# An assessment of the climate damage costs of European short-lived climate forcers – Supplementary Material 1

### Adjusting for differences in atmospheric lifetime of pollutants

Although SCM is a more suitable metric than SCC, methane has a longer lifetime in the atmosphere and a different temporal profile (how long after an emission pulse that the temperature response occurs) than the other SLCFs. Since future values are discounted, it is reasonable to adjust the SCC values with respect to difference in temporal profiles. To do this we use the results from IWG (2021) and information from Figure 6.15 in Szopa, Naik et al. (2021) and the following assumptions:

* An emission pulse of an SLCF has no significant surface air temperature response after 400 years,
* the net-present values of SCM given by IWG are based on similar surface air temperature response temporal profiles as reported for gases with a 10-year lifetime as in figure 6.15,
* Mitigating and exacerbating SLCFs with the same lifetime have the same global mean surface air temperature response in absolute terms.

The adjustment is made in six steps.

**Step 1: Measure idealised global mean surface air temperature responses**

From figure 6.15 in Szopa, Naik et al. (2021) we measure data on the global mean surface air temperature (*GSAT*) response for idealised gases with atmospheric lifetimes (*lt*) of 0.01, 1, 5, and 10 years for time after emission pulse (*tep*) = 0 → 400.

**Step 2: Calibrate response function for CH4**

Based on the measurements, we estimate an indicative GSAT response function as a function of *lt* for the *tep*-years 2→400:

Where:

*a, b* = constants specified per *lt* and *tep*

For *tep*-values of 0 and 1 we used GSAT-values from the measurements.

**Step 3: Calculate response function for other SLCPs**

CH4 has an average climate perturbation lifetime of 11.8 years (Szopa, Naik et al., 2021). The atmospheric lifetime of the other SLCP air pollutants varies much dependent on temperature, precipitation, wind strength etc. Based on information from the United States Agency for Toxic Substances and Disease Registry (2022), and AEA Technology (2022) we assume lifetimes of 0.027 year (10 days) for PMres, BC, OC, & SO2, and 0.01 year (3.65 days) for NMVOC, NOx, and NH3.

Based on these SLCF-specific lifetimes, we re-calculated *GSATlt,tep* for each SLCF. We used *a0.01,tep* and *b0.01,tep* values for PMres, BC, OC, SO2, NMVOC, NOx, and NH3. We used *a10,tep* and *b10,tep* values for CH4.

**Step 4: Calculate GSAT-ratios for each SLCF and *tep0→400*.**

Based on the estimated SLCF-specific GSAT values, we then calculate the annual incremental contribution to GSAT.

Where *GSATtep=0* = 0, and *GSATTEP* = 0.69 (the temperature response at *tep*=400).

**Step 5: Calibrate cumulative cost of CH4 = *A***

The IWG (2021) presents net present values of the social cost of methane specified per emission year and discount rate *i*. Based on the GSAT-ratio, IWG-values for *i* and a standard net present value function we can identify a cumulative, non-discounted cost of CH4, *A*.

The value of *ACH4,i* is identified just by using the goal seek function in Microsoft Excel on the following function.

*ACH4* is identified for the emission years (*t*) 2020, 2025, 2030, 2035, 2040, 2045, 2050 and the discount rates 2.5%, 3%, and 5%.

**Step 6: calculating unit damage costs per SLCF, discount rate and emission year**

The final step of the adjustments is to recalculate the net present value of the unit damage cost per SCLF, discount rate, and emission year, as in the following equation:

### Resulting unit damage costs

Table SM1.: Unit Damage Cost per SLCP, discount rate, uncertainty range, and emission year (€2020/ton pollutant)

| **Discount rate** | **SC-Range** | **Pollutant** | **2020** | **2030** | **2040** | **2050** |
| --- | --- | --- | --- | --- | --- | --- |
| 2.5% | Low (5th perc.) | CH4 | 316.7 | 421.0 | 543.6 | 653.6 |
| 2.5% | Mid | CH4 | 1797.4 | 2311.3 | 2904.1 | 3490.3 |
| 2.5% | High (95th perc.) | CH4 | 4819.7 | 6229.4 | 7855.1 | 9317.6 |
| 3.0% | Low (5th perc.) | CH4 | 238.1 | 327.8 | 434.3 | 535.7 |
| 3.0% | Mid | CH4 | 1363.6 | 1798.4 | 2312.3 | 2833.0 |
| 3.0% | High (95th perc.) | CH4 | 3591.4 | 4766.9 | 6210.0 | 7548.5 |
| 5.0% | Low (5th perc.) | CH4 | 96.0 | 145.8 | 212.2 | 284.0 |
| 5.0% | Mid | CH4 | 604.5 | 855.2 | 1173.3 | 1522.2 |
| 5.0% | High (95th perc.) | CH4 | 1478.3 | 2172.3 | 3108.8 | 4106.7 |
| 2.5% | Low (5th perc.) | PMres | 389.3 | 517.5 | 668.2 | 803.4 |
| 2.5% | Mid | PMres | 2209.3 | 2840.9 | 3569.6 | 4290.1 |
| 2.5% | High (95th perc.) | PMres | 5924.1 | 7656.8 | 9654.9 | 11452.7 |
| 3.0% | Low (5th perc.) | PMres | 303.6 | 418.0 | 553.8 | 683.1 |
| 3.0% | Mid | PMres | 1738.7 | 2293.2 | 2948.4 | 3612.4 |
| 3.0% | High (95th perc.) | PMres | 4579.4 | 6078.3 | 7918.4 | 9625.2 |
| 5.0% | Low (5th perc.) | PMres | 140.0 | 212.6 | 309.4 | 414.0 |
| 5.0% | Mid | PMres | 881.3 | 1246.8 | 1710.5 | 2219.1 |
| 5.0% | High (95th perc.) | PMres | 2155.1 | 3166.9 | 4532.2 | 5987.0 |
| 2.5% | Low (5th perc.) | BC | 389.3 | 517.5 | 668.2 | 803.4 |
| 2.5% | Mid | BC | 2209.3 | 2840.9 | 3569.6 | 4290.1 |
| 2.5% | High (95th perc.) | BC | 5924.1 | 7656.8 | 9654.9 | 11452.7 |
| 3.0% | Low (5th perc.) | BC | 303.6 | 418.0 | 553.8 | 683.1 |
| 3.0% | Mid | BC | 1738.7 | 2293.2 | 2948.4 | 3612.4 |
| 3.0% | High (95th perc.) | BC | 4579.4 | 6078.3 | 7918.4 | 9625.2 |
| 5.0% | Low (5th perc.) | BC | 140.0 | 212.6 | 309.4 | 414.0 |
| 5.0% | Mid | BC | 881.3 | 1246.8 | 1710.5 | 2219.1 |
| 5.0% | High (95th perc.) | BC | 2155.1 | 3166.9 | 4532.2 | 5987.0 |
| 2.5% | Low (5th perc.) | OC | 389.3 | 517.5 | 668.2 | 803.4 |
| 2.5% | Mid | OC | 2209.3 | 2840.9 | 3569.6 | 4290.1 |
| 2.5% | High (95th perc.) | OC | 5924.1 | 7656.8 | 9654.9 | 11452.7 |
| 3.0% | Low (5th perc.) | OC | 303.6 | 418.0 | 553.8 | 683.1 |
| 3.0% | Mid | OC | 1738.7 | 2293.2 | 2948.4 | 3612.4 |
| 3.0% | High (95th perc.) | OC | 4579.4 | 6078.3 | 7918.4 | 9625.2 |
| 5.0% | Low (5th perc.) | OC | 140.0 | 212.6 | 309.4 | 414.0 |
| 5.0% | Mid | OC | 881.3 | 1246.8 | 1710.5 | 2219.1 |
| 5.0% | High (95th perc.) | OC | 2155.1 | 3166.9 | 4532.2 | 5987.0 |
| 2.5% | Low (5th perc.) | NMVOC | 398.2 | 529.3 | 683.5 | 821.8 |
| 2.5% | Mid | NMVOC | 2259.9 | 2906.1 | 3651.5 | 4388.5 |
| 2.5% | High (95th perc.) | NMVOC | 6060.0 | 7832.5 | 9876.4 | 11715.4 |
| 3.0% | Low (5th perc.) | NMVOC | 311.7 | 429.1 | 568.5 | 701.2 |
| 3.0% | Mid | NMVOC | 1784.8 | 2354.0 | 3026.6 | 3708.2 |
| 3.0% | High (95th perc.) | NMVOC | 4700.9 | 6239.5 | 8128.4 | 9880.4 |
| 5.0% | Low (5th perc.) | NMVOC | 145.3 | 220.7 | 321.3 | 430.0 |
| 5.0% | Mid | NMVOC | 915.2 | 1294.8 | 1776.4 | 2304.6 |
| 5.0% | High (95th perc.) | NMVOC | 2238.2 | 3288.9 | 4706.8 | 6217.6 |
| 2.5% | Low (5th perc.) | NOx | 398.2 | 529.3 | 683.5 | 821.8 |
| 2.5% | Mid | NOx | 2259.9 | 2906.1 | 3651.5 | 4388.5 |
| 2.5% | High (95th perc.) | NOx | 6060.0 | 7832.5 | 9876.4 | 11715.4 |
| 3.0% | Low (5th perc.) | NOx | 311.7 | 429.1 | 568.5 | 701.2 |
| 3.0% | Mid | NOx | 1784.8 | 2354.0 | 3026.6 | 3708.2 |
| 3.0% | High (95th perc.) | NOx | 4700.9 | 6239.5 | 8128.4 | 9880.4 |
| 5.0% | Low (5th perc.) | NOx | 145.3 | 220.7 | 321.3 | 430.0 |
| 5.0% | Mid | NOx | 915.2 | 1294.8 | 1776.4 | 2304.6 |
| 5.0% | High (95th perc.) | NOx | 2238.2 | 3288.9 | 4706.8 | 6217.6 |
| 2.5% | Low (5th perc.) | SO2 | 389.3 | 517.5 | 668.2 | 803.4 |
| 2.5% | Mid | SO2 | 2209.3 | 2840.9 | 3569.6 | 4290.1 |
| 2.5% | High (95th perc.) | SO2 | 5924.1 | 7656.8 | 9654.9 | 11452.7 |
| 3.0% | Low (5th perc.) | SO2 | 303.6 | 418.0 | 553.8 | 683.1 |
| 3.0% | Mid | SO2 | 1738.7 | 2293.2 | 2948.4 | 3612.4 |
| 3.0% | High (95th perc.) | SO2 | 4579.4 | 6078.3 | 7918.4 | 9625.2 |
| 5.0% | Low (5th perc.) | SO2 | 140.0 | 212.6 | 309.4 | 414.0 |
| 5.0% | Mid | SO2 | 881.3 | 1246.8 | 1710.5 | 2219.1 |
| 5.0% | High (95th perc.) | SO2 | 2155.1 | 3166.9 | 4532.2 | 5987.0 |
| 2.5% | Low (5th perc.) | NH3 | 398.2 | 529.3 | 683.5 | 821.8 |
| 2.5% | Mid | NH3 | 2259.9 | 2906.1 | 3651.5 | 4388.5 |
| 2.5% | High (95th perc.) | NH3 | 6060.0 | 7832.5 | 9876.4 | 11715.4 |
| 3.0% | Low (5th perc.) | NH3 | 311.7 | 429.1 | 568.5 | 701.2 |
| 3.0% | Mid | NH3 | 1784.8 | 2354.0 | 3026.6 | 3708.2 |
| 3.0% | High (95th perc.) | NH3 | 4700.9 | 6239.5 | 8128.4 | 9880.4 |
| 5.0% | Low (5th perc.) | NH3 | 145.3 | 220.7 | 321.3 | 430.0 |
| 5.0% | Mid | NH3 | 915.2 | 1294.8 | 1776.4 | 2304.6 |
| 5.0% | High (95th perc.) | NH3 | 2238.2 | 3288.9 | 4706.8 | 6217.6 |

### SM1 – References

AEA Technology (2022). The Chemistry of Atmospheric Pollutants, <https://www.slb.nu/e/chem.htm>, accessed 5th December 2022.

Interagency Working Group on Social Cost of Greenhouse Gases (2021). Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990.

Szopa, S., V. Naik, B. Adhikary, P. Artaxo, T. Berntsen, W. D. Collins, S. Fuzzi, L. Gallardo, A. Kiendler Scharr, Z. Klimont, H. Liao, N. Unger and P. Zanis (2021). Short-Lived Climate Forcers. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani et al., Cambridge University Press.

United States Agency for Toxic Substances and Disease Registry (2022). Toxic Substances Portal, <https://wwwn.cdc.gov/TSP/index.aspx>, accessed 5th December 2022