Consistency of the bottom up national scenarios with the Paris Agreement temperature goals

Prepared by Climate Change Advisory Council Secretariat September 2021

Introduction

The legislation requires the Council to consider whether national mitigation scenarios which also must achieve the national climate objective by 2050 and a 51% emissions reduction by 2030, are consistent with what is required at a global level to meet the objectives of the Paris agreement.

The IPCC Sixth Assessment Report Working Group I (AR6 WGI) estimates the likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. (SPM A.1.3). This implies distance to the 1.5°C warming threshold is 0.43°C (within a likely range of 0.2 to 0.7 °C).

The Paris Agreement seeks to coordinate and assess global efforts to address climate change through consideration of the Nationally Determined Contributions (NDCs) submitted to the UNFCCC. Important aspects of the Paris Agreement are the reporting requirements, which enable assessment of progress of each Party on meeting the commitments in these NDCs and scientific analysis of whether the commitments and progress has been sufficient to achieve the aims of the Paris Agreement. Recent analysis published by Höhne, et al (2021)[1] considered the recent commitments from 131 countries to achieve net zero emissions. The analysis suggests that with these commitments, if perfectly implemented, the best estimate of global warming is in the range of 2.0-2.4°C. While the cumulative impact is not as yet consistent with the global temperature aims of Paris Agreement, there has been progress.

As countries across the globe attempt to reduce their greenhouse gas emissions to combat climate change, many are also expected to make significant efforts and progress in reducing air pollution. Many air pollutants and greenhouse gases have common sources, and much of the reduction of air pollution will occur in tandem with actions to reduce greenhouse gas emissions particularly from combustion and agricultural sources of methane and nitrogen compounds.. Reduced air pollution has additional unintended, but unavoidable, impacts on climate change. High concentrations of aerosol air pollutants in certain parts of the world, caused by emissions of SO_2, NH_3, etc., despite short atmospheric lifetimes, have a significant cooling impact on global temperatures. Their removal, while necessary from a public health and environmental perspective, will have the impact of increasing [or unmasking additional] warming over the next couple of decades. This effect is anticipated and calculated in the IPCC AR6 WG1 scenarios. Thus the IPCC assessment of the remaining global carbon dioxide budgets includes an adjustment for the warming impact due to a reduction in the aerosol cooling effect. The adjustment associated with global mitigation scenarios consistent with the 1.5°C target is an additional warming of 0.2C which reduce the distance to the 1.5 °C threshold to 0.23°C (within a range of 0.14 °C and 0.32 °C), with additional uncertainty associated with the specific mitigation pathway.[2]

[1] Höhne, N., Gidden, M.J., den Elzen, M. *et al.* Wave of net zero emission targets opens window to meeting the Paris Agreement. *Nat. Clim. Chang.* (2021). https://doi.org/10.1038/s41558-021-01142-2

[2] Conversion between RCB 500 GtCO2 (50% probable of 1.5oC, from Table 5.8 IPCC ARG6 WGI), and a TCRE of 0.45°C per $GtCO_2$ and a range of 0.27°C per $GtCO_2$ and 0.63°C per $GtCO_2$)

What is the global carbon budget, GCB and the remaining global carbon budget (RCB)?

The term is shorthand for the cumulative amount of carbon dioxide which if emitted into the atmosphere will cause a specific amount of warming relative to the pre-industrial era, *all else being equal*. A closely related term is the remaining global carbon dioxide budget (RCB) which matches specific temperature targets with levels of carbon dioxide which if emitted would cause warming to reach this temperature. If the aim to limit warming to a specific temperature, then it is necessary that global emissions of carbon dioxide reach net zero before cumulative emission go above the threshold carbon budget estimated for this temperature. The remaining global carbon dioxide budget is calculated by subtracting the estimated warming and cumulative emissions of CO_2 to date from the global carbon dioxide budget associated with a given temperature. For more ambitious temperature targets, the time frame over which stabilisation of emissions is achieved is also relevant, for example 1.5°C scenarios tend to require achieving net zero of CO_2 emissions in the 2050's.

How does the Remaining Carbon Dioxide Budget relate to other greenhouse gases and climate forcers?

Of course, all else is not equal. In addition to CO_2, other climate forcers are active and impact on global warming in complex ways. The approach adopted in the AR6 WGI assessment of remaining global carbon dioxide budget is to make adjustments to the RCBs which reflect the climate impact of emissions (and removals) of other climate forcers. For example, if it is assumed that on-going N_2O emissions will cause and additional warming of 0.03°C in the period to 2050, then the warming allowable for carbon dioxide must reduce by this amount, and so the remaining global carbon dioxide budget is adjusted downwards by the amount of carbon dioxide which would cause similar warming.

The IPCC Special Report on Global Warming of 1.5°C (SR1.5) provides details of the approach which was used in the ARG WGI1 to estimate the adjustment made to the remaining global carbon budget on the basis of likely additional warming due to non-CO_2 climate forcers. Figure 0-1 shows the range of global emissions scenarios consistent with 1.5°C warming from the SR1.5. While there are multiple emissions pathways consistent with 1.5°C warming, some common features are apparent. Net zero carbon dioxide emissions sooner rather later around 2050-2070. Strong and rapid reduction in the rate of methane in the period to 2059, with a more gradual rate of reduction thereafter, but methane emissions are not required to reach net zero. Pathways for Nitrous oxide emissions are complex, but with most scenarios seeing significant reductions. The AR6 WGI has updated this analysis to take account of global emissions in the period since SP1.5 but references back to the SR1.5 for detailed discussion of the approach. The AR6 estimates a remaining global carbon budget of 500Gt CO_2 from 2020 to 2050, if the target is a 50% probably of global warming of 1.5°C. This implies a remaining distance to 1.5°C of 0.23°C, and further implies the net impact of non-CO2 climate forcers of the order of 0.2°C contingent on the levels of global emissions reduction, and other mitigation activities inferred from the scenario analysis. [3]

The adjustments required to account for the climate impact of non-CO2 emissions to establish the remaining global carbon budget are:

- Impact of change in in aerosols cooling effect (warming)
- Impact of change in the rate of methane emissions (cooling)

[3] Conversion between RCB 500 GtCO2 (50% probable of 1.5oC, from Table 5.8 IPCC ARG6 WGI), and a TCRE of 0.45°C per $GtCO_2$ and a range of 0.27°C per $GtCO_2$ and 0.63°C per $GtCO_2$)

- Impact of change in Ozone concentrations (cooling)
- Impact of on-going emissions of nitrous oxide (warming)
- Impact of Earth System feedbacks (warming)
- Zero Emissions Commitment (ZEC) (neutral)

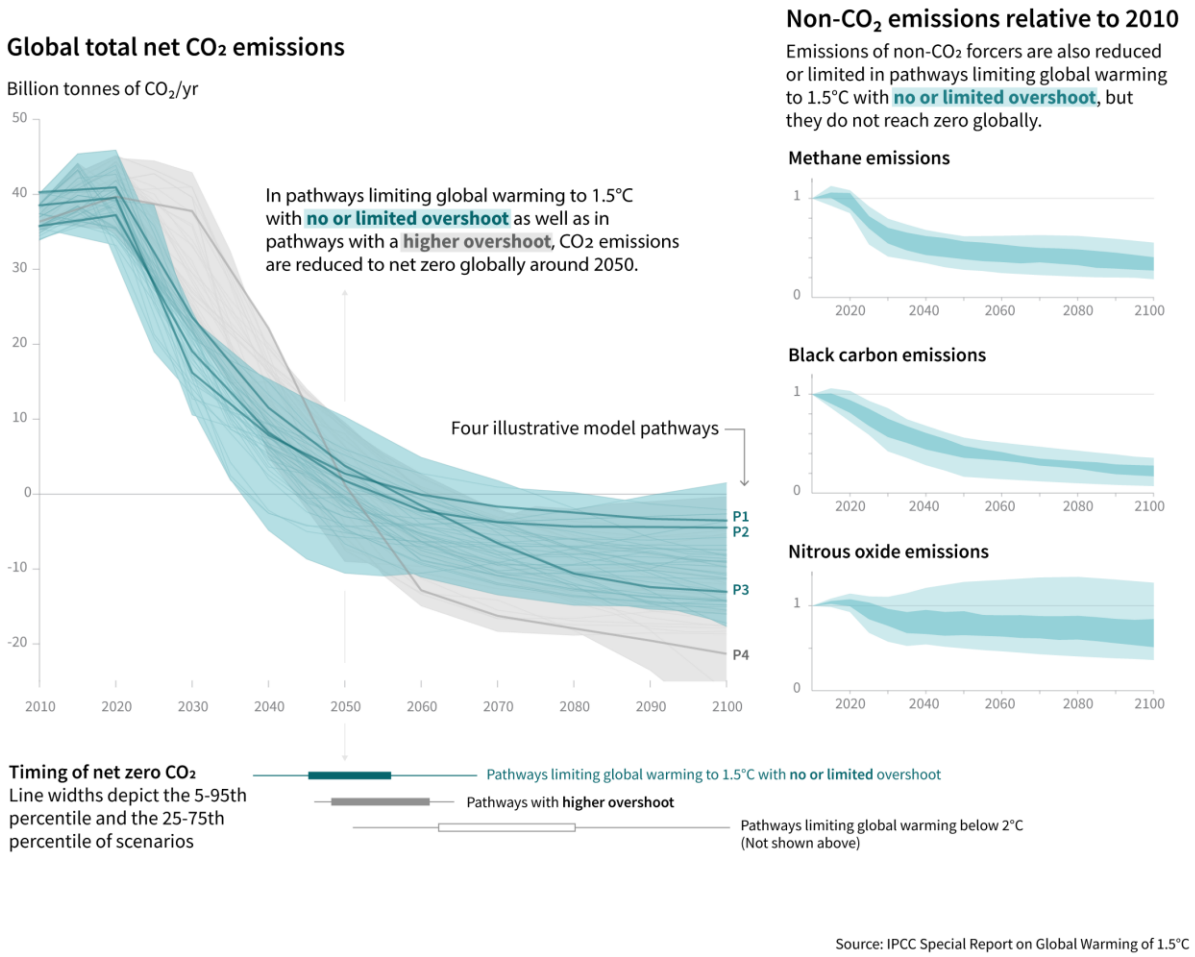

Figure 0-1

How can we establish a relationship between global and national carbon dioxide budgets?

All countries have agreed to share the effort to address climate change. It then falls on each country to assess how much it should do and over what time frame, given its own circumstances, profile of greenhouse gases and options for reducing emissions and enhancing removals. In light of this assessment, a country formally submits their nationally determined contribution under the Paris Agreement to the UNFCCC. How the country undertakes its assessment strongly on considerations of equity and other value judgements., and many approaches have been proposed in the literature (Joeri 2019, Smith, 2021). [4],[5]The IPCC makes clear that the remaining global carbon budget is a global estimate and that actions at a national or regional level are policy decisions with important value judgements associated with them. Downscaling the IPCC estimates of remaining global carbon

[4] Joeri Rogelj and Carl-Friedrich Schleussner 2019 "Unintentional unfairness when applying new greenhouse gas emissions metrics at country level", *Environ. Res. Lett.* **14** 114039

[5] Andrew Smith's Literature Review.

dioxide budgets to a regional or national level is thus very challenging and would involve, amongst other considerations, an assessment of the adjustments made to the global carbon dioxide budget in the context of a regional profile of emissions, and mitigation options which are markedly different from those available at a global level along with considerations of historical responsibility, equity and equality of opportunity.A simple, screening approach can be used to assess the consistency of proposed mitigation efforts or carbon budgets with the Paris temperature goals. The screening approach presented here considers whether at a minimum the impact of the national illustrative scenario on a *per capita* basis are consistent with the Paris Agreement temperature goal.

Impact of bottom up scenarios on global temperature

An analysis can be made to estimate the impact of the emissions reduction scenarios explored in the bottom up approach and global temperature. The analysis presented here follows the methodology documented in Lynch et al 2020[6] and presented by Myles Allen in the Carbon Budget Committee's expert meeting on the science of national mitigation efforts, gases, and the 1.5C degrees goal (22nd June 2021).

Figure 0-1 shows the estimate impact of emissions assumed in each of the illustrative scenarios on global temperatures. The illustrative scenarios achieve 51% emissions reduction by 2030 across all gases on the basis of GWP_{100} as specified in the Regulation and used in EU accounting. However, the scenarios have different impacts on global temperature. The most striking differences between scenarios are the impact of different rates of methane emissions and the magnitude of removals required to balance residual N_2O emissions. Stabilisation of the warming requires residual emissions of CO_2 and N_2O to be balanced by the deployment of sufficient removals measures, either through technologies or changes in land use and management practices, which balance any residual and on-going emissions of these gases. The magnitude of annual removals to offset nitrous oxide, for example, would be significant and will require investment and land use change at scale to realise. With the bottom up scenarios, we assume a ramping up of removals so that by 2050 balance is achieved on an annual basis. Post 2050 the rate of nitrous oxide emission is assumed to stabilise, and therefore the rate of removals to balance or offset this is also stabilised. This represents an on-going, indefinite commitment to achieve high rates of removals. The challenge this represents should not be underestimated. The removals required to balance residual carbon dioxide and other gases would be additional to this and depends on the degree to which the whole economy can be decarbonised and carbon losses from LULUCF are addressed. This ongoing challenge to offset residual emissions of N_2O, CO_2 and other gases is a common feature of ambitious global mitigation scenarios.

[6] https://iopscience.iop.org/article/10.1088/1748-9326/ab6d7e

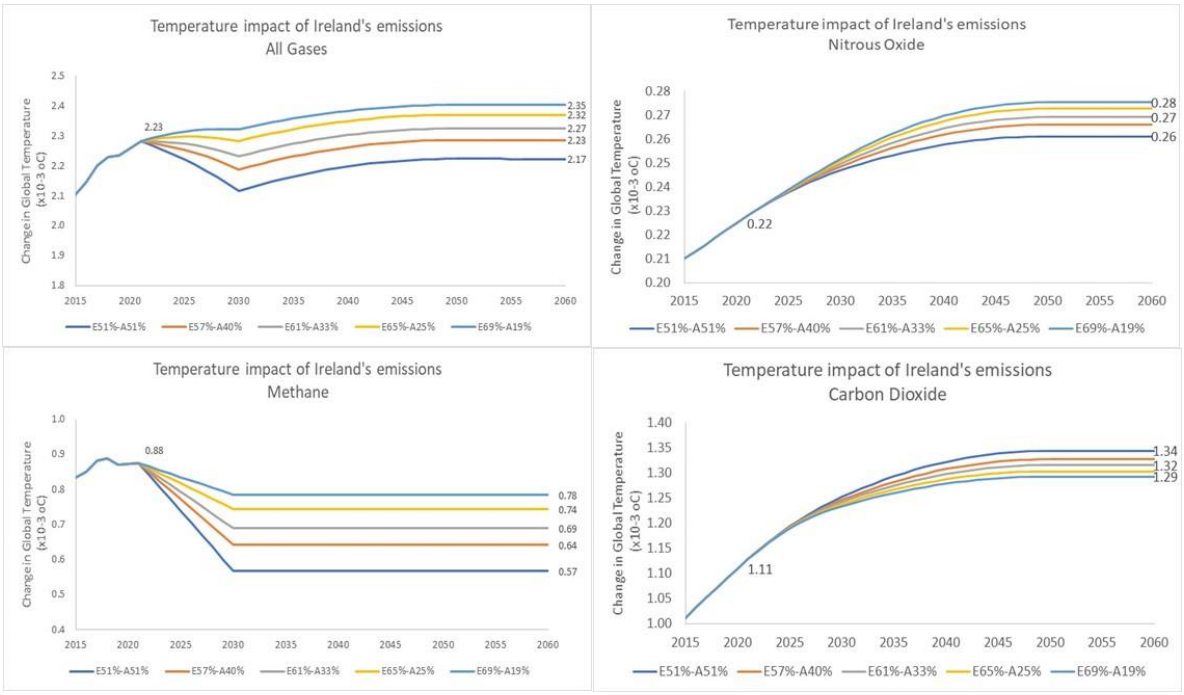

Figure 0-1 Estimated temperature response to emission of the main greenhouse gases based on the illustrative scenarios

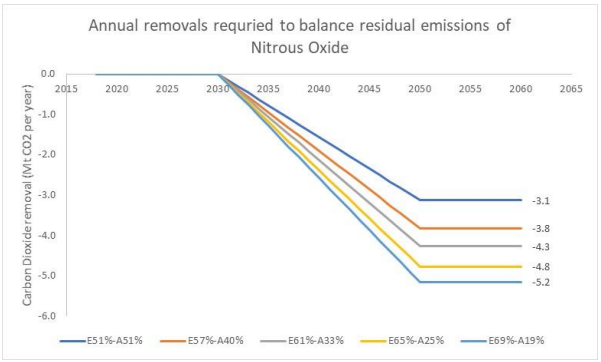

Figure 0-2 Illustrative scenario where removals are ramped up from 2030 to so as achieve a balancing of nitrous oxide emissions by 2050. Removals continue at this rate thereafter, so as to balance residual emissions of nitrous oxide.

Table 1 provides a summary of the outcomes from the illustrative scenarios shown in Figure 0-1.

Table 1 Summary of outcome from the illustrative scenarios showing the impact on temperature, the cumulative emissions of carbon dioxide which would achieve the same temperature response and the scaling up to a hypothetical global population with the same emission profile as Ireland.

		Additional Impact of Ireland's emissions from 2020 on Global Temperature in 2050 (in thousandths of degrees Celsius) x10^{-3} ºC				
Estimated Warming from 1850 to 2020 (x10^{-3} ºC)		E51%-A51%	E57%-A40%	E61%-A33%	E65%-A25%	E69%-A19%
Warming from 1850 to 2020		2.21	2.21	2.21	2.21	2.21
CO2	1.11	1.34	1.33	1.32	1.3	1.29
N2O	0.22	0.26	0.27	0.27	0.27	0.28
CH4	0.87	0.57	0.64	0.69	0.74	0.78
Total	2.21	2.17	2.24	2.27	2.32	2.35

Net Change in Global Temperature in 2050? relative to 2020 (x10^{-3} °C)		-0.03	0.03	0.07	0.11	0.14
	Emissions of Carbon Dioxide require to achieve the same temperature outcome					
Carbon Dioxide Budget consumed (2020-2050) (in Mt CO_2)		E51%-A51%	E57%-A40%	E61%-A33%	E65%-A25%	E69%-A19%
CO2		512	490	467	423	401
N2O		78	100	100	100	123
CH4 (see note)		-673	-518	-407	-296	-207
Total Budget Consumed		-83	72	161	228	317
Note: Negative values indicate removal of CO_2 would be required to achieve negative temperature outcomes. There is evidence in the IPCC WG1 report that using TCRE to calculate this value may underestimate by 10%.						
	*Recalling the previous estimate that there is a remaining 0.2 gap to the 1.5 degree goal.					
	In Degrees Celsius.					
Upscale to Global Temperature change to 2050*		-0.05	0.05	0.11	0.17	0.22

Screening on the basis of a simple upscaling and conclusions:

To reiterate, the IPCC mitigation scenarios consistent with 1.5°C of global warming estimates that if implemented, the additional warming due to non-CO2 climate forcers reduces the allowable warming to 0.23°C (within a range of 0.14°C and 0.32 °C).[7]

The analysis above presents the temperature impact of simplified pathways where Ireland achieves a 51% emissions reduction across all gases by 2030 and achieves net zero emissions of CO_2 and N_2O by 2050, while also stabilising the climate impact of CH_4 from 2030 onwards.

The screening analysis involves a thought experiment utilising the Kantian categorical imperative[8], where Ireland's emissions profile is applied to the global population. We simply scale up according to Ireland's population proportional share of global population, which is of the order of 0.064%. The final row of Table 1 gives the estimated temperature response if all the world had a similar profile and behaved similarly to the illustrative emissions scenarios

Although highly simplistic, the screening experiment indicates that most of the scenarios are broadly consistent with remaining within the thresholds for warming identified by the IPCC. However utilising the precautionary principle, the E69%A19% scenarios could be considered inconsistent with the Paris objective, both because warming would approach the threshold value, and because this scenario requires very significant and challenging levels of ongoing removals to achieve climate neutrality. In the design and implementation of national climate action plans, targets which envisage reduction in methane and nitrous oxide of an order of less the 25% would require more rigorous analysis to establish consistency with the objective of the Paris Agreement.

[7] Conversion between RCB 500 GtCO2 (50% probable of 1.5oC, from Table 5.8 IPCC ARG6 WGI), and a TCRE of 0.45°C per $GtCO_2$ and a range of 0.27°C per $GtCO_2$ and 0.63°C per $GtCO_2$)

[8] "act only in accordance with that maxim through which you can at the same time will that it become a universal law" https://plato.stanford.edu/entries/kant-moral/