Supplementary Data for

Considering the interplay between sectoral co-emissions of warmers, coolers, and their lifespans can improve the design of climate change mitigation policies

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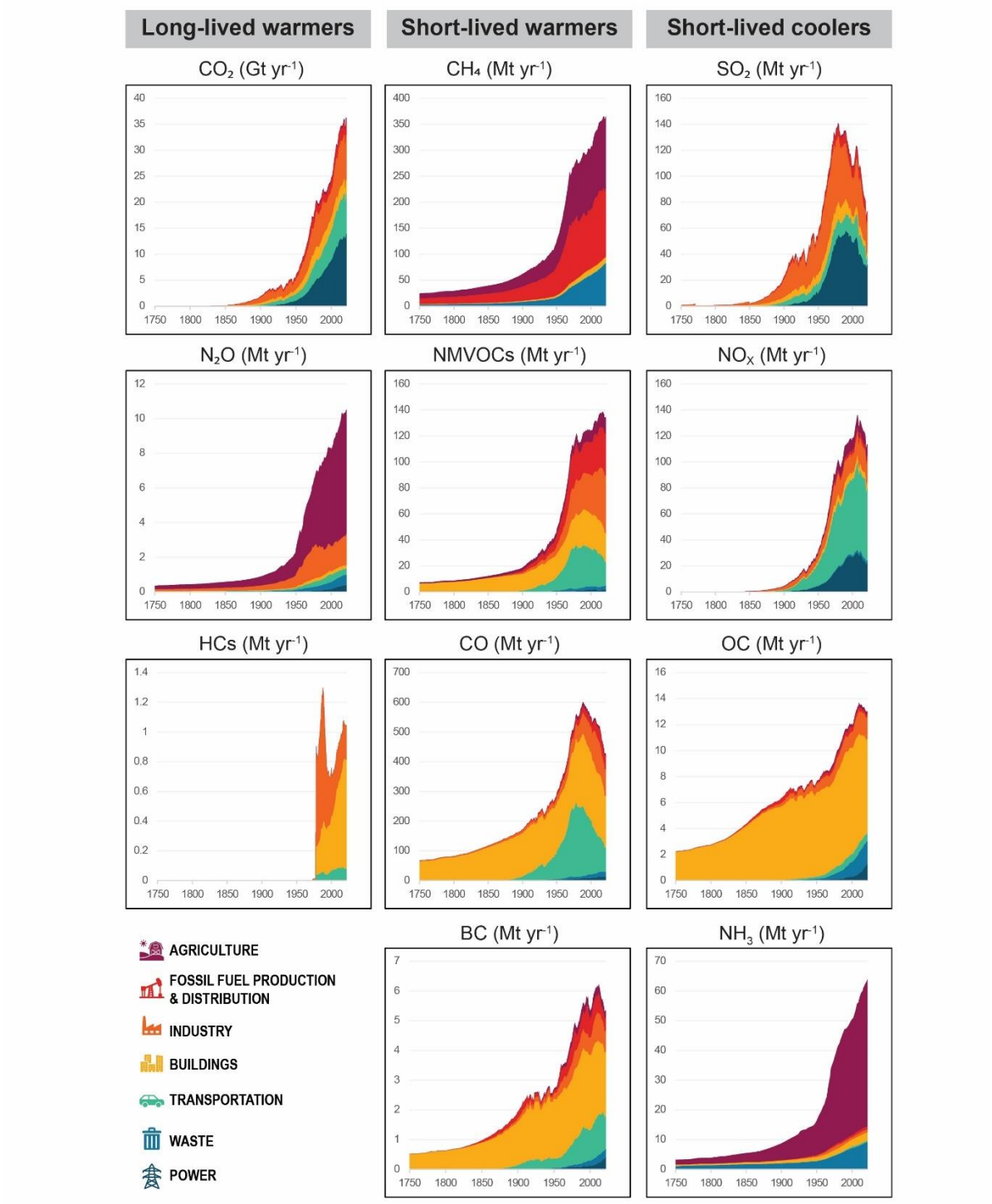

Figure S1. Annual anthropogenic emissions by species, colored by sector, since 1750. Note differing scales. Not all HCs are long-lived. Power refers to power generation. Biomass burning and land-use change emissions not included.

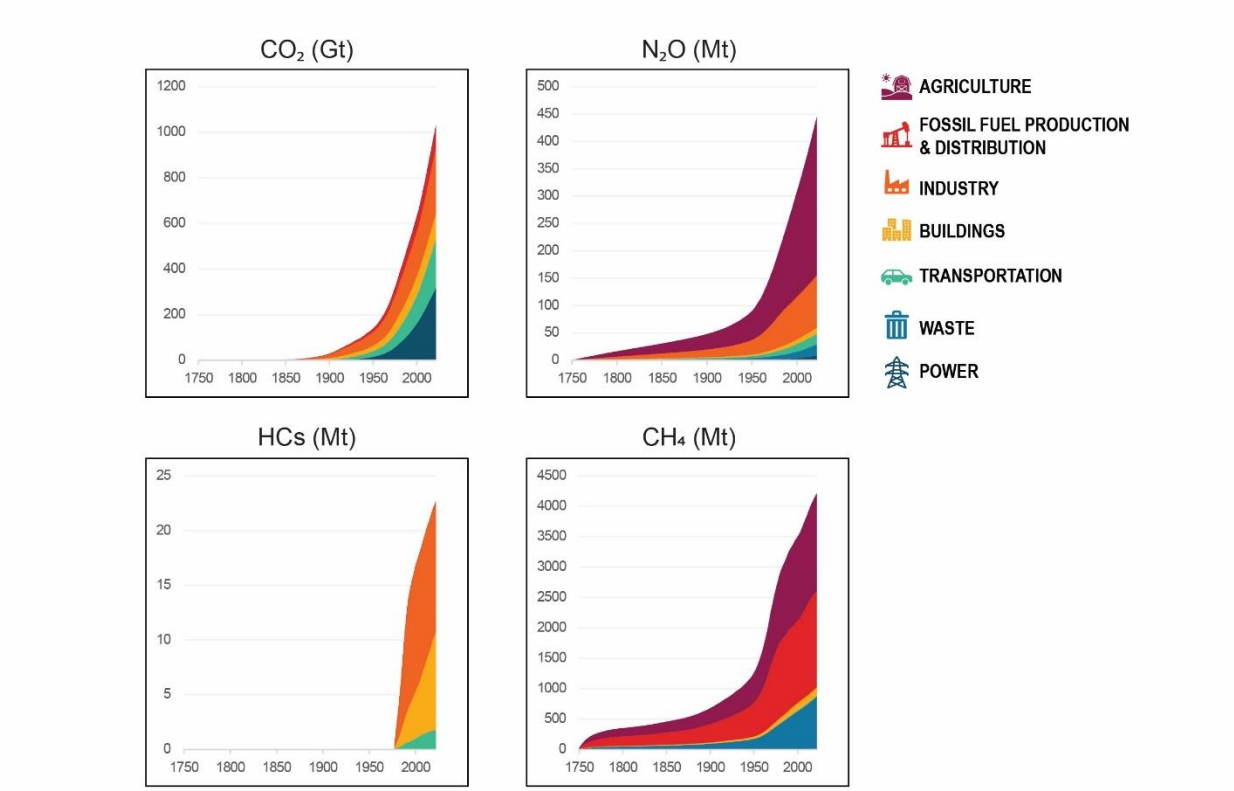

Figure S2. Accumulated anthropogenic emissions by species, colored by sector, since 1750. Note differing scales. See Methods for description of calculations. All other species considered in this study are assumed to not accumulate as they have lifetimes of less than one year. Power refers to power generation. Biomass burning and land-use change emissions not included.

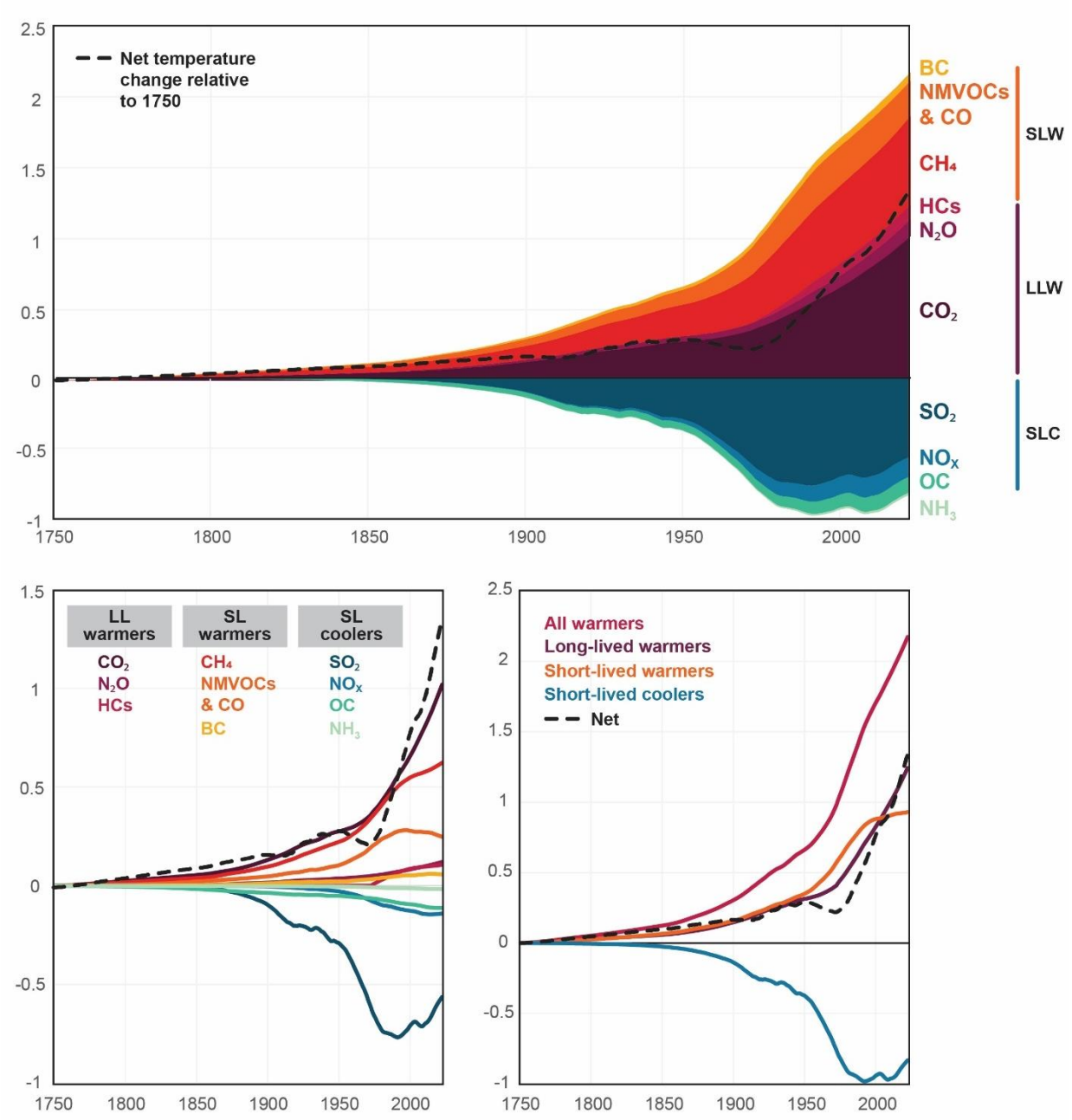

Figure S3. Surface temperature changes 1750-2022 from anthropogenic emissions, by species. LLW is long-lived warmers; SLW is short-lived warmers; SLC is short-lived coolers. Temperature impacts from biomass burning and land-use change emissions not included.

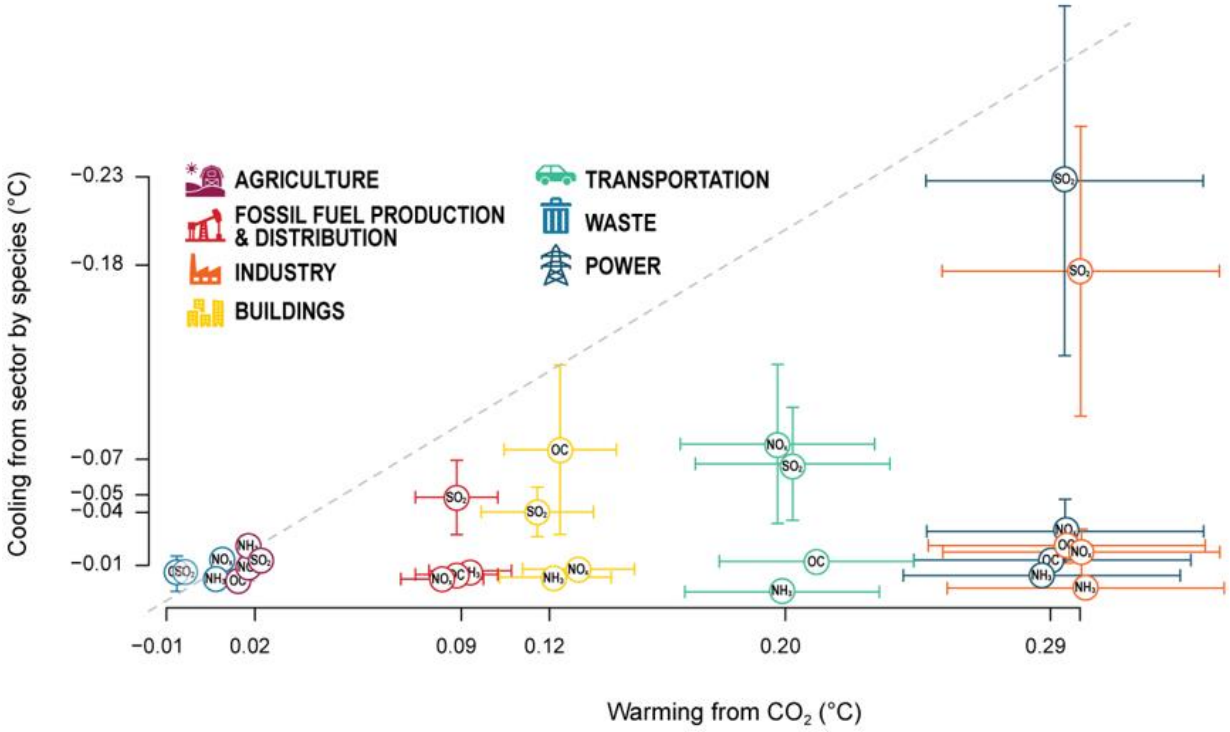

Figure S4. Correlation between current warming from accumulated CO2 and cooling from emissions of coolers, by sector and cooling emission species. 1:1 line between CO2-driven warming and gross cooling shown. Lowest warming from CO2 is the waste sector, with an estimated 0.001 deg C. Error bars represent one standard deviation. Tick marks on graph refer to points specifically. Power refers to power generation. Biomass burning and land-use change emissions not included.

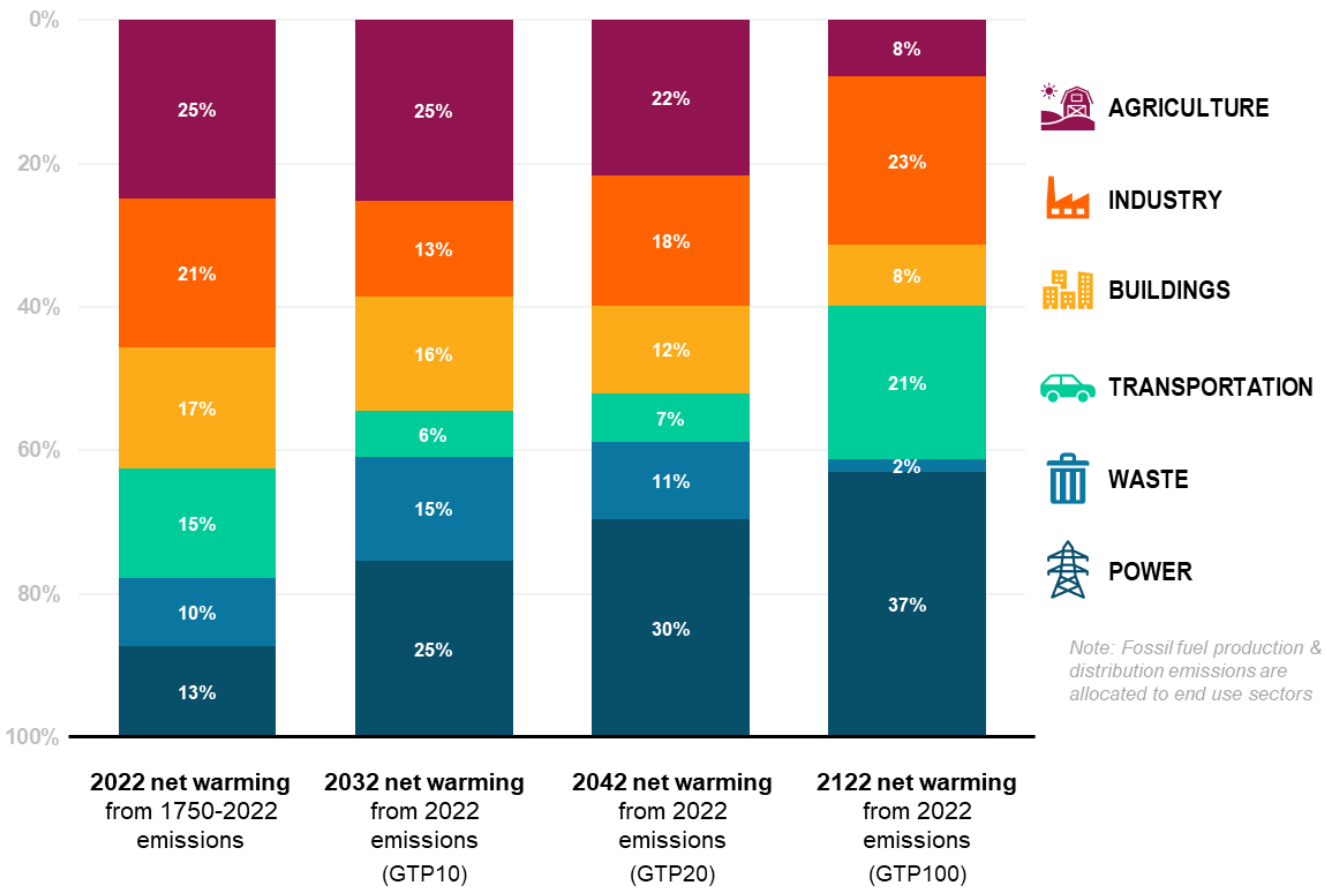

Figure S5. Sectoral shares contributing to current and future net warming from historical emissions and current present-day emissions, respectively (including both warmers and coolers). Future climate change impacts calculated using global temperature change potentials with time horizons of 10, 20, and 100 years (see Table S6 for values used for each species). Fossil fuel production and distribution (FFPD) emissions allocated to end sectors for this analysis. See Figure 4 for the same projection with FFPD incorporated. Power refers to power generation. Biomass burning and land-use change emissions not included.

Table S1. Surface temperature changes (ºC) from each sector and species, including FFPD. Note not all HCs are long-lived. Power refers to power generation. Temperature impacts from biomass burning and land-use change emissions not included.

			Agriculture	FFPD	Industry	Buildings	Transportation	Waste	Power	Species Total
Warmers	Long-lived species	CO_2	0.02	0.09	0.3	0.1	0.2	0.0007	0.3	1
		N_2O	0.08	0.0003	0.03	0.003	0.005	0.005	0.002	0.1
		HC	0	0	0.06	0.04	0.008	0	0	0.1
	Short-lived species	CH_4	0.2	0.2	0.002	0.02	0.003	0.1	0.002	0.6
		NMVOC&CO	0.004	0.02	0.05	0.1	0.06	0.008	0.006	0.2
		BC	0.003	0.005	0.008	0.02	0.01	0.003	0.003	0.06
Coolers		SO_2	-0.005	-0.05	-0.2	-0.03	-0.07	-0.001	-0.2	-0.6
		NO_X	-0.01	-0.004	-0.02	-0.006	-0.07	-0.003	-0.03	-0.1
		OC	-0.002	-0.002	-0.01	-0.07	-0.005	-0.01	-0.008	-0.1
		NH_3	-0.01	-0.0003	-0.0003	-0.0008	-0.0001	-0.002	-0.0001	-0.02
Sector totals		**Net impact**	0.3	0.3	0.2	0.2	0.1	0.1	0.05	1.3
		Net %	23%	22%	16%	15%	11%	9%	4%	
		Warming	0.3	0.4	0.4	0.3	0.3	0.1	0.3	2.2
		Warming %	16%	16%	20%	14%	13%	6%	14%	
		Cooling	-0.03	-0.05	-0.2	-0.1	-0.1	-0.02	-0.3	-0.83
		Cooling %	4%	7%	26%	13%	17%	2%	31%	

Table S2: Standard deviations for temperature changes (ºC) in Table S1 for each sector and species, including FFPD.

	Agriculture	**FFPD**	**Industry**	**Buildings**	**Transportation**	**Waste**	**Power**
CO_2	0.002	0.01	0.05	0.02	0.03	0	0.05
N_2O	0.02	0	0.008	0.001	0.002	0.002	0.001
HC	0	0	0.03	0.02	0.004	0	0
CH_4	0.05	0.05	0	0.004	0.001	0.03	0
NMVOC&CO	0.001	0.007	0.02	0.04	0.02	0.003	0.002
BC	0.005	0.009	0.01	0.04	0.02	0.005	0.005
SO_2	0.002	0.02	0.08	0.01	0.03	0.001	0.1
NO_X	0.007	0.003	0.01	0.004	0.05	0.002	0.02
OC	0.001	0.002	0.01	0.05	0.004	0.01	0.005
NH_3	0.002	0	0	0	0	0	0

Table S3: Surface temperature changes (ºC) from each sector and species, but reallocating FFPD to the other six sectors. Power refers to power generation. Temperature impacts from biomass burning and land-use change emissions not included.

			Agriculture	Industry	Buildings	Transportation	Waste	Power	Species Total
Warmers	Long-lived species	CO_2	0.03	0.3	0.1	0.2	0.005	0.3	1
		N_2O	0.08	0.03	0.003	0.005	0.005	0.002	0.1
		HCs	0	0.06	0.04	0.008	0	0	0.1
Coolers	Short-lived species	CH_4	0.3	0.05	0.03	0.03	0.1	0.1	0.6
		NMVOC&CO	0.007	0.05	0.1	0.07	0.009	0.01	0.2
		BC	0.003	0.009	0.03	0.01	0.003	0.005	0.06
		SO_2	-0.009	-0.2	-0.03	-0.08	-0.002	-0.2	-0.6
		NO_X	-0.01	-0.02	-0.006	-0.07	-0.003	-0.03	-0.1
		OC	-0.002	-0.01	-0.07	-0.006	-0.01	-0.008	-0.1
		NH_3	-0.01	0	-0.001	0	-0.002	0	-0.02
Sector totals		**Net impact**	0.3	0.3	0.2	0.2	0.1	0.2	1.3
		Net %	25%	21%	17%	15%	9%	14%	
		Warming	0.4	0.5	0.3	0.3	0.1	0.5	2.2
		Warming %	17%	24%	15%	16%	7%	21%	
		Cooling	-0.04	-0.2	-0.1	-0.2	-0.02	-0.3	-0.83
		Cooling %	4%	28%	13%	19%	3%	34%	

Table S4: Standard deviations for temperature changes (ºC) in Table S3 for each sector and species, partitioning out FFPD

	Agriculture	**Industry**	**Buildings**	**Transportation**	**Waste**	**Power**
CO_2	0.004	0.05	0.02	0.04	0.001	0.05
N_2O	0.02	0.008	0.001	0.002	0.002	0.001
HCs	0	0.03	0.02	0.004	0	0
CH_4	0.06	0.01	0.007	0.006	0.03	0.03
NMVOC&CO	0.002	0.02	0.04	0.02	0.003	0.004
BC	0.005	0.02	0.04	0.02	0.005	0.009
SO_2	0.004	0.09	0.02	0.04	0.001	0.1
NO_X	0.007	0.01	0.004	0.05	0.002	0.02
OC	0.001	0.01	0.05	0.004	0.01	0.006
NH_3	0.002	0	0	0	0	0

Table S5. Global Temperature change Potential (GTP) values for Figure 4.

	GTP10	GTP20	GTP100	Sources
CO_2	1	1	1	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR6 Table 7.15
N_2O	254	277	233	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR6 Table 7.15
HCs (HFC-134a)	5000	3160	306	GTP10: Aamaas et al (2013) GTP20: Hodnebrog et al (2020) GTP100: AR6 7.SM.7
CH_4 fossil	115	68	8	GTP10: AR5 8.SM.17 GTP20: AR5 8.A.1 GTP100: AR6 Table 7.15
CH_4 non-fossil	100	67	5	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR6 Table 7.15
NMVOC	20	10	0.8	GTP10: Collins et al (2013) GTP20: Åström & Johansson (2019) GTP100: Åström & Johansson (2019)
CO	7	4	0.3	GTP10: AR5 8.SM.16 GTP20: AR5 8.SM.16 GTP100: AR5 8.SM.16
BC	2398	703	91	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR5 8.SM.17
SO2	-140	-41	-5	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR5 8.SM.17
NOX	3	-86	-3	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR5 8.SM.17
OC	-242	-71	-9	GTP10: AR5 8.SM.17 GTP20: AR5 8.SM.17 GTP100: AR5 8.SM.17
NH3	-74	-23	-3	GTP10: Aamaas et al (2013) GTP20: AR5 8.SM.18 GTP100: AR5 8.SM.18

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