**Accounting for the non-CO2 contributions to remaining carbon budgets – Supplementary Information**

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**IIASA IAMC database of SR15 scenarios**

The IIASA IAMC database of scenarios[1] is the source material used in the production of figure 1. Scenarios are coloured by category, according to their label in the database, and annual CO2 emissions (panel a) along with non-CO2 RF (panel c, right hand axis) are shown for each model where both variables are reported.

-------------- BOX for Simple Formula --------------

**A simple formula for accounting for the non-CO2 contribution to remaining carbon budgets**

Converting all climate forcing agents to CO2-forcing-equivalent (CO2-fe) emissions provides the most accurate and physically justified definition of an ‘all-pollutants CO2 budget’ but requires full forcing histories and an invertible carbon cycle model. On decade-to-century timescales, however, CO2-fe emissions associated with any individual forcing agent may be approximated by “warming equivalent” emissions, CO2-we, or a simple linear combination of the current emission level and how this has changed over a recent time-interval, . If non-CO2 climate forcers are expressed as CO2-equivalent (CO2-e) emissions by multiplying emissions by their Global Warming Potential, GWP (or equivalently, for components such as aerosols, by dividing their contribution to effective radiative forcing by the Absolute Global Warming Potential (AGWP) of CO2) then

(1)

where is the time-horizon used for the GWP and AGWP (conventionally 100 years), depends on the properties and time-history of that forcing agent, being the fractional rate at which would need to decline to cause no further warming in the decades following year , and is approximately double the atmospheric lifetime for a short-lived climate pollutant.

For long-lived climate pollutants (LLCPs, with lifetimes longer than ) such as CO2 and N2O, . For methane, and years, reflecting its recent emissions history and lifetime (Cain et al, 2019). For aerosols, the best-fit year while , reflecting their very short lifetime and the fact that GMST is already partially equilibrated with current net global aerosol forcing.

Hence human-induced warming over a multi-decade interval to may be approximated by

(2)

where the TCRE is the transient climate response to emissions and the term in curly brackets represents total warming-equivalent emissions over the interval to . represents combined CO2 and N2O emissions, while represents methane emissions, all in units of GtCO2-e using GWP100 (including the impact of tropospheric ozone changes into the GWP of methane),  is the average and the change in other radiative forcing (primarily aerosols), in units of W/m2, all computed over the interval to . All coefficients here are based on values from the IPCC 5th Assessment Report: years; 0.092 W-yr/m2/GtCO2; for ; GtCO2 per W/m2 as noted in figure SPM.1 of ref. (SR1.5); and GtCO2 per W-yr/m2 for . The AR5 likely range for TCRE is 0.45±0.23°C per 1000 GtCO2, which far outweighs uncertainty in other coefficients.

Figure 3 shows contributions to cumulative CO2-fe emissions relative to 2018 in the median 1.5°C-compatible scenarios (solid lines, left axis), cumulative warming-equivalent emissions (dashed lines) computed using equation 2 applied to the emissions of CO2, N2O and CH4 and radiative forcing from aerosols, and contributions to warming (dotted lines, right axis) using the same model as figure 2b. This single equation is a much better predictor of future warming than CO2 emissions alone or cumulative CO2-equivalent emissions, and almost as accurate as CO2-fe emissions.

[FIGURE X HERE]

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NOTES:

Ranges of non-CO2 budgets for scenarios (blue and orange): 30 – 585 GtCO2

TCRE range = 0.86-2.49 C/TtC == 0.23-0.68 C/TtCO2.

Current globally averaged temperature anomaly = 1.10 C, (5th-9th percentile = 0.98-1.28 C)

Therefore remaining budget to 1.5C likely range assuming best estimate warming to date:

(1.5 – 1.1) \* 1000 / 0.23 = 1740 GtCO2

(1.5 – 1.1) \* 1000 / 0.68 = 590 GtCO2

Best estimate: (1.5 – 1.1) \* 1000 / 0.35 = 1140 GtCO2

Assuming median non-CO2 budget (of blue and orange scenarios) = 240 GtCO2 we have remaining carbon budget:

5th percentile: (0.4 \* 1000 / 0.23) – 240 = 1740 – 240 = 1500 GtCO2

33rd percentile: (0.4 \* 1000 / 0.31) – 240 = 1740 – 240 = 1050 GtCO2

50th percentile: (0.4 \* 1000 / 0.35) – 240 = 1740 – 240 = 900 GtCO2

66th percentile: (0.4 \* 1000 / 0.40) – 240 = 1740 – 240 = 760 GtCO2

95th percentile: (0.4 \* 1000 / 0.68) – 240 = 1740 – 240 = 350 GtCO2