budget estimates can still be smaller by 220 $GtCO_2$ or more. In case the mitigation potential for non-CO_2 emissions ends up at the lower end of what is currently identified in the scientific literature, the remaining carbon budget for limiting global warming to 1.5°C with a 50% probability would be 280 $GtCO_2$ rather than 500 $GtCO_2$. Moreover, the scientific literature describes how national greenhouse gas inventories reported by countries use a different convention to define forest emissions compared to global scientific models that are used to estimate the remaining carbon budget (*28*). This discrepancy implies that cumulative emissions based on national inventories likely represent an underestimate of the actual net anthropogenic emissions seen by the atmosphere (*29*). Therefore, from a precautionary principle, only a remaining carbon budget that is markedly below 500 $GtCO_2$ is aligned with limiting global warming to 1.5°C.

Global emissions pathways consistent with limiting warming to 1.5°C

The global remaining carbon budget for 1.5°C sets clear limits for the total amount of global anthropogenic CO_2 emissions that can still be emitted until net-zero levels are achieved. The IPCC SR1.5 reported that pathways that limit global warming to 1.5°C 'with no or limited overshoot'[1] are characterised by a global reduction in CO_2 emissions of 45% by 2030 relative to 2010 levels and the achievement of net zero CO_2 emissions around mid-century. This 1.5°C pathway characteristic is now further strengthened by the latest IPCC AR6 assessment of the remaining carbon budget. Starting from historical emissions for the year 2020 (*26*), a 45% reduction by 2030 relative to 2010 levels and a further linear reduction to net zero in 2050 implies 500 $GtCO_2$ being spent cumulatively from 2020 to 2050. These implied cumulative emissions are therefore aligned with the assessed remaining carbon budget for limiting global warming to 1.5°C with 50% probability. Despite updates to carbon budgets and global pathways, the emission reduction milestones of the SR1.5 that were also included in the Glasgow Climate Pact therefore remain supported by the best available science.

Belgium's global carbon budget share

The IPCC's remaining carbon budget for 1.5°C is defined at the global level. However, implications for Belgium can be derived by translating the global budget to the national level. This translation implies using international equity and fairness principles as a distribution key to the global carbon budget. A wide set of equity approaches have been identified in the literature, although importantly, not all of them are supported by principles of international law (*30*). To illustrate the implications of the global remaining carbon budget for 1.5°C for Belgium, we here quantify the share of the remaining carbon budget for Belgium under three different approaches: grandfathering of current historical emissions, equal per capita shares, and equal cumulative per capita emissions.

Although quantified here as a distribution key for the global remaining carbon budget, the academic literature on equity, fairness and burden sharing overwhelmingly considers grandfathering not to be an appropriate basis for fair distribution of efforts (for example, as expressed in (*30–32*)). A grandfathering approach rewards historical high polluters by allowing them to continue to emit a proportionally larger share in the future – the exact opposite of a polluter pays principle. It is here included to illustrate what would be the most beneficial interpretation of burden sharing from the perspective of a developed country such as Belgium.

The equal per capita share approach divides the remaining carbon budget amongst countries proportional to their current global population share based on the latest population data from the World Bank (*33*). It embodies a way to quantify the principle of equality. Finally, the cumulative per capita emissions approach divides the remaining carbon budget in a way such that the per capita emissions over a

[1] Global warming in 1.5°C pathways 'with no or limited overshoot' reported in the IPCC SR1.5 do not keep warming below 1.5°C with a high probability. They result in global warming more likely than not (with 50% to 67% probability) exceeding the 1.5°C and require global net negative CO_2 emissions to reverse warming and return warming below 1.5°C towards the end of the century.

given period are equal between countries. The latter approach has been proposed by experts from the BASIC countries (Brazil, South Africa, India, and China) (*34*). Here, per capita emissions are cumulative either from 1990, the publication of the first IPCC Assessment (*35*), or 2015 when the Paris Agreement was adopted.

Applying these different distribution keys to the global carbon budget provides quantified estimates of Belgium's share (see Table 2). The national share of the global remaining carbon budget that would be available for Belgium over the next years and decades differs markedly depending on which distribution key is applied. As expected, the grandfathering distribution key that by design benefits large historical emitters results in the largest remaining national carbon budget share for Belgium. At the same time, when the equal cumulative per capita distribution key that was proposed by developing countries is applied, the remaining carbon budget for Belgium becomes negative. That means Belgium has already overspent its allowable share of remaining carbon emissions when considering that action could have been taken starting in 1990 after the first IPCC assessment report or starting in 2015 after adoption of the Paris Agreement.

A 1.5°C-compatible national emissions pathway for Belgium

The estimated national carbon budget shares for Belgium can subsequently be used to estimate implied necessary emissions reductions by 2030. Here we assume a linear reduction from 2020 to 2030 in Belgian domestic CO_2 emissions, starting from the 2020 value reported in Belgium's official national greenhouse gas inventory submission to the UNFCCC (*36*). To allow for the achievement of net zero greenhouse gas emissions in 2050, Belgian CO_2 emissions decline further to net zero by 2045 from their estimated 2030 value. The net zero CO_2 by 2045 value has been chosen to allow for the subsequent achievement of Belgium's mid-century net zero greenhouse gas target by 2050. The achievement of net zero greenhouse gas emissions is always later than the achievement of net zero CO_2 emissions (*37*) (Table 2).

As for remaining carbon budget shares, the implied 2030 emissions reductions for Belgium vary strongly as a function of the carbon budget distribution key or principle that is assumed. Assuming a conservative global remaining carbon budget for limiting global warming to 1.5°C and the most lenient emissions distribution key for developed countries suggests a minimum national emissions reduction in 2030 of -69% relative to 1990 levels for Belgium. Applying any other, more salient fairness principle or distribution key results in even deeper implied 1.5°C-compatible emissions reductions by 2030 for Belgium.

An alternative to the piece-wise linear path, where Belgium's net zero greenhouse gas target is kept fixed at the year 2050, is a direct linear reduction to net zero (Figure 1). In this case, the year in which Belgium should achieve net zero greenhouse gas emissions is advanced so that Belgium stays within its fair share of global emissions. Indeed, for Belgium to stay within its remaining carbon budget, the implied net zero dates are always before 2050 (Table 3). Even for the most lenient grandfathering approach (which is not considered a fair distribution approach (*30*)), Belgium's net zero greenhouse gas date aligned with 1.5°C is closer to 2040 than to 2050. Because Belgium's net zero date is advanced, emissions reductions by 2030 can be slightly less stringent. Here, the most lenient reductions in line with 1.5°C are estimated at a 61% reduction in 2030 relative to 1990 levels, but more salient fairness approaches indicate reductions of more than 80%. The results for corresponding calculations for the EU-27 are reported in Tables 4 and 5 for comparison.

Conclusion

This Science Brief has assessed the implications of the latest and best available scientific evidence on carbon budgets compatible with limiting global warming to 1.5°C for national carbon budgets and emissions reductions in Belgium. The choice of distribution key or fairness principle is a key determinant of the size of the remaining carbon budget for Belgium. Here, a variety of principles was applied ranging from approaches that are considered inherently unfair (a grandfathering approach) to approaches that have been proposed by developing country experts. Based on this wide range, the minimum emissions reduction for Belgium that puts their national trajectory in line with limiting global warming to 1.5°C and on track to reach net zero greenhouse gas emissions by mid-century is -69% in 2030 relative to 1990 levels. Alternatively, if Belgium advances its national net zero greenhouse gas date to around 2040, the corresponding reductions in 2030 would be -61% relative to 1990 levels. Annual reductions implied by these paths are reported in Table 6.

About the author

Prof Joeri Rogelj is a Professor in Climate Science and Policy at the Centre for Environmental Policy at Imperial College London (UK), and Director of Research at Imperial College's Grantham Institute for Climate Change and the Environment. He researches how societies can transform towards more sustainable futures. He has published more than 120 scientific papers in the peer-reviewed literature on carbon budgets, climate change mitigation pathways limiting warming to 1.5°C, and adequacy and fairness of climate targets. He has served the Intergovernmental Panel on Climate Change (IPCC) as a Coordinating Lead Author on the Special Report on Global Warming of 1.5°C and a Lead Author on the IPCC's latest Sixth Assessment Report. He also serves as a Lead Author on the annual UN Environment Programme's Emissions Gap Reports, since their inception in 2010. In 2019, he was the youngest member of the UN Secretary-General's Climate Science Advisory Group and since 2022 he serves as one of the fifteen members of the EU Scientific Advisory Board on Climate Change.

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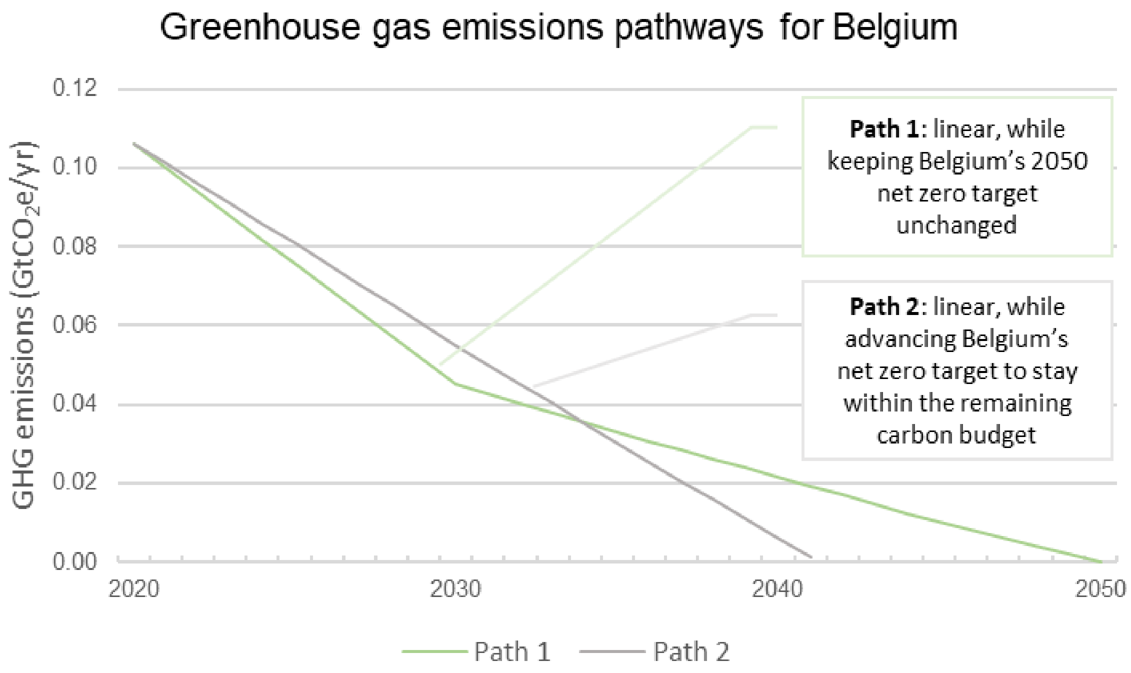

Two alternative linear pathway trajectories are illustrated. Path 1 keeps Belgium's current 2050 net zero greenhouse gas emissions target and adjusts 2030 emissions levels so that Belgium's emissions stay within Belgium's share of a global remaining carbon budget of 400 $GtCO_2$ when (unfairly) distributed based on the grandfathering of current emissions levels. Path 2 advances Belgium's net zero greenhouse gas target to achieve the same outcome.

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Table 1: Global remaining carbon budget for limiting global warming to 1.5 °C, 1.7 °C or 2.0 °C with a given likelihood.

Table adapted from the IPCC AR6 Working Group 1 Report (*2*, *4*, *21*). In light of known differences in how emissions are reported by countries and in climate models that estimate remaining carbon budgets (*29*), the value for limiting global warming to 1.5°C with 50% represents a lenient value. Following a precautionary approach, the analysis presented in this brief takes a global remaining carbon budget of **400 $GtCO_2$** as its default value.

Global warming between 1850–1900 and 2010–2019 *(°C)*	**Historical cumulative CO_2 emissions from 1850 to 2019 *($GtCO_2$)***
1.07 (0.8–1.3; *likely* range)	2390 (± 240; *likely* range)

Global warming since 2010–2019 *(°C)* *(1)	**Approximate global warming since 1850–1900 *(°C)* *(1)**	**Estimated remaining carbon budgets from January 2020 *($GtCO_2$)* *Likelihood of limiting global warming***					**Variations in reductions in non-CO_2 emissions*(2)**
		17%	*33%*	*50%*	*67%*	*83%*	
0.43	1.5	900	650	500	**400**	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
0.63	1.7	1450	1050	850	700	550	
0.73	1.8	1750	1250	1000	850	650	
0.93	2.0	2300	1700	1350	1150	900	

*(1) Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8 of refs (*4*) and (*21*), respectively.
*(2) Remaining carbon budget estimates consider the warming from non-CO_2 forcers as implied by the scenarios assessed in IPCC SR1.5 (*18*, *19*).

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Table 2: Estimated remaining carbon budget for Belgium and implied emissions reductions by 2030 (PATH 1).

Values based on a set of distribution keys and for global remaining carbon budget values of 500 and 400 $GtCO_2$, consistent with limiting global warming to 1.5°C with 50% and 66% probability, respectively. *Note that grandfathering of emissions is included here as an example of an approach that would be most beneficial to developed countries such as Belgium, but is not supported by principles of international environmental law, including the UNFCCC and the Paris Agreement, as a fair principle for the distribution of future emissions (*30*). The remaining carbon budget for Belgium accounts for emissions emitted by Belgium in the year 2020.

Implied national emissions reductions by 2030 for Belgium are estimated on a linear CO_2 reduction trajectory between 2020 and 2030, declining further to net zero CO_2 by 2045 so that net zero greenhouse gas emissions can be achieved by 2050. Note that net zero greenhouse gas emissions are always achieved after net zero CO_2 emissions are achieved because some emissions of the non-CO_2 greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) cannot be eliminated fully and need to be compensated by negative CO_2 emissions (*37*). To estimate the implied total greenhouse gas reduction, national non-CO_2 emissions for Belgium are assumed to decline proportional to the emissions reductions of global pathways that limit warming to 1.5°C with no or limited overshoot, as reported by the latest IPCC assessment (*38*, *39*) (i.e., the IPCC AR6 C1 category with a 31% reduction in 2030 from 2015 levels and an interquartile range of 28–35%). Total greenhouse gas emissions reduction calculations applied Global Warming Potentials over 100 years as currently used in UNFCCC reporting.

PATH 1: **linear trajectory in CO_2 emissions from 2020 until 2030 and continuing linearly thereafter until Belgium's 2050 net zero target**			
Distribution Key/Principle	**Remaining carbon budget for Belgium, starting from January 2021 ($MtCO_2$)**	**Implied Belgian CO_2 emissions reduction in 2030, relative to 1990 levels (%)**	**Implied Belgian total greenhouse gas emissions reduction in 2030, relative to 1990 levels (%)**
Global remaining carbon budget: 400 $GtCO_2$ (66% probability)			
Grandfathering of year-2020 historical emissions	856*	-72%	-69%
Equal per capita share (population in 2020)	538	-94%	-86%
Equal cumulative per capita emissions from 2015 to 2050	238	-114%	-103%
Equal cumulative per capita emissions from 1990 to 2050	-1466	-231%	-199%
Global remaining carbon budget: 500 $GtCO_2$ (50% probability)			
Grandfathering of year-2020 historical emissions	1093*	-56%	-55%
Equal per capita share (population in 2020)	687	-84%	-78%
Equal cumulative per capita emissions from 2015 to 2050	375	-105%	-95%
Equal cumulative per capita emissions from 1990 to 2050	-1319	-221%	-190%

Table 3: Estimated remaining carbon budget for Belgium and implied emissions reductions by 2030 (PATH 2).

Values based on a set of distribution keys and for global remaining carbon budget values of 500 and 400 $GtCO_2$, consistent with limiting global warming to 1.5°C with 50% and 66% probability, respectively. *Note that grandfathering of emissions is included here as an example of an approach that would be most beneficial to developed countries such as Belgium, but is not supported by principles of international environmental law, including the UNFCCC and the Paris Agreement, as a fair principle for the distribution of future emissions (*30*). The remaining carbon budget for Belgium accounts for emissions emitted by Belgium in the year 2020.

Implied national emissions reductions by 2030 for Belgium are estimated on a linear CO_2 reduction trajectory between 2020 and the time the remaining carbon budget for Belgium is exhausted. After reaching net zero CO_2 emissions, CO_2 emissions reductions are assumed to continue the same linear trajectory until net zero greenhouse gas emissions levels are reached. The first year in which projected total greenhouse gas emissions cross the net zero threshold under these assumptions is reported as the net zero greenhouse gas date. To estimate the implied total greenhouse gas reduction, national non-CO_2 emissions for Belgium are assumed to decline proportional to the emissions reductions of global pathways that limit warming to 1.5°C with no or limited overshoot, as reported by the latest IPCC assessment (*38*, *39*) (i.e., the IPCC AR6 C1 category).

N/A = not applicable

PATH 2: linear trajectory in CO_2 emissions from 2020 until the remaining carbon budget for Belgium is exhausted			
Distribution Key/Principle	**Net zero CO_2 date implied by linear path (year)**	**Net zero greenhouse gas date implied by linear path (year)**	**Implied Belgian total greenhouse gas emissions reduction in 2030, relative to 1990 levels (%)**
Global remaining carbon budget: 400 $GtCO_2$ (66% probability)			
Grandfathering of year-2020 historical emissions	2039*	2042	-61%
Equal per capita share (population in 2020)	2032	2034	-81%
Equal cumulative per capita emissions from 2015 to 2050	2025	2026	already net zero in 2025
Equal cumulative per capita emissions from 1990 to 2050	would fall before 2020	N/A	N/A
Global remaining carbon budget: 500 $GtCO_2$ (50% probability)			
Grandfathering of year-2020 historical emissions	2044*	2047	-54%
Equal per capita share (population in 2020)	2035	2037	-70%
Equal cumulative per capita emissions from 2015 to 2050	2028	2030	-104%
Equal cumulative per capita emissions from 1990 to 2050	would fall before 2020	N/A	N/A

Table 4: Estimated remaining carbon budget for EU-27 and implied emissions reductions by 2030 (PATH 1).

Values based on a set of distribution keys and for global remaining carbon budget values of 500 and 400 $GtCO_2$, consistent with limiting global warming to 1.5°C with 50% and 66% probability, respectively. *Note that grandfathering of emissions is included here as an example of an approach that would be most beneficial to developed countries, but is not supported by principles of international environmental law, including the UNFCCC and the Paris Agreement, as a fair principle for the distribution of future emissions (*30*). The remaining carbon budget accounts for emissions emitted in the year 2020.

Implied national emissions reductions by 2030 are estimated on a linear CO_2 reduction trajectory between 2020 and 2030, declining further to net zero CO_2 by 2045 so that net zero greenhouse gas emissions can be achieved by 2050. Note that net zero greenhouse gas emissions are always achieved after net zero CO_2 emissions are achieved because some emissions of the non-CO_2 greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) cannot be eliminated fully and need to be compensated by negative CO_2 emissions (*37*). To estimate the implied total greenhouse gas reduction, national non-CO_2 emissions for EU-27 are assumed to decline proportional to the emissions reductions of global pathways that limit warming to 1.5°C with no or limited overshoot, as reported by the latest IPCC assessment (*38*, *39*) (i.e., the IPCC AR6 C1 category with a 31% reduction in 2030 from 2015 levels and an interquartile range of 28–35%). Total greenhouse gas emissions reduction calculations applied Global Warming Potentials over 100 years as currently used in UNFCCC reporting.

PATH 1: linear trajectory in CO_2 emissions from 2020 until 2030 and continuing linearly thereafter			
Distribution Key/Principle	**Remaining carbon budget for EU-27, starting from January 2021 ($GtCO_2$)**	**Implied EU-27 CO_2 emissions reduction in 2030, relative to 1990 levels (%)**	**Implied EU-27 total greenhouse gas emissions reduction in 2030, relative to 1990 levels (%)**
Global remaining carbon budget: 400 $GtCO_2$ (66% probability)			
Grandfathering of year-2020 historical emissions	22.7*	-76%	-71%
Equal per capita share (population in 2020)	20.9	-80%	-74%
Equal cumulative per capita emissions from 2015 to 2050	14.2	-95%	-85%
Equal cumulative per capita emissions from 1990 to 2050	-17.6	-165%	-140%
Global remaining carbon budget: 500 $GtCO_2$ (50% probability)			
Grandfathering of year-2020 historical emissions	29.0*	-62%	-60%
Equal per capita share (population in 2020)	26.6	-68%	-64%
Equal cumulative per capita emissions from 2015 to 2050	19.3	-84%	-76%
Equal cumulative per capita emissions from 1990 to 2050	-11.9	-152%	-130%

Table 5: Estimated remaining carbon budget for EU-27 and implied emissions reductions by 2030 (PATH 2).

Values based on a set of distribution keys and for global remaining carbon budget values of 500 and 400 $GtCO_2$, consistent with limiting global warming to 1.5°C with 50% and 66% probability, respectively. *Note that grandfathering of emissions is included here as an example of an approach that would be most beneficial to developed countries, but is not supported by principles of international environmental law, including the UNFCCC and the Paris Agreement, as a fair principle for the distribution of future emissions (*30*). The remaining carbon budget accounts for emissions emitted in the year 2020.

Implied national emissions reductions by 2030 are estimated on a linear CO_2 reduction trajectory between 2020 and the time the remaining carbon budget for EU-27 is exhausted. After reaching net zero CO_2 emissions, CO_2 emissions reductions are assumed to continue the same linear trajectory until net zero greenhouse gas emissions levels are reached. The first year in which projected total greenhouse gas emissions cross the net zero threshold under these assumptions is reported as the net zero greenhouse gas date. To estimate the implied total greenhouse gas reduction, national non-CO_2 emissions for EU-27 are assumed to decline proportional to the emissions reductions of global pathways that limit warming to 1.5°C with no or limited overshoot, as reported by the latest IPCC assessment (*38*, *39*) (i.e., the IPCC AR6 C1 category).

N/A = not applicable

PATH 2: linear trajectory in CO_2 emissions from 2020 until the remaining carbon budget for EU-27 is exhausted			
Distribution Key/Principle	**Net zero CO_2 date implied by linear path (year)**	**Net zero greenhouse gas date implied by linear path (year)**	**Implied EU-27 total greenhouse gas emissions reduction in 2030, relative to 1990 levels (%)**
Global remaining carbon budget: 400 $GtCO_2$ (66% probability)			
Grandfathering of year-2020 historical emissions	2039*	2043	-65%
Equal per capita share (population in 2020)	2038	2041	-67%
Equal cumulative per capita emissions from 2015 to 2050	2032	2034	-81%
Equal cumulative per capita emissions from 1990 to 2050	would fall before 2020	N/A	N/A
Global remaining carbon budget: 500 $GtCO_2$ (50% probability)			
Grandfathering of year-2020 historical emissions	2044*	2049	-59%
Equal per capita share (population in 2020)	2042	2046	-61%
Equal cumulative per capita emissions from 2015 to 2050	2036	2039	-69%
Equal cumulative per capita emissions from 1990 to 2050	would fall before 2020	N/A	N/A

Table 6 (part 1): Estimated annual reductions for four distribution principles and two pathway assumptions.

Annual emissions reductions for total greenhouse gas emissions relative to 1990, for a global 400 $GtCO_2$ remaining carbon budget consistent with holding global warming to 1.5°C.
Path 1: Linear reduction from 2020 to 2030 continued by linear reduction until Belgium's current 2050 net zero greenhouse gas target is achieved.
Path 2: Linear reduction from 2020 to net zero in a way that the remaining carbon budget is not exceeded. Belgium's net zero date is advanced in this case. No values are estimated for after the net zero greenhouse gas date.

Distribution Key/Principle	Path	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Grandfathering of year-2020 historical emissions	Path 1	-26%	-30%	-34%	-38%	-43%	-47%	-51%	-56%	-60%	-64%	-69%	-70%	-72%	-74%	-75%	-77%
	Path 2	-26%	-29%	-33%	-36%	-40%	-43%	-47%	-51%	-54%	-58%	-61%	-65%	-68%	-72%	-75%	-79%
Equal per capita share (population in 2020)	Path 1	-26%	-32%	-38%	-44%	-50%	-56%	-62%	-68%	-74%	-80%	-86%	-87%	-87%	-88%	-88%	-89%
	Path 2	-26%	-31%	-37%	-42%	-48%	-53%	-59%	-64%	-70%	-75%	-81%	-86%	-92%	-97%	net zero	
Equal cumulative per capita emissions from 2015 to 2050	Path 1	-26%	-33%	-41%	-49%	-57%	-64%	-72%	-80%	-88%	-95%	-103%	-102%	-102%	-101%	-101%	-100%
	Path 2	-26%	-39%	-51%	-64%	-77%	-90%	net zero									
Equal cumulative per capita emissions from 1990 to 2050	Path 1	-26%	Remaining carbon budget for Belgium exhausted - no pathway possible anymore														
	Path 2	-26%	Remaining carbon budget for Belgium exhausted - no pathway possible anymore														

Table 6 (part 2): Estimated annual reductions for four distribution principles and two pathway assumptions.

Annual emissions reductions relative to 1990, for a global 400 $GtCO_2$ remaining carbon budget consistent with holding global warming to 1.5°C

Distribution Key/Principle	Path	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Grandfathering of year-2020 historical emissions	Path 1	-78%	-80%	-82%	-83%	-85%	-86%	-88%	-90%	-91%	-93%	-94%	-96%	-97%	-99%	-100%
	Path 2	-82%	-86%	-89%	-92%	-96%	-99%	net zero								
Equal per capita share (population in 2020)	Path 1	-89%	-90%	-90%	-90%	-91%	-91%	-92%	-92%	-92%	-93%	-94%	-96%	-97%	-99%	-100%
	Path 2															
Equal cumulative per capita emissions from 2015 to 2050	Path 1	-99%	-99%	-98%	-97%	-96%	-96%	-95%	-94%	-94%	-93%	-94%	-96%	-97%	-99%	-100%
	Path 2															
Equal cumulative per capita emissions from 1990 to 2050	Path 1	Remaining carbon budget for Belgium exhausted - no pathway possible anymore														
	Path 2	Remaining carbon budget for Belgium exhausted - no pathway possible anymore														

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