Supporting Information

Global warming from refrigerant HFCs is underestimated by their CO_2 equivalent emissions within the century

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Supporting Information

Miranda et al. - How reporting HFC emissions can misrepresent their atmospheric warming.

Supporting Information A: HFC lifetimes, GWPs and emissions

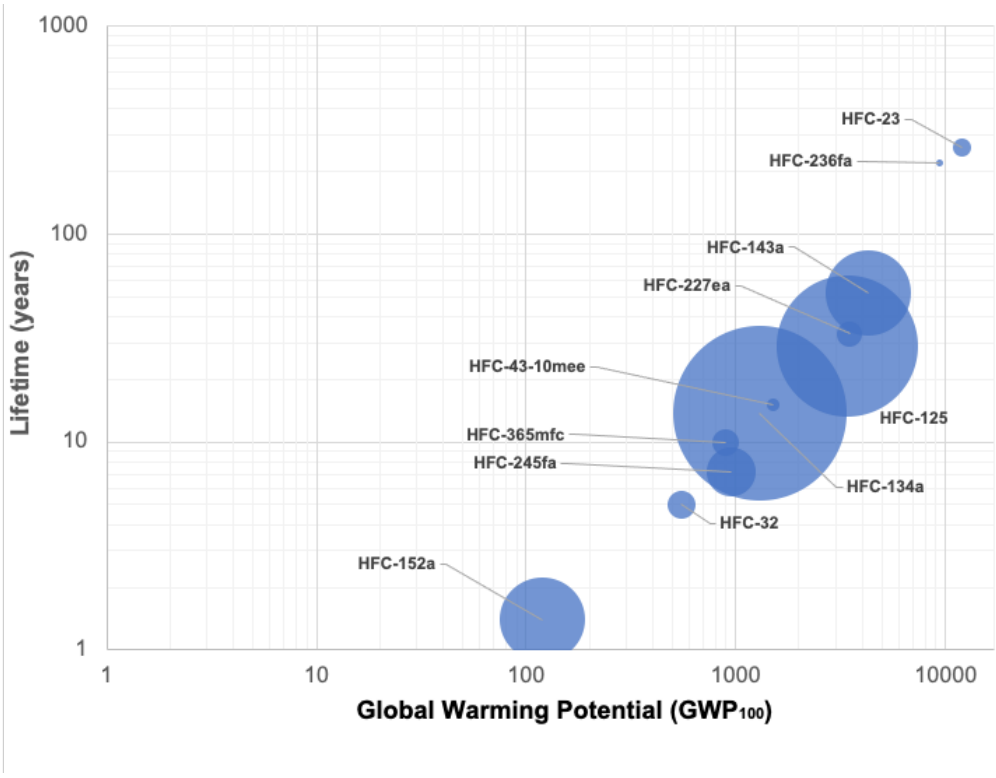

Figure S1. Global warming potential (GWP_{100}), lifetime (logarithmic scale) and emissions of 2020 (area of circles), for common hydrofluorocarbons (HFCs) used as refrigerants. Source: IPCC (1) and FaIR 2.0 (SSP Pathways) (2).

Table S1. Global warming potential (GWP_{100}), lifetime, and emissions reported for different years as per SSP 245 (2).

Industrial designation	**Chemical name (common name)** (3)	**GWP_{100}**	**Lifetime [years]** (1)	**Emissions [Gg/year]** (2)				
				1990	2000	2010	2020	2025[1]
HFC-125	Pentafluoroethane	3,230	29	0.96	10.64	35.07	176.65	201.93
HFC-134a	1,1,1,2-tetrafluoroethane	1,290	13.8	1.72	99.66	165.04	267.17	240.08
HFC-143a	1,1,1-trifluoroethane	4,820	52	0.70	8.60	20.46	64.34	72.88
HFC-152a	1,1-difluoroethane	146	1.4	2.38	21.40	59.88	63.48	50.48
HFC-227ea	1,1,1,2,3,3,3-heptafluoropropane	3,000	33	0.19	0.86	3.18	5.67	5.55
HFC-23	Trifluoromethane (fluoroform)	11,900	260	6.68	9.30	11.24	2.69	1.62
HFC-236fa	1,1,1,3,3,3-hexafluoropropane	7,230	220	1.36Í10^{-4}	0.14	0.28	0.48	0.54
HFC-245fa	1,1,1,3,3-pentafluoropropane	841	7.2	0.00	0.03	8.78	21.61	24.30
HFC-32	Difluoromethane	682	5.0	0.03	1.41	15.91	7.18	4.33
HFC-365mfc	1,1,1,3,3-pentafluorobutane	785	9.9	0.02	0.27	3.31	6.15	5.53
HFC-43-10mee	1,1,1,2,2,3,4,5,5,5-decafluoropentane	1,420	15	0.09	0.57	1.34	1.30	1.04

[1] Interpolation of SSP 245 Pathway between years 2020 and 2030.

Supporting Information B: Full set of results for each of the HFCs examined in Case B (Reducing 100% of each HFC from 2025 onwards).

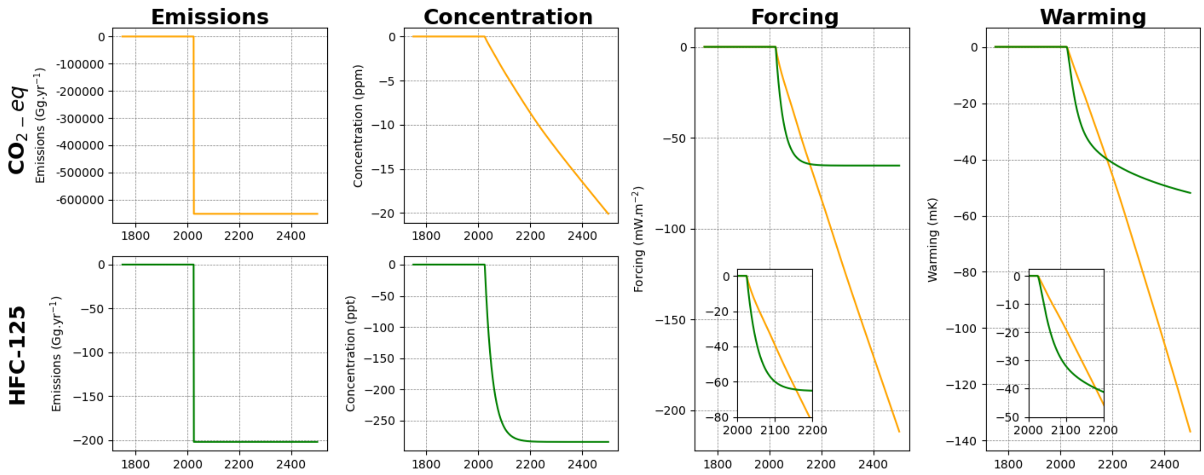

Figure B1. Case B – A step change 100% reduction in HFC-125 emissions (green) from 2025 onwards, of the equivalent CO_2 emissions (orange) with GWP_{100} of 3,230 and resulting effect on atmospheric concentration, radiative forcing, and temperature. Subplots of forcing and warming are magnified results between 2000 and 2200.

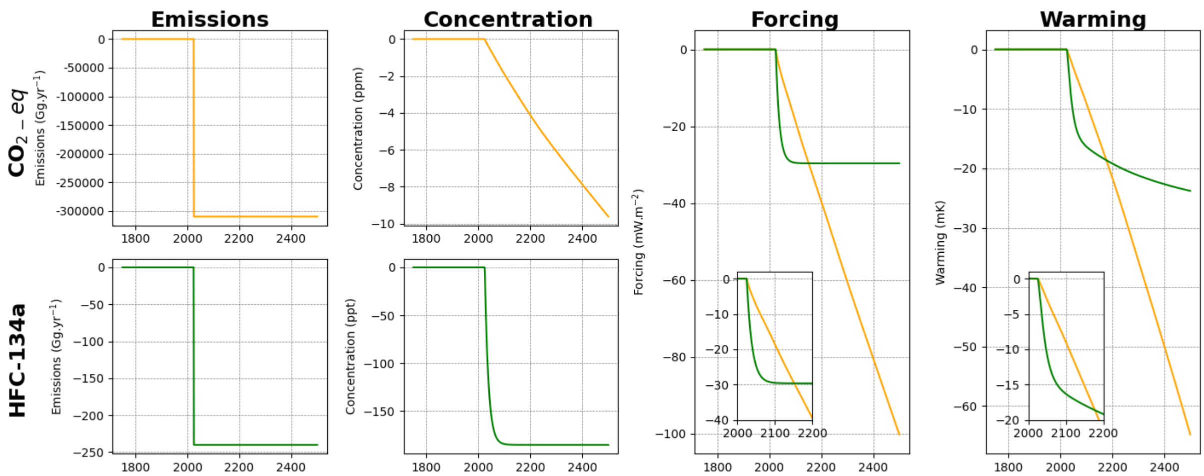

Figure B2. Case B – A step change 100% reduction in HFC-134a emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 1,290; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

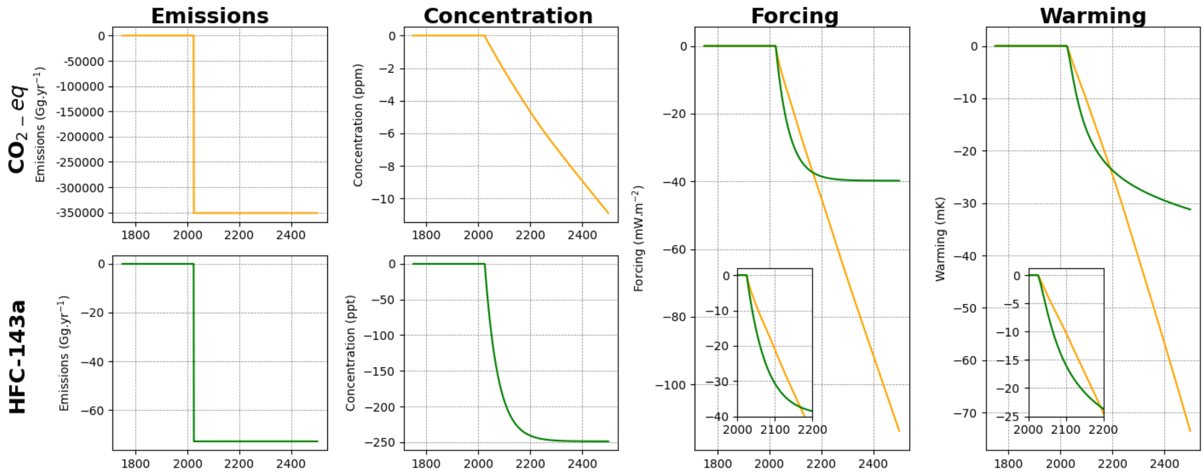

Figure B3. Case B – A step change 100% reduction in HFC-143a emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 4,820; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

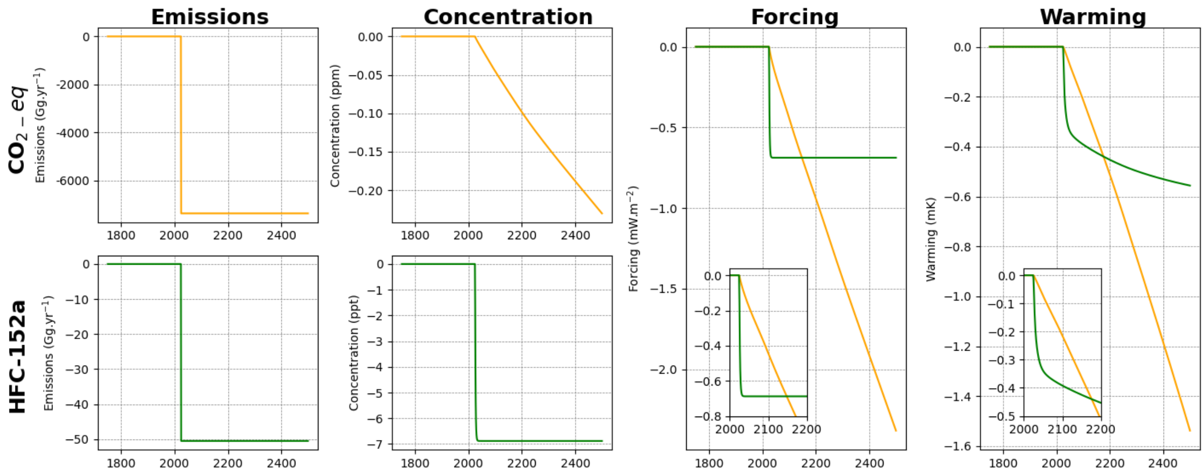

Figure B4. Case B – A step change 100% reduction in HFC-152a emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 146; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

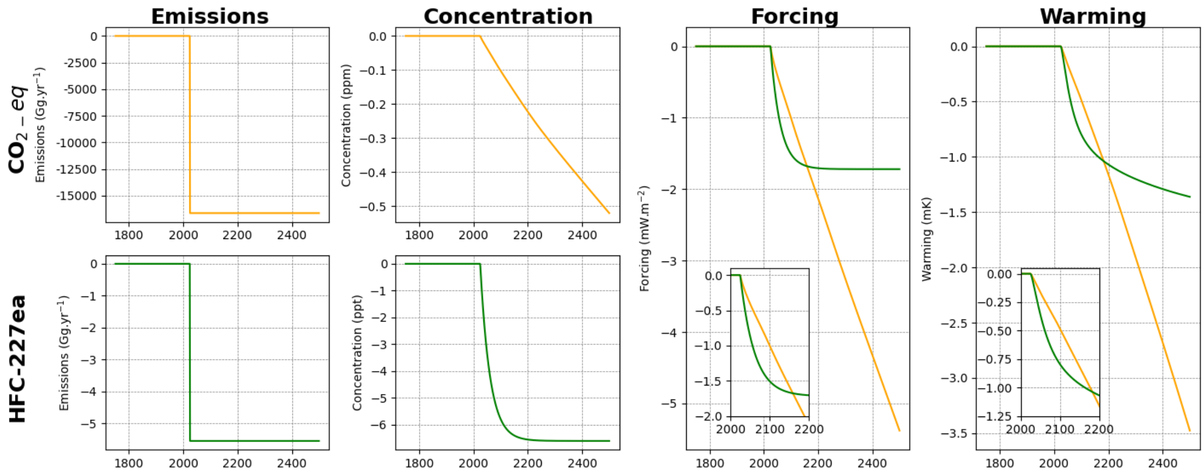

Figure B5. Case B – A step change 1% reduction in HFC-227ea emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 3,000; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

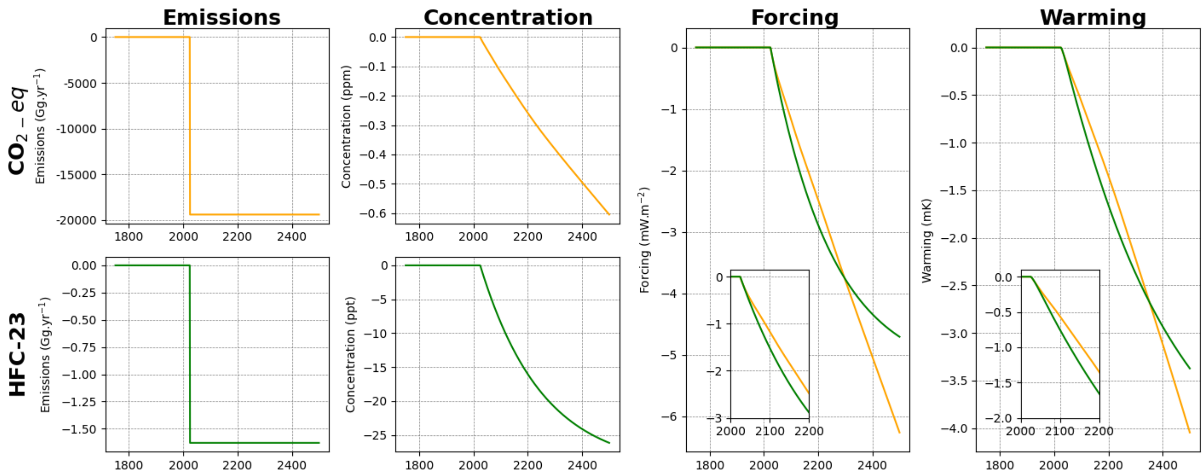

Figure B6. Case B – A step change 100% reduction in HFC-23 emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 11,900; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

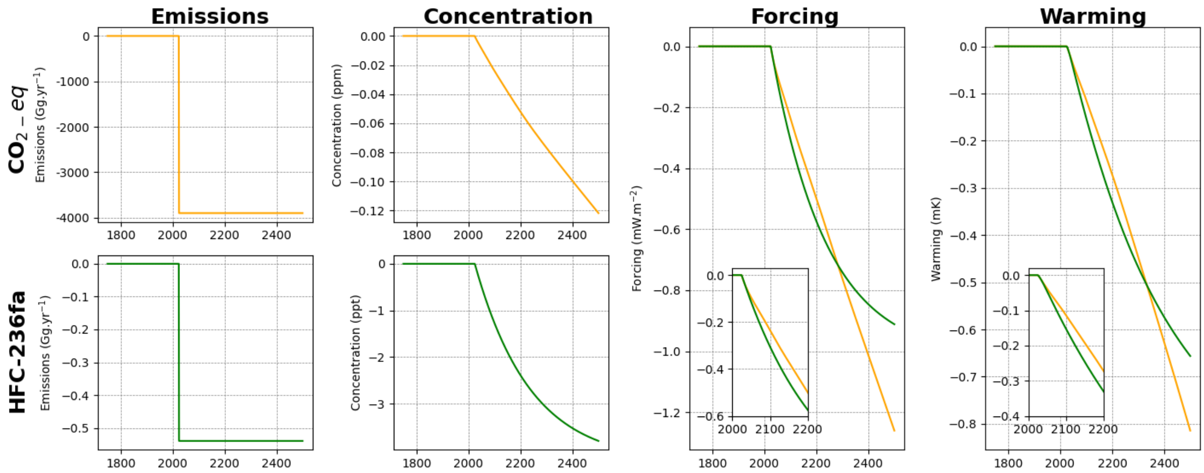

Figure B7. Case B – A step change 100% reduction in HFC-236fa emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 7,230; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

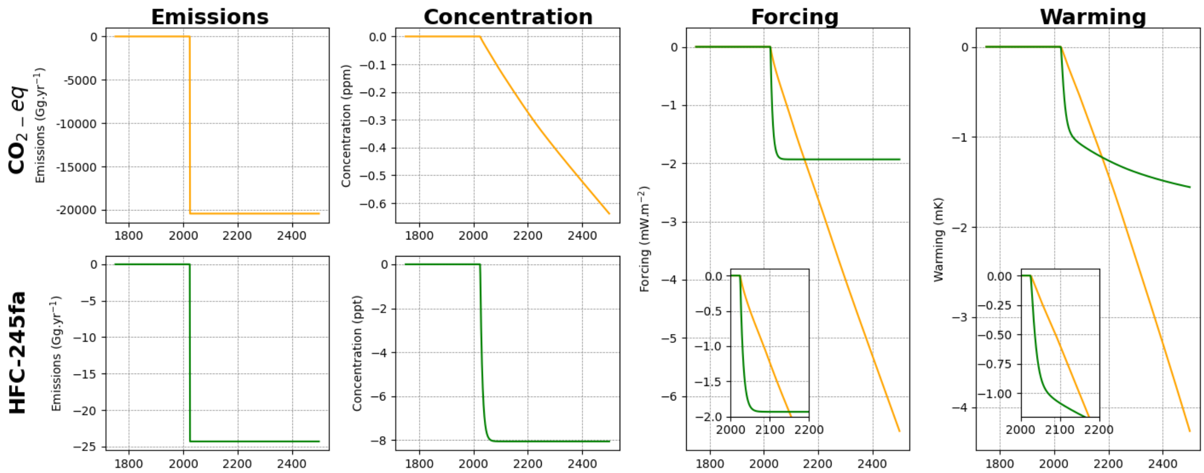

Figure B8. Case B – A step change 100% reduction in HFC-245fa emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 841; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

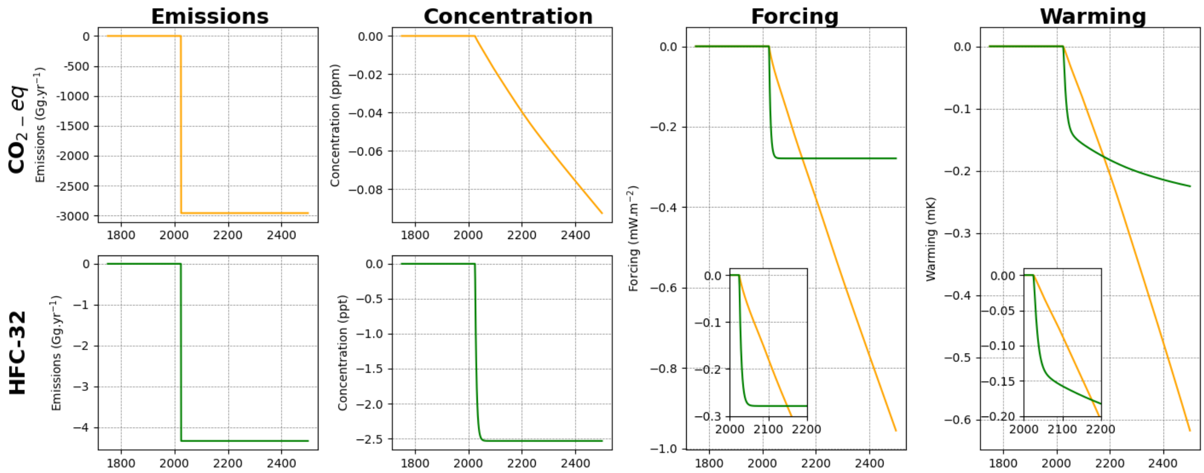

Figure B9. Case B – A step change 100% reduction in HFC-32 emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 682; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

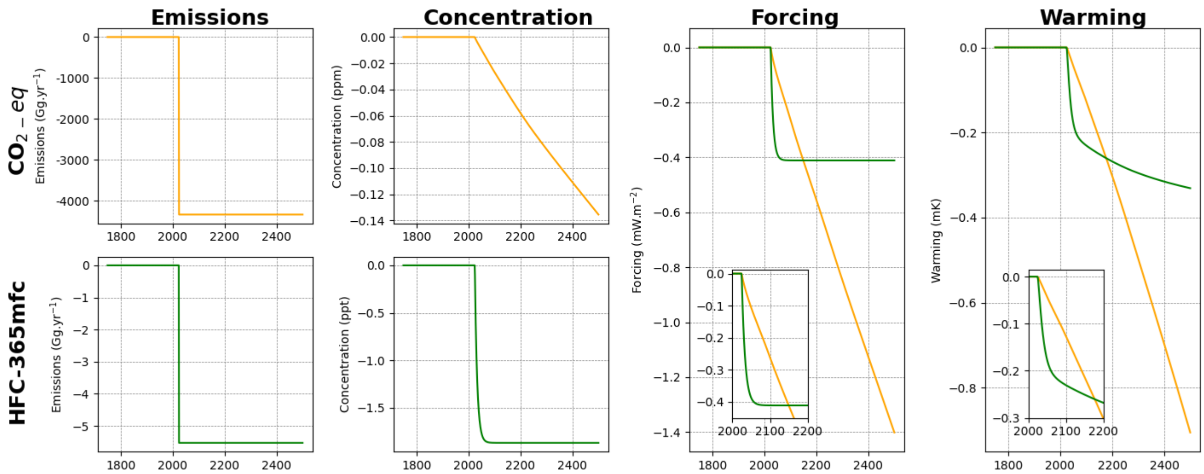

Figure B10. Case B – A step change 100% reduction in HFC-365mfc emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 785; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

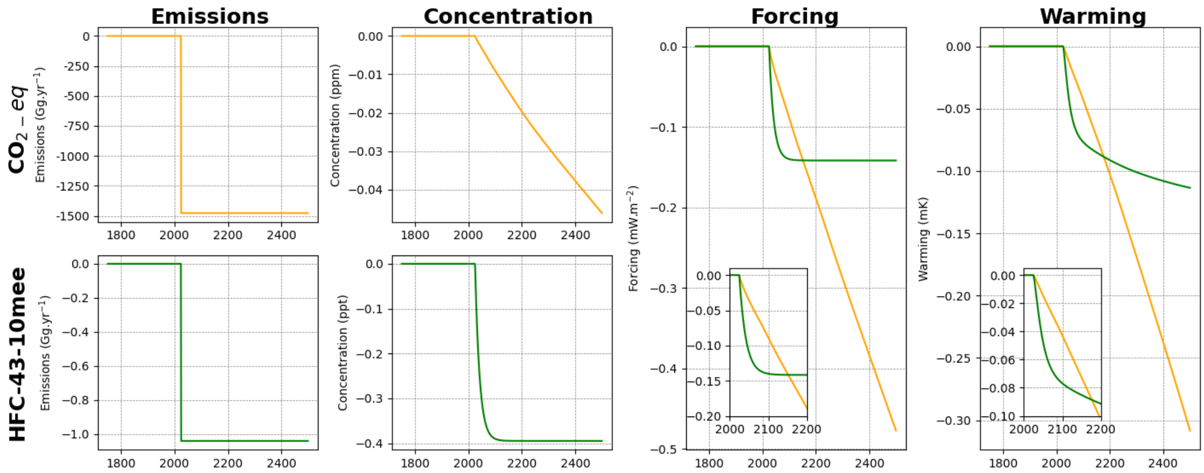

Figure B11. Case B – A step change 100% reduction in HFC43-10mee emissions (green) from 2025, of the equivalent CO_2 emissions (orange) with GWP_{100} of 1,420; and resulting effect on atmospheric concentration, radiative forcing, and temperature.

Table S2. Avoided warming from eliminating HFC emissions - in percentages with respect to maximum avoidance (assumed to be reached in 2500).

HFC	Lifetime (years)	2030	2050	2070	2100	2200	2500
Short-lived (<20 yr)							
HFC-152a	1.4	35	61	66	71	82	100
HFC-32	5	20	58	65	70	81	100
HFC-245fa	7.2	16	55	65	70	81	100
HFC-365mfc	9.9	14	53	64	70	81	100
HFC-134a	13.8	10	46	61	69	81	100
HFC-4310mee	15	8	42	58	68	81	100
Long-lived (>200yr)							
HFC-236fa	220	1	7	14	23	50	100
HFC-23	260	1	7	13	22	49	100
Others							
HFC-125	29	5	30	47	62	79	100
HFC-227ea	33	4	27	43	59	79	100
HFC-143a	52	3	21	35	51	76	100

*Red: 0-33%, Amber: 34-66%, Green: 67-100%, percentage calculated as avoided warming of HFCs in the specific year, divided by its warming in 2500.

Table S3. Individual contributions of HFCs to warming (in mK) for specific years when reduced by a 100% step-change in 2025.

	2030		2050		2500	
HFC Name	**HFC**	**CO2**	**HFC**	**CO2**	**HFC**	**CO2**
HFC-125	-2.60	-1.10	-15.7	-6.49	-51.9	-1.36E+02
HFC-134a	-2.33	-0.52	-10.9	-3.08	-23.8	-6.4.6
HFC-143a	-0.96	-0.59	-6.43	-3.50	-31.2	-73.3
HFC-245fa	-0.24	-3.45E-02	-0.86	-0.20	-1.56	-4.27
HFC-152a	-0.19	-1.25E-02	-0.34	-7.34E-02	-0.56	-1.54
HFC-227ea	-5.7E-02	-2.81E-02	-0.36	-0.17	-1.36	-3.47
HFC-365mfc	-4.7E-02	-7.34E-03	-0.18	-4.3E-02	-0.33	-0.91
HFC-32	-4.5E-02	-5.01E-03	-0.13	-3.0E-02	-0.23	-0.62
HFC-23	-3.0E-02	-3.27E-02	-0.23	-0.193	-3.37	-4.05
HFC-4310mee	-9.4E-03	-2.50E-03	-4.77E-02	-1.5E-02	-0.11	-0.31
HFC-236fa	-6.1E-03	-6.61E-03	-4.62E-02	-3.9E-02	-0.66	-0.81

Additional references.

1. Ehhalt D, Prather M. 2001. Atmospheric Chemistry and Greenhouse Gases. *Clim. Chang. 2001 Sci. Basis*, pp. 239–87

2. Leach NJ, Jenkins S, Nicholls Z, Smith CJ, Lynch J, et al. 2021. FaIRv2.0.0: a generalized impulse response model for climate uncertainty and future scenario exploration. *Geosci. Model Dev.* 14(5):3007–36

3. GOV.UK. *Calculate the carbon dioxide equivalent quantity of an F gas*. https://www.gov.uk/guidance/calculate-the-carbon-dioxide-equivalent-quantity-of-an-f-gas