New York State Department of Environmental Conservation

DAR Technical Guidance Memo

Title: Climate Leadership and Community Protection Act (CLCPA) and Permit Applications	
Date Developed: 09/01/2020	**Last Date Revised: 09/01/2020**
Previous Revision Dates:	
Initiated By: Mark Lanzafame P.E. / Bureau of Stationary Sources	
Approved By:	

Purpose: DAIG-11 requires all applications for new air state facility (ASF) and Title V (ATV) permits and significant modifications to ASF and ATV permits to be evaluated in accordance with the Climate Leadership and Community Protection Act (CLCPA). Chapter 106 of the Laws of 2019, effective January 1, 2020. This technical guidance memo discusses the information that should be included in the analysis, and DEC staff's evaluation of that information. This technical guidance is meant to provide DEC staff with internal guidance on evaluating CLCPA in permitting actions and does not supersede or in any way affect the requirements and responsibilities of either the DEC or permit applicant to comply with CLCPA and other applicable laws.

Guidance: When issuing permits, Section 7(2) of CLCPA requires all state agencies to consider "whether such decisions are inconsistent with, or will interfere with, the attainment of the statewide greenhouse gas (GHG) emission limits established in Article 75 of the environmental conservation law." Such limits require a Statewide reduction in GHG emissions from 1990 levels of 40% by 2030 and 85% by 2050. For purposes of the CLCPA, Statewide GHG emissions include "upstream" out-of-state GHG emissions associated with the generation of electricity imported into the State, or the extraction and transmission of fossil fuel imported into the State.

To make this determination, DEC needs to request an objective analysis of the GHG and carbon dioxide equivalent (CO2e) emissions from the project, including any "upstream" out-of-state emissions known to be attributable to the project, and a description of any proposed mitigation measures from the facility owner or operator. It is important to note that the CLCPA review is independent from other reviews (e.g. New Source Review, Part 212). The facility owner or operator may state that mitigation measures employed to comply with other applicable requirements will also influence emissions subject to CLCPA, but the requirement to complete another regulatory review is not a valid reason to avoid CLCPA review.

Each CLCPA analysis should include calculations showing the project's potential GHG and CO2e emissions, particularly in the years 2030 and 2050 if possible. CO2e should be calculated using the 20-year global warming potentials found in Appendix 8.A: Lifetimes, Radiative Efficiencies and Metric Values of *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth*

Assessment Report of the Intergovernmental Panel on Climate Change (pp. 731-740). A copy of this table is included as Appendix A to this document. The calculations should at least reflect all aspects of the project, including any GHG emissions that may result from the operation of control equipment and exempt activities. In the case of a facility that handles a fossil fuel for energy production, generation, transmission, or storage, this should include "upstream" out-of-state emissions associated with the fuel combusted or utilized at the facility. The analysis may also include an assessment of projected changes in Statewide emissions as a result of the project, such as in the case of a power plant projected to result in a change in net Statewide emissions.

If the facility concludes that GHG emissions, expressed in CO2e, will increase as a result of the project, including any "upstream" or other indirect emissions known to be attributable to the project, an explanation of that increase and any proposed mitigation measures or alternatives should be included. Acceptable mitigation measures will depend on the particulars of the project. If the facility concludes that further mitigation of the emissions is not possible and that the alternatives considered are not feasible, a detailed justification for each item should be included. It is not acceptable for the facility to provide a general "further mitigation is not possible" statement or a simple "it is what it is" statement. Finally, if the project will result in a decrease in GHG or CO2e emissions, that should be highlighted in the analysis.

In addition to the GHG requirements outlined above, Section 7(3) of CLCPA requires that all state agencies shall "prioritize reductions of GHG emissions and co-pollutants in disadvantaged communities". Co-pollutants are defined as hazardous air pollutants (HAPs) emitted by GHG sources. To address this requirement, the facility should provide calculations and a discussion of mitigation measures for any co-pollutants as discussed above. Like the GHG analysis above, acceptable mitigation methods will depend on the particulars of the project, but they may include items such as add-on controls, periodic equipment tune-ups, firing less emissive fuels, and other similar items. Unlike GHG emissions, it is possible that the facility is already required to minimize co-pollutant emissions (e.g. by Part 212). In that situation, it is acceptable for the facility to discuss the existing mitigation measures and explain that further reductions are not feasible.

DEC will evaluate the applicant's information based on adherence to the requirements of CLCPA, as well as any additional regulatory requirements or guidance that may be issued after the effective date of this technical guidance. If a facility has satisfied the requirements of CLCPA and any attendant requirements, a brief discussion of the CLCPA analysis for both GHG and co-pollutants described above should be included in the project description portion of the DEC permit. Additionally, a similar discussion should be included in the basis for monitoring section of the permit review report (PRR) for Title V facilities. The discussion should indicate that the facility submitted a CLCPA analysis and has undergone DEC evaluation in accordance with Sections 7(2) and (3) of CLCPA. If additional mitigation measures are proposed by the applicant, they should be discussed. If additional mitigation is not possible, a brief discussion as to why mitigation is not possible should be included.

Condition for Expiration of TGM: This TGM does not expire unless changes are made to the Department's approach to implementing CLCPA, or new requirements addressing CLCPA reviews are promulgated.

Appendix 8.A: Lifetimes, Radiative Efficiencies and Metric Values

Table 8.A.1 | Radiative efficiencies (REs), lifetimes/adjustment times, AGWP and GWP values for 20 and 100 years, and AGTP and GTP values for 20, 50 and 100 years. Climate–carbon feedbacks are included for CO_2 while no climate feedbacks are included for the other components (see discussion in Sections 8.7.1.4 and 8.7.2.1, Supplementary Material and notes below the table; Supplementary Material Table 8.SM.16 gives analogous values including climate–carbon feedbacks for non-CO_2 emissions). For a complete list of chemical names and CAS numbers, and for accurate replications of metric values, see Supplementary Material Section 8.SM.13 and references therein.

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
Carbon dioxide	CO_2	see*	1.37e-5	2.49e-14	**1**	9.17e-14	**1**	6.84e-16	**1**	6.17e-16	**1**	5.47e-16	**1**
Methane	CH_4	12.4†	3.63e-4	2.09e-12	**84**	2.61e-12	**28**	4.62e-14	**67**	8.69e-15	**14**	2.34e-15	**4**
Fossil methane‡	CH_4	12.4†	3.63e-4	2.11e-12	**85**	2.73e-12	**30**	4.68e-14	**68**	9.55e-15	**15**	3.11e-15	**6**
Nitrous Oxide	N_2O	121†	3.00e-3	6.58e-12	**264**	2.43e-11	**265**	1.89e-13	**277**	1.74e-13	**282**	1.28e-13	**234**
Chlorofluorocarbons													
CFC-11	CCl_3F	45.0	0.26	1.72e-10	**6900**	4.28e-10	**4660**	4.71e-12	**6890**	3.01e-12	**4890**	1.28e-12	**2340**
CFC-12	CCl_2F_2	100.0	0.32	2.69e-10	**10,800**	9.39e-10	**10,200**	7.71e-12	**11,300**	6.75e-12	**11,000**	4.62e-12	**8450**
CFC-13	$CClF_3$	640.0	0.25	2.71e-10	**10,900**	1.27e-09	**13,900**	7.99e-12	**11,700**	8.77e-12	**14,200**	8.71e-12	**15,900**
CFC-113	CCl_2FCClF_2	85.0	0.30	1.62e-10	**6490**	5.34e-10	**5820**	4.60e-12	**6730**	3.85e-12	**6250**	2.45e-12	**4470**
CFC-114	$CClF_2CClF_2$	190.0	0.31	1.92e-10	**7710**	7.88e-10	**8590**	5.60e-12	**8190**	5.56e-12	**9020**	4.68e-12	**8550**
CFC-115	$CClF_2CF_3$	1,020.0	0.20	1.46e-10	**5860**	7.03e-10	**7670**	4.32e-12	**6310**	4.81e-12	**7810**	4.91e-12	**8980**
Hydrochlorofluorocarbons													
HCFC-21	$CHCl_2F$	1.7	0.15	1.35e-11	**543**	1.35e-11	**148**	1.31e-13	**192**	1.59e-14	**26**	1.12e-14	**20**
HCFC-22	$CHClF_2$	11.9	0.21	1.32e-10	**5280**	1.62e-10	**1760**	2.87e-12	**4200**	5.13e-13	**832**	1.43e-13	**262**
HCFC-122	$CHCl_2CF_2Cl$	1.0	0.17	5.43e-12	**218**	5.43e-12	**59**	4.81e-14	**70**	6.25e-15	**10**	4.47e-15	**8**
HCFC-122a	$CHFClCFCl_2$	3.4	0.21	2.36e-11	**945**	2.37e-11	**258**	2.91e-13	**426**	2.99e-14	**48**	1.96e-14	**36**
HCFC-123	$CHCl_2CF_3$	1.3	0.15	7.28e-12	**292**	7.28e-12	**79**	6.71e-14	**98**	8.45e-15	**14**	6.00e-15	**11**
HCFC-123a	$CHClFCF_2Cl$	4.0	0.23	3.37e-11	**1350**	3.39e-11	**370**	4.51e-13	**659**	4.44e-14	**72**	2.81e-14	**51**
HCFC-124	$CHClFCF_3$	5.9	0.20	4.67e-11	**1870**	4.83e-11	**527**	7.63e-13	**1120**	7.46e-14	**121**	4.03e-14	**74**
HCFC-132c	CH_2FCFCl_2	4.3	0.17	3.07e-11	**1230**	3.10e-11	**338**	4.27e-13	**624**	4.14e-14	**67**	2.58e-14	**47**
HCFC-141b	CH_3CCl_2F	9.2	0.16	6.36e-11	**2550**	7.17e-11	**782**	1.27e-12	**1850**	1.67e-13	**271**	6.09e-14	**111**
HCFC-142b	CH_3CClF_2	17.2	0.19	1.25e-10	**5020**	1.82e-10	**1980**	3.01e-12	**4390**	8.46e-13	**1370**	1.95e-13	**356**
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.22	1.17e-11	**469**	1.17e-11	**127**	1.17e-13	**170**	1.38e-14	**22**	9.65e-15	**18**
HCFC-225cb	$CHClFCF_2CClF_2$	5.9	0.29	4.65e-11	**1860**	4.81e-11	**525**	7.61e-13	**1110**	7.43e-14	**120**	4.01e-14	**73**
(E)-1-Chloro-3,3,3-trifluoroprop-1-ene	trans-CF_3CH=$CHCl$	26.0 days	0.04	1.37e-13	**5**	1.37e-13	**1**	1.09e-15	**2**	1.54e-16	**<1**	1.12e-16	**<1**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
Hydrofluorocarbons													
HFC-23	CHF_3	222.0	0.18	2.70e-10	**10,800**	1.14e-09	**12,400**	7.88e-12	**11,500**	7.99e-12	**13,000**	6.95e-12	**12,700**
HFC-32	CH_2F_2	5.2	0.11	6.07e-11	**2430**	6.21e-11	**677**	9.32e-13	**1360**	8.93e-14	**145**	5.17e-14	**94**
HFC-41	CH_3F	2.8	0.02	1.07e-11	**427**	1.07e-11	**116**	1.21e-13	**177**	1.31e-14	**21**	8.82e-15	**16**
HFC-125	CHF_2CF_3	28.2	0.23	1.52e-10	**6090**	2.91e-10	**3170**	3.97e-12	**5800**	1.84e-12	**2980**	5.29e-13	**967**
HFC-134	CHF_2CHF_2	9.7	0.19	8.93e-11	**3580**	1.02e-10	**1120**	1.82e-12	**2660**	2.54e-13	**412**	8.73e-14	**160**
HFC-134a	CH_2FCF_3	13.4	0.16	9.26e-11	**3710**	1.19e-10	**1300**	2.09e-12	**3050**	4.33e-13	**703**	1.10e-13	**201**
HFC-143	CH_2FCHF_2	3.5	0.13	3.00e-11	**1200**	3.01e-11	**328**	3.76e-13	**549**	3.82e-14	**62**	2.49e-14	**46**
HFC-143a	CH_3CF_3	47.1	0.16	1.73e-10	**6940**	4.41e-10	**4800**	4.76e-12	**6960**	3.12e-12	**5060**	1.37e-12	**2500**
HFC-152	CH_2FCH_2F	0.4	0.04	1.51e-12	**60**	1.51e-12	**16**	1.25e-14	**18**	1.71e-15	**3**	1.24e-15	**2**
HFC-152a	CH_3CHF_2	1.5	0.10	1.26e-11	**506**	1.26e-11	**138**	1.19e-13	**174**	1.47e-14	**24**	1.04e-14	**19**
HFC-161	CH_3CH_2F	66.0 days	0.02	3.33e-13	**13**	3.33e-13	**4**	2.70e-15	**4**	3.76e-16	**<1**	2.74e-16	**<1**
HFC-227ca	$CF_3CF_2CHF_2$	28.2	0.27	1.27e-10	**5080**	2.42e-10	**2640**	3.31e-12	**4830**	1.53e-12	**2480**	4.41e-13	**806**
HFC-227ea	CF_3CHFCF_3	38.9	0.26	1.34e-10	**5360**	3.07e-10	**3350**	3.61e-12	**5280**	2.12e-12	**3440**	7.98e-13	**1460**
HFC-236cb	$CH_2FCF_2CF_3$	13.1	0.23	8.67e-11	**3480**	1.11e-10	**1210**	1.94e-12	**2840**	3.92e-13	**636**	1.01e-13	**185**
HFC-236ea	CHF_2CHFCF_3	11.0	0.30[a]	1.03e-10	**4110**	1.22e-10	**1330**	2.18e-12	**3190**	3.53e-13	**573**	1.06e-13	**195**
HFC-236fa	$CF_3CH_2CF_3$	242.0	0.24	1.73e-10	**6940**	7.39e-10	**8060**	5.06e-12	**7400**	5.18e-12	**8400**	4.58e-12	**8380**
HFC-245ca	$CH_2FCF_2CHF_2$	6.5	0.24[b]	6.26e-11	**2510**	6.56e-11	**716**	1.07e-12	**1570**	1.09e-13	**176**	5.49e-14	**100**
HFC-245cb	$CF_3CF_2CH_3$	47.1	0.24	1.67e-10	**6680**	4.24e-10	**4620**	4.58e-12	**6690**	3.00e-12	**4870**	1.32e-12	**2410**
HFC-245ea	$CHF_2CHFCHF_2$	3.2	0.16[c]	2.15e-11	**863**	2.16e-11	**235**	2.59e-13	**378**	2.70e-14	**44**	1.79e-14	**33**
HFC-245eb	$CH_2FCHFCF_3$	3.1	0.20[c]	2.66e-11	**1070**	2.66e-11	**290**	3.15e-13	**460**	3.31e-14	**54**	2.20e-14	**40**
HFC-245fa	$CHF_2CH_2CF_3$	7.7	0.24	7.29e-11	**2920**	7.87e-11	**858**	1.35e-12	**1970**	1.51e-13	**245**	6.62e-14	**121**
HFC-263fb	$CH_3CH_2CF_3$	1.2	0.10[c]	6.93e-12	**278**	6.93e-12	**76**	6.31e-14	**92**	8.02e-15	**13**	5.70e-15	**10**
HFC-272ca	$CH_3CF_2CH_3$	2.6	0.07	1.32e-11	**530**	1.32e-11	**144**	1.46e-13	**213**	1.61e-14	**26**	1.09e-14	**20**
HFC-329p	$CHF_2CF_2CF_2CF_3$	28.4	0.31	1.13e-10	**4510**	2.16e-10	**2360**	2.94e-12	**4290**	1.37e-12	**2220**	3.96e-13	**725**
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.7	0.22	6.64e-11	**2660**	7.38e-11	**804**	1.30e-12	**1890**	1.62e-13	**262**	6.24e-14	**114**
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	16.1	0.42[b]	1.08e-10	**4310**	1.51e-10	**1650**	2.54e-12	**3720**	6.62e-13	**1070**	1.54e-13	**281**
HFC-1132a	$CH_2=CF_2$	4.0 days	0.004[d]	3.87e-15	**<1**	3.87e-15	**<1**	3.08e-17	**<1**	4.35e-18	**<1**	3.18e-18	**<1**
HFC-1141	$CH_2=CHF$	2.1 days	0.002[d]	1.54e-15	**<1**	1.54e-15	**<1**	1.23e-17	**<1**	1.73e-18	**<1**	1.27e-18	**<1**
(Z)-HFC-1225ye	$CF_3CF=CHF(Z)$	8.5 days	0.02	2.14e-14	**<1**	2.14e-14	**<1**	1.70e-16	**<1**	2.40e-17	**<1**	1.76e-17	**<1**
(E)-HFC-1225ye	$CF_3CF=CHF(E)$	4.9 days	0.01	7.25e-15	**<1**	7.25e-15	**<1**	5.77e-17	**<1**	8.14e-18	**<1**	5.95e-18	**<1**
(Z)-HFC-1234ze	$CF_3CH=CHF(Z)$	10.0 days	0.02	2.61e-14	**1**	2.61e-14	**<1**	2.08e-16	**<1**	2.93e-17	**<1**	2.14e-17	**<1**
HFC-1234yf	$CF_3CF=CH_2$	10.5 days	0.02	3.22e-14	**1**	3.22e-14	**<1**	2.57e-16	**<1**	3.62e-17	**<1**	2.65e-17	**<1**
(E)-HFC-1234ze	trans-$CF_3CH=CHF$	16.4 days	0.04	8.74e-14	**4**	8.74e-14	**<1**	6.98e-16	**<1**	9.82e-17	**<1**	7.18e-17	**<1**
(Z)-HFC-1336	$CF_3CH=CHCF_3(Z)$	22.0 days	0.07[d]	1.54e-13	**6**	1.54e-13	**2**	1.23e-15	**2**	1.73e-16	**<1**	1.26e-16	**<1**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
HFC-1243zf	$CF_3CH=CH_2$	7.0 days	0.01	1.37e-14	**1**	1.37e-14	**<1**	1.09e-16	**<1**	1.53e-17	**<1**	1.12e-17	**<1**
HFC-1345zfc	$C_2F_5CH=CH_2$	7.6 days	0.01	1.15e-14	**<1**	1.15e-14	**<1**	9.19e-17	**<1**	1.30e-17	**<1**	9.48e-18	**<1**
3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene	$C_4F_9CH=CH_2$	7.6 days	0.03	1.25e-14	**<1**	1.25e-14	**<1**	9.92e-17	**<1**	1.40e-17	**<1**	1.02e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene	$C_6F_{13}CH=CH_2$	7.6 days	0.03	9.89e-15	**<1**	9.89e-15	**<1**	7.87e-17	**<1**	1.11e-17	**<1**	8.12e-18	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene	$C_8F_{17}CH=CH_2$	7.6 days	0.03	8.52e-15	**<1**	8.52e-15	**<1**	6.79e-17	**<1**	9.57e-18	**<1**	7.00e-18	**<1**
Chlorocarbons and Hydrochlorocarbons													
Methyl chloroform	CH_3CCl_3	5.0	0.07	1.44e-11	**578**	1.47e-11	**160**	2.17e-13	**317**	2.07e-14	**34**	1.22e-14	**22**
Carbon tetrachloride	CCl_4	26.0	0.17	8.69e-11	**3480**	1.59e-10	**1730**	2.24e-12	**3280**	9.68e-13	**1570**	2.62e-13	**479**
Methyl chloride	CH_3Cl	1.0	0.01[a]	1.12e-12	**45**	1.12e-12	**12**	9.93e-15	**15**	1.29e-15	**2**	9.20e-16	**2**
Methylene chloride	CH_2Cl_2	0.4	0.03[b]	8.18e-13	**33**	8.18e-13	**9**	6.78e-15	**10**	9.26e-16	**2**	6.72e-16	**1**
Chloroform	$CHCl_3$	0.4	0.08	1.50e-12	**60**	1.50e-12	**16**	1.25e-14	**18**	1.70e-15	**3**	1.24e-15	**2**
1,2-Dichloroethane	CH_2ClCH_2Cl	65.0 days	0.01	8.24e-14	**3**	8.24e-14	**<1**	6.67e-16	**<1**	9.29e-17	**<1**	6.77e-17	**<1**
Bromocarbons, Hydrobromocarbons and Halons													
Methyl bromide	CH_3Br	0.8	0.004	2.16e-13	**9**	2.16e-13	**2**	1.87e-15	**3**	2.47e-16	**<1**	1.78e-16	**<1**
Methylene bromide	CH_2Br_2	0.3	0.01	9.31e-14	**4**	9.31e-14	**1**	7.66e-16	**1**	1.05e-16	**<1**	7.65e-17	**<1**
Halon-1201	$CHBrF_2$	5.2	0.15	3.37e-11	**1350**	3.45e-11	**376**	5.17e-13	**756**	4.96e-14	**80**	2.87e-14	**52**
Halon-1202	CBr_2F_2	2.9	0.27	2.12e-11	**848**	2.12e-11	**231**	2.43e-13	**356**	2.61e-14	**42**	1.75e-14	**32**
Halon-1211	$CBrClF_2$	16.0	0.29	1.15e-10	**4590**	1.60e-10	**1750**	2.70e-12	**3950**	6.98e-13	**1130**	1.62e-13	**297**
Halon-1301	$CBrF_3$	65.0	0.30	1.95e-10	**7800**	5.77e-10	**6290**	5.46e-12	**7990**	4.16e-12	**6750**	2.28e-12	**4170**
Halon-2301	CH_2BrCF_3	3.4	0.14	1.59e-11	**635**	1.59e-11	**173**	1.96e-13	**286**	2.01e-14	**33**	1.32e-14	**24**
Halon-2311 / Halothane	$CHBrClCF_3$	1.0	0.13	3.77e-12	**151**	3.77e-12	**41**	3.35e-14	**49**	4.34e-15	**7**	3.10e-15	**6**
Halon-2401	$CHFBrCF_3$	2.9	0.19	1.68e-11	**674**	1.68e-11	**184**	1.94e-13	**283**	2.07e-14	**34**	1.39e-14	**25**
Halon-2402	$CBrF_2CBrF_2$	20.0	0.31	8.59e-11	**3440**	1.35e-10	**1470**	2.12e-12	**3100**	7.08e-13	**1150**	1.66e-13	**304**
Fully Fluorinated Species													
Nitrogen trifluoride	NF_3	500.0	0.20	3.19e-10	**12,800**	1.47e-09	**16,100**	9.39e-12	**13,700**	1.02e-11	**16,500**	9.91e-12	**18,100**
Sulphur hexafluoride	SF_6	3,200.0	0.57	4.37e-10	**17,500**	2.16e-09	**23,500**	1.29e-11	**18,900**	1.47e-11	**23,800**	1.54e-11	**28,200**
(Trifluoromethyl) sulphur pentafluoride	SF_5CF_3	800.0	0.59	3.36e-10	**13,500**	1.60e-09	**17,400**	9.93e-12	**14,500**	1.10e-11	**17,800**	1.11e-11	**20,200**
Sulphuryl fluoride	SO_2F_2	36.0	0.20	1.71e-10	**6840**	3.76e-10	**4090**	4.58e-12	**6690**	2.55e-12	**4140**	9.01e-13	**1650**
PFC-14	CF_4	50,000.0	0.09	1.22e-10	**4880**	6.08e-10	**6630**	3.61e-12	**5270**	4.12e-12	**6690**	4.40e-12	**8040**
PFC-116	C_2F_6	10,000.0	0.25	2.05e-10	**8210**	1.02e-09	**11,100**	6.07e-12	**8880**	6.93e-12	**11,200**	7.36e-12	**13,500**
PFC-c216	$c\text{-}C_3F_6$	3,000.0	0.23[e]	1.71e-10	**6850**	8.44e-10	**9200**	5.06e-12	**7400**	5.74e-12	**9310**	6.03e-12	**11,000**
PFC-218	C_3F_8	2,600.0	0.28	1.66e-10	**6640**	8.16e-10	**8900**	4.91e-12	**7180**	5.56e-12	**9010**	5.83e-12	**10,700**
PFC-318	$c\text{-}C_4F_8$	3,200.0	0.32	1.77e-10	**7110**	8.75e-10	**9540**	5.25e-12	**7680**	5.96e-12	**9660**	6.27e-12	**11,500**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
PFC-31-10	C_4F_{10}	2,600.0	0.36	1.71e-10	**6870**	8.44e-10	**9200**	5.08e-12	**7420**	5.75e-12	**9320**	6.02e-12	**11,000**
Perfluorocyclopentene	c-C_5F_8	31.0 days	0.08[f]	1.71e-13	**7**	1.71e-13	**2**	1.37e-15	**2**	1.92e-16	**<1**	1.40e-16	**<1**
PFC-41-12	n-C_5F_{12}	4,100.0	0.41	1.58e-10	**6350**	7.84e-10	**8550**	4.69e-12	**6860**	5.33e-12	**8650**	5.62e-12	**10,300**
PFC-51-14	n-C_6F_{14}	3,100.0	0.44	1.47e-10	**5890**	7.26e-10	**7910**	4.35e-12	**6370**	4.94e-12	**8010**	5.19e-12	**9490**
PFC-61-16	n-C_7F_{16}	3,000.0	0.50	1.45e-10	**5830**	7.17e-10	**7820**	4.31e-12	**6290**	4.88e-12	**7920**	5.13e-12	**9380**
PFC-71-18	C_8F_{18}	3,000.0	0.55	1.42e-10	**5680**	6.99e-10	**7620**	4.20e-12	**6130**	4.76e-12	**7710**	5.00e-12	**9140**
PFC-91-18	$C_{10}F_{18}$	2,000.0	0.55	1.34e-10	**5390**	6.59e-10	**7190**	3.98e-12	**5820**	4.49e-12	**7290**	4.68e-12	**8570**
Perfluorodecalin (cis)	Z-$C_{10}F_{18}$	2,000.0	0.56	1.35e-10	**5430**	6.64e-10	**7240**	4.01e-12	**5860**	4.52e-12	**7340**	4.72e-12	**8630**
Perfluorodecalin (trans)	E-$C_{10}F_{18}$	2,000.0	0.48	1.18e-10	**4720**	5.77e-10	**6290**	3.48e-12	**5090**	3.93e-12	**6380**	4.10e-12	**7500**
PFC-1114	$CF_2=CF_2$	1.1 days	0.002	2.68e-16	**<1**	2.68e-16	**<1**	2.13e-18	**<1**	3.00e-19	**<1**	2.20e-19	**<1**
PFC-1216	$CF_3CF=CF_2$	4.9 days	0.01	6.42e-15	**<1**	6.42e-15	**<1**	5.11e-17	**<1**	7.21e-18	**<1**	5.27e-18	**<1**
Perfluorobuta-1,3-diene	$CF_2=CFCF=CF_2$	1.1 days	0.003	3.29e-16	**<1**	3.29e-16	**<1**	2.61e-18	**<1**	3.69e-19	**<1**	2.70e-19	**<1**
Perfluorobut-1-ene	$CF_3CF_2CF=CF_2$	6.0 days	0.02	8.38e-15	**<1**	8.38e-15	**<1**	6.67e-17	**<1**	9.41e-18	**<1**	6.88e-18	**<1**
Perfluorobut-2-ene	$CF_3CF=CFCF_3$	31.0 days	0.07	1.62e-13	**6**	1.62e-13	**2**	1.30e-15	**2**	1.82e-16	**<1**	1.33e-16	**<1**
Halogenated Alcohols and Ethers													
HFE-125	CHF_2OCF_3	119.0	0.41	3.10e-10	**12,400**	1.14e-09	**12,400**	8.91e-12	**13,000**	8.14e-12	**13,200**	5.97e-12	**10,900**
HFE-134 (HG-00)	CHF_2OCHF_2	24.4	0.44	2.90e-10	**11,600**	5.10e-10	**5560**	7.42e-12	**10,800**	3.02e-12	**4900**	7.83e-13	**1430**
HFE-143a	CH_3OCF_3	4.8	0.18	4.72e-11	**1890**	4.80e-11	**523**	6.95e-13	**1020**	6.66e-14	**108**	3.99e-14	**73**
HFE-227ea	$CF_3CHFOCF_3$	51.6	0.44	2.22e-10	**8900**	5.92e-10	**6450**	6.15e-12	**8980**	4.22e-12	**6850**	1.98e-12	**3630**
HCFE-235ca2 (enflurane)	CHF_2OCF_2CHFCl	4.3	0.41	5.30e-11	**2120**	5.35e-11	**583**	7.36e-13	**1080**	7.14e-14	**116**	4.44e-14	**81**
HCFE-235da2 (isoflurane)	$CHF_2OCHClCF_3$	3.5	0.42	4.49e-11	**1800**	4.50e-11	**491**	5.62e-13	**822**	5.72e-14	**93**	3.73e-14	**68**
HFE-236ca	$CHF_2OCF_2CHF_2$	20.8	0.56[g]	2.42e-10	**9710**	3.89e-10	**4240**	6.03e-12	**8820**	2.10e-12	**3400**	4.98e-13	**912**
HFE-236ea2 (desflurane)	$CHF_2OCHFCF_3$	10.8	0.45	1.39e-10	**5550**	1.64e-10	**1790**	2.93e-12	**4280**	4.64e-13	**753**	1.42e-13	**260**
HFE-236fa	$CF_3CH_2OCF_3$	7.5	0.36	8.35e-11	**3350**	8.98e-11	**979**	1.53e-12	**2240**	1.68e-13	**273**	7.54e-14	**138**
HFE-245cb2	$CF_3CF_2OCH_3$	4.9	0.33	5.90e-11	**2360**	6.00e-11	**654**	8.77e-13	**1280**	8.40e-14	**136**	4.99e-14	**91**
HFE-245fa1	$CHF_2CH_2OCF_3$	6.6	0.31	7.22e-11	**2900**	7.59e-11	**828**	1.25e-12	**1820**	1.27e-13	**206**	6.35e-14	**116**
HFE-245fa2	$CHF_2OCH_2CF_3$	5.5	0.36	7.25e-11	**2910**	7.45e-11	**812**	1.15e-12	**1670**	1.10e-13	**179**	6.21e-14	**114**
2,2,3,3,3-Pentafluoropropan-1-ol	$CF_3CF_2CH_2OH$	0.3	0.14	1.72e-12	**69**	1.72e-12	**19**	1.42e-14	**21**	1.95e-15	**3**	1.42e-15	**3**
HFE-254cb1	$CH_3OCF_2CHF_2$	2.5	0.26	2.76e-11	**1110**	2.76e-11	**301**	2.99e-13	**438**	3.34e-14	**54**	2.28e-14	**42**
HFE-263fb2	$CF_3CH_2OCH_3$	23.0 days	0.04	1.22e-13	**5**	1.22e-13	**1**	9.72e-16	**1**	1.37e-16	**<1**	9.98e-17	**<1**
HFE-263m1	$CF_3OCH_2CH_3$	0.4	0.13	2.70e-12	**108**	2.70e-12	**29**	2.25e-14	**33**	3.06e-15	**5**	2.22e-15	**4**
3,3,3-Trifluoropropan-1-ol	$CF_3CH_2CH_2OH$	12.0 days	0.02	3.57e-14	**1**	3.57e-14	**<1**	2.85e-16	**<1**	4.01e-17	**<1**	2.93e-17	**<1**
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$	22.5	0.53	1.68e-10	**6720**	2.81e-10	**3070**	4.23e-12	**6180**	1.59e-12	**2580**	3.93e-13	**718**
HFE-338mmz1	$(CF_3)_2CHOCHF_2$	21.2	0.44	1.48e-10	**5940**	2.40e-10	**2620**	3.70e-12	**5410**	1.31e-12	**2130**	3.14e-13	**575**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$	7.5	0.44	7.93e-11	**3180**	8.52e-11	**929**	1.45e-12	**2120**	1.60e-13	**259**	7.16e-14	**131**
Sevoflurane (HFE-347mmz1)	$(CF_3)_2CHOCH_2F$	2.2	0.32	1.98e-11	**795**	1.98e-11	**216**	2.06e-13	**302**	2.37e-14	**38**	1.64e-14	**30**
HFE-347mcc3 (HFE-7000)	$CH_3OCF_2CF_2CF_3$	5.0	0.35	4.78e-11	**1910**	4.86e-11	**530**	7.18e-13	**1050**	6.87e-14	**111**	4.05e-14	**74**
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$	6.6	0.42	7.45e-11	**2990**	7.83e-11	**854**	1.29e-12	**1880**	1.31e-13	**212**	6.55e-14	**120**
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	6.0	0.48[h]	7.86e-11	**3150**	8.15e-11	**889**	1.30e-12	**1900**	1.27e-13	**206**	6.81e-14	**124**
HFE-347mmy1	$(CF_3)_2CFOCH_3$	3.7	0.32	3.32e-11	**1330**	3.33e-11	**363**	4.27e-13	**624**	4.28e-14	**69**	2.76e-14	**51**
HFE-356mec3	$CH_3OCF_2CHFCF_3$	3.8	0.30	3.53e-11	**1410**	3.55e-11	**387**	4.60e-13	**673**	4.58e-14	**74**	2.94e-14	**54**
HFE-356mff2	$CF_3CH_2OCH_2CF_3$	105.0 days	0.17	1.54e-12	**62**	1.54e-12	**17**	1.26e-14	**18**	1.74e-15	**3**	1.26e-15	**2**
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$	5.7	0.37	6.40e-11	**2560**	6.59e-11	**719**	1.03e-12	**1500**	9.97e-14	**162**	5.50e-14	**101**
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$	3.5	0.38	4.08e-11	**1640**	4.09e-11	**446**	5.11e-13	**747**	5.20e-14	**84**	3.39e-14	**62**
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	3.8	0.32	3.77e-11	**1510**	3.79e-11	**413**	4.91e-13	**718**	4.89e-14	**79**	3.14e-14	**57**
HFE-356mmz1	$(CF_3)_2CHOCH_3$	97.1 days	0.15	1.25e-12	**50**	1.25e-12	**14**	1.02e-14	**15**	1.41e-15	**2**	1.02e-15	**2**
HFE-365mcf3	$CF_3CF_2CH_2OCH_3$	19.3 days	0.05	8.51e-14	**3**	8.51e-14	**<1**	6.80e-16	**<1**	9.56e-17	**<1**	6.99e-17	**<1**
HFE-365mcf2	$CF_3CF_2OCH_2CH_3$	0.6	0.26[i]	5.35e-12	**215**	5.35e-12	**58**	4.53e-14	**66**	6.10e-15	**10**	4.40e-15	**8**
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	5.0	0.30	5.65e-11	**2260**	5.75e-11	**627**	8.48e-13	**1240**	8.12e-14	**132**	4.79e-14	**88**
4,4,4-Trifluorobutan-1-ol	$CF_3(CH_2)_2CH_2OH$	4.0 days	0.01	1.73e-15	**<1**	1.73e-15	**<1**	1.38e-17	**<1**	1.94e-18	**<1**	1.42e-18	**<1**
2,2,3,3,4,4,5,5-Octafluorocyclopentanol	$-(CF_2)_4CH(OH)-$	0.3	0.16	1.18e-12	**47**	1.18e-12	**13**	9.67e-15	**14**	1.33e-15	**2**	9.69e-16	**2**
HFE-43-10pccc124 (H-Galden 1040x, HG-11)	$CHF_2OCF_2OC_2F_4OCHF_2$	13.5	1.02	2.00e-10	**8010**	2.58e-10	**2820**	4.52e-12	**6600**	9.46e-13	**1530**	2.38e-13	**436**
HFE-449s1 (HFE-7100)	$C_4F_9OCH_3$	4.7	0.36	3.80e-11	**1530**	3.86e-11	**421**	5.54e-13	**809**	5.32e-14	**86**	3.21e-14	**59**
n-HFE-7100	$n\text{-}C_4F_9OCH_3$	4.7	0.42	4.39e-11	**1760**	4.45e-11	**486**	6.39e-13	**934**	6.14e-14	**99**	3.70e-14	**68**
i-HFE-7100	$i\text{-}C_4F_9OCH_3$	4.7	0.35	3.68e-11	**1480**	3.73e-11	**407**	5.35e-13	**783**	5.14e-14	**83**	3.10e-14	**57**
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	0.8	0.30	5.21e-12	**209**	5.21e-12	**57**	4.52e-14	**66**	5.97e-15	**10**	4.29e-15	**8**
n-HFE-7200	$n\text{-}C_4F_9OC_2H_5$	0.8	0.35[i]	5.92e-12	**237**	5.92e-12	**65**	5.14e-14	**75**	6.78e-15	**11**	4.87e-15	**9**
i-HFE-7200	$i\text{-}C_4F_9OC_2H_5$	0.8	0.24	4.06e-12	**163**	4.06e-12	**44**	3.52e-14	**52**	4.65e-15	**8**	3.34e-15	**6**
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	25.0	0.65	2.75e-10	**11,000**	4.91e-10	**5350**	7.06e-12	**10,300**	2.94e-12	**4770**	7.75e-13	**1420**
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	12.9	0.86	2.10e-10	**8430**	2.67e-10	**2910**	4.69e-12	**6860**	9.28e-13	**1500**	2.42e-13	**442**
1,1,1,3,3,3-Hexafluoropropan-2-ol	$(CF_3)_2CHOH$	1.9	0.26	1.67e-11	**668**	1.67e-11	**182**	1.66e-13	**243**	1.97e-14	**32**	1.38e-14	**25**
HG-02	$HF_2C-(OCF_2CF_2)_2-OCF_2H$	12.9	1.24[i]	1.97e-10	**7900**	2.50e-10	**2730**	4.40e-12	**6430**	8.70e-13	**1410**	2.27e-13	**415**
HG-03	$HF_2C-(OCF_2CF_2)_3-OCF_2H$	12.9	1.76[i]	2.06e-10	**8270**	2.62e-10	**2850**	4.60e-12	**6730**	9.10e-13	**1480**	2.37e-13	**434**
HG-20	$HF_2C-(OCF_2)_2-OCF_2H$	25.0	0.92[i]	2.73e-10	**10,900**	4.86e-10	**5300**	7.00e-12	**10,200**	2.91e-12	**4730**	7.68e-13	**1400**
HG-21	$HF_2C-OCF_2CF_2OC-F_2OCF_2O-CF_2H$	13.5	1.71[i]	2.76e-10	**11,100**	3.57e-10	**3890**	6.23e-12	**9110**	1.31e-12	**2120**	3.29e-13	**602**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
HG-30	$HF_2C-(OCF_2)_3-OCF_2H$	25.0	1.65[i]	3.77e-10	**15,100**	6.73e-10	**7330**	9.68e-12	**14,100**	4.03e-12	**6530**	1.06e-12	**1940**
1-Ethoxy-1,1,2,2,3,3,3-heptafluoropropane	$CF_3CF_2CF_2OCH_2CH_3$	0.8	0.28[i]	5.56e-12	**223**	5.56e-12	**61**	4.80e-14	**70**	6.36e-15	**10**	4.57e-15	**8**
Fluoroxene	$CF_3CH_2OCH=CH_2$	3.6 days	0.01[i]	4.97e-15	**<1**	4.97e-15	**<1**	3.95e-17	**<1**	5.58e-18	**<1**	4.08e-18	**<1**
1,1,2,2-Tetrafluoro-1-(fluoromethoxy)ethane	$CH_2FOCF_2CF_2H$	6.2	0.34[i]	7.68e-11	**3080**	7.99e-11	**871**	1.29e-12	**1880**	1.28e-13	**207**	6.68e-14	**122**
2-Ethoxy-3,3,4,4,5-pentafluorotetrahydro-2,5-bis[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]-furan	$C_{12}H_5F_{19}O_2$	1.0	0.49[i]	5.09e-12	**204**	5.09e-12	**56**	4.53e-14	**66**	5.86e-15	**10**	4.19e-15	**8**
Fluoro(methoxy)methane	CH_3OCH_2F	73.0 days	0.07[g]	1.15e-12	**46**	1.15e-12	**13**	9.34e-15	**14**	1.30e-15	**2**	9.46e-16	**2**
Difluoro(methoxy)methane	CH_3OCHF_2	1.1	0.17[g]	1.32e-11	**528**	1.32e-11	**144**	1.18e-13	**173**	1.52e-14	**25**	1.08e-14	**20**
Fluoro(fluoromethoxy)methane	CH_2FOCH_2F	0.9	0.19[g]	1.20e-11	**479**	1.20e-11	**130**	1.05e-13	**153**	1.37e-14	**22**	9.84e-15	**18**
Difluoro(fluoromethoxy)methane	CH_2FOCHF_2	3.3	0.30[g]	5.65e-11	**2260**	5.66e-11	**617**	6.88e-13	**1010**	7.11e-14	**115**	4.69e-14	**86**
Trifluoro(fluoromethoxy)methane	CH_2FOCF_3	4.4	0.33[g]	6.82e-11	**2730**	6.89e-11	**751**	9.59e-13	**1400**	9.27e-14	**150**	5.72e-14	**105**
HG'-01	$CH_3OCF_2CF_2OCH_3$	2.0	0.29	2.03e-11	**815**	2.03e-11	**222**	2.06e-13	**301**	2.42e-14	**39**	1.68e-14	**31**
HG'-02	$CH_3O(CF_2CF_2O)_2CH_3$	2.0	0.56	2.16e-11	**868**	2.16e-11	**236**	2.19e-13	**320**	2.57e-14	**42**	1.79e-14	**33**
HG'-03	$CH_3O(CF_2CF_2O)_3CH_3$	2.0	0.76	2.03e-11	**812**	2.03e-11	**221**	2.05e-13	**299**	2.41e-14	**39**	1.67e-14	**31**
HFE-329me3	$CF_3CFHCF_2OCF_3$	40.0	0.48	1.79e-10	**7170**	4.17e-10	**4550**	4.85e-12	**7090**	2.89e-12	**4690**	1.12e-12	**2040**
3,3,4,4,5,5,6,6,7,7,7-Undecafluoroheptan-1-ol	$CF_3(CF_2)_4CH_2CH_2OH$	20.0 days	0.06	3.91e-14	**2**	3.91e-14	**<1**	3.12e-16	**<1**	4.39e-17	**<1**	3.21e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-Pentadecafluorononan-1-ol	$CF_3(CF_2)_6CH_2CH_2OH$	20.0 days	0.07	3.00e-14	**1**	3.00e-14	**<1**	2.40e-16	**<1**	3.37e-17	**<1**	2.46e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,11-Nonadecafluoroundecan-1-ol	$CF_3(CF_2)_8CH_2CH_2OH$	20.0 days	0.05	1.72e-14	**<1**	1.72e-14	**<1**	1.37e-16	**<1**	1.93e-17	**<1**	1.41e-17	**<1**
2-Chloro-1,1,2-trifluoro-1-methoxyethane	CH_3OCF_2CHFCl	1.4	0.21	1.12e-11	**449**	1.12e-11	**122**	1.05e-13	**153**	1.31e-14	**21**	9.24e-15	**17**
PFPMIE (perfluoropolymethylisopropyl ether)	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	800.0	0.65	1.87e-10	**7500**	8.90e-10	**9710**	5.52e-12	**8070**	6.11e-12	**9910**	6.15e-12	**11,300**
HFE-216	$CF_3OCF=CF_2$	8.4 days	0.02	1.92e-14	**<1**	1.92e-14	**<1**	1.53e-16	**<1**	2.15e-17	**<1**	1.58e-17	**<1**
Trifluoromethyl formate	$HCOOCF_3$	3.5	0.31[i]	5.37e-11	**2150**	5.39e-11	**588**	6.73e-13	**984**	6.85e-14	**111**	4.47e-14	**82**
Perfluoroethyl formate	$HCOOCF_2CF_3$	3.5	0.44[i]	5.30e-11	**2130**	5.32e-11	**580**	6.64e-13	**971**	6.76e-14	**110**	4.41e-14	**81**
Perfluoropropyl formate	$HCOOCF_2CF_2CF_3$	2.6	0.50[i]	3.45e-11	**1380**	3.45e-11	**376**	3.80e-13	**555**	4.19e-14	**68**	2.85e-14	**52**
Perfluorobutyl formate	$HCOOCF_2CF_2CF_2CF_3$	3.0	0.56[i]	3.59e-11	**1440**	3.59e-11	**392**	4.19e-13	**613**	4.45e-14	**72**	2.97e-14	**54**
2,2,2-Trifluoroethyl formate	$HCOOCH_2CF_3$	0.4	0.16[i]	3.07e-12	**123**	3.07e-12	**33**	2.55e-14	**37**	3.48e-15	**6**	2.52e-15	**5**
3,3,3-Trifluoropropyl formate	$HCOOCH_2CH_2CF_3$	0.3	0.13[i]	1.60e-12	**64**	1.60e-12	**17**	1.31e-14	**19**	1.80e-15	**3**	1.31e-15	**2**
1,2,2,2-Tetrafluoroethyl formate	$HCOOCHFCF_3$	3.2	0.35[i]	4.30e-11	**1720**	4.31e-11	**470**	5.17e-13	**755**	5.39e-14	**87**	3.57e-14	**65**
1,1,1,3,3,3-Hexafluoropropan-2-yl formate	$HCOOCH(CF_3)_2$	3.2	0.33[i]	3.05e-11	**1220**	3.05e-11	**333**	3.66e-13	**535**	3.81e-14	**62**	2.53e-14	**46**
Perfluorobutyl acetate	$CH_3COOCF_2CF_2CF_2CF_3$	21.9 days	0.12[i]	1.52e-13	**6**	1.52e-13	**2**	1.21e-15	**2**	1.71e-16	**<1**	1.25e-16	**<1**
Perfluoropropyl acetate	$CH_3COOCF_2CF_2CF_3$	21.9 days	0.11[i]	1.59e-13	**6**	1.59e-13	**2**	1.27e-15	**2**	1.78e-16	**<1**	1.30e-16	**<1**
Perfluoroethyl acetate	$CH_3COOCF_2CF_3$	21.9 days	0.10[i]	1.89e-13	**8**	1.89e-13	**2**	1.51e-15	**2**	2.12e-16	**<1**	1.55e-16	**<1**
Trifluoromethyl acetate	CH_3COOCF_3	21.9 days	0.07[i]	1.90e-13	**8**	1.90e-13	**2**	1.52e-15	**2**	2.14e-16	**<1**	1.56e-16	**<1**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
Methyl carbonofluoridate	$FCOOCH_3$	1.8	0.07[i]	8.74e-12	**350**	8.74e-12	**95**	8.60e-14	**126**	1.03e-14	**17**	7.21e-15	**13**
1,1-Difluoroethyl carbonofluoridate	$FCOOCF_2CH_3$	0.3	0.17[i]	2.46e-12	**99**	2.46e-12	**27**	2.02e-14	**30**	2.78e-15	**5**	2.02e-15	**4**
1,1-Difluoroethyl 2,2,2-trifluoroacetate	$CF_3COOCF_2CH_3$	0.3	0.27[i]	2.83e-12	**113**	2.83e-12	**31**	2.33e-14	**34**	3.20e-15	**5**	2.32e-15	**4**
Ethyl 2,2,2-trifluoroacetate	$CF_3COOCH_2CH_3$	21.9 days	0.05[i]	1.26e-13	**5**	1.26e-13	**1**	1.00e-15	**1**	1.41e-16	**<1**	1.03e-16	**<1**
2,2,2-Trifluoroethyl 2,2,2-trifluoroacetate	$CF_3COOCH_2CF_3$	54.8 days	0.15[i]	6.27e-13	**25**	6.27e-13	**7**	5.06e-15	**7**	7.07e-16	**1**	5.15e-16	**<1**
Methyl 2,2,2-trifluoroacetate	CF_3COOCH_3	0.6	0.18[i]	4.80e-12	**192**	4.80e-12	**52**	4.08e-14	**60**	5.47e-15	**9**	3.95e-15	**7**
Methyl 2,2-difluoroacetate	HCF_2COOCH_3	40.1 days	0.05[i]	3.00e-13	**12**	3.00e-13	**3**	2.41e-15	**4**	3.38e-16	**<1**	2.47e-16	**<1**
Difluoromethyl 2,2,2-trifluoroacetate	$CF_3COOCHF_2$	0.3	0.24[i]	2.48e-12	**99**	2.48e-12	**27**	2.04e-14	**30**	2.81e-15	**5**	2.04e-15	**4**
2,2,3,3,4,4,4-Heptafluorobutan-1-ol	$C_3F_7CH_2OH$	0.6	0.20	3.10e-12	**124**	3.10e-12	**34**	2.61e-14	**38**	3.52e-15	**6**	2.55e-15	**5**
1,1,2-Trifluoro-2-(trifluoromethoxy)-ethane	$CHF_2CHFOCF_3$	9.8	0.35	9.91e-11	**3970**	1.14e-10	**1240**	2.03e-12	**2960**	2.88e-13	**467**	9.74e-14	**178**
1-Ethoxy-1,1,2,3,3,3-hexafluoropropane	$CF_3CHFCF_2OCH_2CH_3$	0.4	0.19	2.14e-12	**86**	2.14e-12	**23**	1.77e-14	**26**	2.43e-15	**4**	1.76e-15	**3**
1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2,2-tetrafluoroethoxy)-propane	$CF_3CF_2CF_2OCHFCF_3$	67.0	0.58	1.98e-10	**7940**	5.95e-10	**6490**	5.57e-12	**8140**	4.29e-12	**6960**	2.39e-12	**4380**
2,2,3,3-Tetrafluoro-1-propanol	$CHF_2CF_2CH_2OH$	91.3 days	0.11	1.19e-12	**48**	1.19e-12	**13**	9.72e-15	**14**	1.35e-15	**2**	9.79e-16	**2**
2,2,3,4,4,4-Hexafluoro-1-butanol	$CF_3CHFCF_2CH_2OH$	94.9 days	0.19	1.56e-12	**63**	1.56e-12	**17**	1.27e-14	**19**	1.76e-15	**3**	1.28e-15	**2**
2,2,3,3,4,4,4-Heptafluoro-1-butanol	$CF_3CF_2CF_2CH_2OH$	0.3	0.16	1.49e-12	**60**	1.49e-12	**16**	1.23e-14	**18**	1.69e-15	**3**	1.23e-15	**2**
1,1,2,2-Tetrafluoro-3-methoxy-propane	$CHF_2CF_2CH_2OCH_3$	14.2 days	0.03	4.82e-14	**2**	4.82e-14	**<1**	3.84e-16	**<1**	5.41e-17	**<1**	3.96e-17	**<1**
perfluoro-2-methyl-3-pentanone	$CF_3CF_2C(O)CF(CF_3)_2$	7.0 days	0.03	9.14e-15	**<1**	9.14e-15	**<1**	7.27e-17	**<1**	1.03e-17	**<1**	7.51e-18	**<1**
3,3,3-Trifluoro-propanal	CF_3CH_2CHO	2.0 days	0.004	9.86e-16	**<1**	9.86e-16	**<1**	7.84e-18	**<1**	1.11e-18	**<1**	8.10e-19	**<1**
2-Fluoroethanol	CH_2FCH_2OH	20.4 days	0.02	8.07e-14	**3**	8.07e-14	**<1**	6.45e-16	**<1**	9.07e-17	**<1**	6.63e-17	**<1**
2,2-Difluoroethanol	CHF_2CH_2OH	40.0 days	0.04	2.78e-13	**11**	2.78e-13	**3**	2.23e-15	**3**	3.12e-16	**<1**	2.28e-16	**<1**
2,2,2-Trifluoroethanol	CF_3CH_2OH	0.3	0.10	1.83e-12	**73**	1.83e-12	**20**	1.50e-14	**22**	2.07e-15	**3**	1.50e-15	**3**
1,1'-Oxybis[2-(difluoromethoxy)-1,1,2,2-tetrafluoroethane	$HCF_2O(CF_2CF_2O)_2CF_2H$	26.0	1.15[k]	2.47e-10	**9910**	4.51e-10	**4920**	6.38e-12	**9320**	2.75e-12	**4460**	7.45e-13	**1360**
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12-hexadecafluoro-2,5,8,11-Tetraoxadodecane	$HCF_2O(CF_2CF_2O)_3CF_2H$	26.0	1.43[k]	2.26e-10	**9050**	4.12e-10	**4490**	5.83e-12	**8520**	2.51e-12	**4080**	6.81e-13	**1250**
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12,13,13,15,15-eicosafluoro-2,5,8,11,14-Pentaoxapentadecane	$HCF_2O(CF_2CF_2O)_4CF_2H$	26.0	1.46[k]	1.83e-10	**7320**	3.33e-10	**3630**	4.71e-12	**6880**	2.03e-12	**3300**	5.50e-13	**1010**

Notes:

For CH_4 we estimate an uncertainty of ±30% and ±40% for 20- and 100-year time horizon, respectively (for 90% uncertainty range). The uncertainty is dominated by AGWP for CO_2 and indirect effects. The uncertainty in GWP for N_2O is estimated to ±20% and ±30% for 20- and 100-year time horizon, with the largest contributions from CO_2. The uncertainty in GWP for HFC-134a is estimated to ±25% and ±35% for 20- and 100-year time horizons while for CFC-11 the GWP the corresponding numbers are approximately ±20% and ±35% (not accounting for the indirect effects). For CFC-12 the corresponding numbers are ±20 and ±30. The uncertainties estimated for HFC-134a and CFC-11 are assessed as representative for most other gases with similar or longer lifetimes. For shorter-lived gases, the uncertainties will be larger. For GTP, few estimates are available in the literature. The uncertainty is assessed to be of the order of ±75% for the methane GTP_{100}.

* No single lifetime can be given. The impulse response function for CO_2 from Joos et al. (2013) has been used. See also Supplementary Material Section 8.SM.11.

† Perturbation lifetime is used in calculation of metrics, not the lifetime of the atmospheric burden.

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Table 8.A.1 Notes (continued)

‡ Metric values for CH_4 of fossil origin include the oxidation to CO_2 (based on Boucher et al., 2009). In applications of these values, inclusion of the CO_2 effect of fossil methane must be done with caution to avoid any double-counting because CO_2 emissions numbers are often based on total carbon content. Methane values without the CO_2 effect from fossil methane are thus appropriate for fossil methane sources for which the carbon has been accounted for elsewhere, or for biospheric methane sources for which there is abalance between CO_2 taken up by the biosphere and CO_2 produced from CH_4 oxidization. The addition effect on GWP and GTP represents lower limits from Boucher et al. (2009) and assume 50% of the carbon is deposited as formaldehyde to the surface and is then lost. The upper limit in Boucher et al. (2009) made the assumption that this deposited formaldehyde was subsequently further oxidized to CO_2 .

[a] RE is unchanged since AR4.

[b] RE is unchanged since AR4 except the absolute forcing is increased by a factor of 1.04 to account for the change in the recommended RE of CFC-11.

[c] Based on Rajakumar et al. (2006) (lifetime correction factor has been applied to account for non-homogeneous horizontal and vertical mixing).

[d] Based on instantaneous RE from Baasandorj et al. (2010); Baasandorj et al. (2011) (correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

[e] Based on instantaneous RE from *ab initio* study of Bravo et al. (2010) (a factor 1.10 has been applied to account for stratospheric temperature adjustment).

[f] Based on average instantaneous RE reported in literature (Vasekova et al., 2006; Bravo et al., 2010) (correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

[g] Based on instantaneous RE from *ab initio* studies of Blowers et al. (2007, 2008)(correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

[h] Based on instantaneous RE from Heathfield et al. (1998) (correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

[i] Note that calculation of RE is based on calculated (*ab initio*) absorption cross-section and uncertainties are therefore larger than for calculations using experimental absorption cross section.

[j] Based on instantaneous RE from Javadi et al. (2007) (correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

[k] Based on instantaneous RE from Andersen et al. (2010) (correction factors have been applied to account for stratospheric temperature adjustment and non-homogeneous horizontal and vertical mixing).

The GTP values are calculated with a temperature impulse response function taken from Boucher and Reddy (2008). See also Supplementary Material Section 8.SM.11.

Table 8.A.2 | Halocarbon indirect GWPs from ozone depletion using the EESC-based method described in WMO (2011), adapted from Daniel et al. (1995). A radiative forcing in year 2011 of –0.15 (–0.30 to 0.0) W m^{-2} relative to preindustrial times is used (see Section 8.3.3). Uncertainty on the indirect AGWPs due to the ozone forcing uncertainty is ±100%.

Gas	GWP_{100}
CFC-11	–2640
CFC-12	–2100
CFC-113	–2150
CFC-114	–914
CFC-115	–223
HCFC-22	–98
HCFC-123	–37
HCFC-124	–46
HCFC-141b	–261
HCFC-142b	–152
CH_3CCl_3	–319
CCl_4	–2110
CH_3Br	–1250
Halon-1211	–19,000
Halon-1301	–44,500
Halon-2402	–32,000
HCFC-225ca	–40
HCFC-225cb	–60

Table 8.A.3 | GWP and GTP for NO_x from surface sources for time horizons of 20 and 100 years from the literature. All values are on a per kilogram of nitrogen basis. Uncertainty for numbers from Fry et al. (2012) and Collins et al. (2013) refer to 1-σ. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP_{100} and GTP_{100} values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
NO_x East Asia[a]	6.4 (±38.1)	–5.3 (±11.5)	–55.6 (±23.8)	–1.3 (±2.1)
NO_x EU + North Africa[a]	–39.4 (±17.5)	–15.6 (±5.8)	–48.0 (±14.9)	–2.5 (±1.3)
NO_x North America[a]	–2.4 (±30.3)	–8.2 (±10.3)	–61.9 (±27.8)	–1.7 (±2.1)
NO_x South Asia[a]	–40.7 (±88.3)	–25.3 (±29.0)	–124.6 (±67.4)	–4.6 (±5.1)
NO_x four above regions[a]	–15.9 (±32.7)	–11.6 (±10.7)	–62.1 (±26.2)	–2.2 (±2.1)
Mid-latitude NOx[c]	–43 to +23	–18 to +1.6	–55 to –37	–2.9 to –0.02
Tropical NO_x[c]	43 to 130	–28 to –10	–260 to –220	–6.6 to –5.4
NO_x global[b]	19	–11	–87	–2.9
NO_x global[d]	–108 ± 35 –335 ± 110 –560 ± 279	–31 ± 10 –95 ± 31 –159 ± 79		

Notes:

[a] Fry et al. (2012) (updated by including stratospheric H_2O) and Collins et al. (2013).

[b] Fuglestvedt et al. (2010); based on Wild et al. (2001).

[c] Fuglestvedt et al. (2010).

[d] Shindell et al. (2009). Three values are given: First, without aerosols, second, direct aerosol effect included (sulfate and nitrate), third, direct and indirect aerosol effects included. Uncertainty ranges from Shindell et al. (2009) are given for 95% confidence levels.

Table 8.A.4 | GWP and GTP for CO for time horizons of 20 and 100 years from the literature. Uncertainty for numbers from Fry et al. (2012) and Collins et al. (2013) refer to 1-σ. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP_{100} and GTP_{100} values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
CO East Asia[a]	5.4 (±1.7)	1.8 (±0.6)	3.5 (±1.3)	0.26 (±0.12)
CO EU + North Africa[a]	4.9 (±1.5)	1.6 (±0.5)	3.2 (±1.2)	0.24 (±0.11)
CO North America[a]	5.6 (±1.8)	1.8 (±0.6)	3.7 (±1.3)	0.27 (±0.12)
CO South Asia[a]	5.7 (±1.3)	1.8 (±0.4)	3.4 (±1.0)	0.27 (±0.10)
CO four regions above[a]	5.4 (±1.6)	1.8 (±0.5)	3.5 (±1.2)	0.26 (±0.11)
CO global[b]	6 to 9.3	2 to 3.3	3.7 to 6.1	0.29 to 0.55
CO global[c]	7.8 ± 2.0 11.4 ± 2.9 18.6 ± 8.3	2.2 ± 0.6 3.3 ± 0.8 5.3 ± 2.3		

Notes:

[a] Fry et al. (2012) (updated by including stratospheric H_2O) and Collins et al. (2013).

[b] Fuglestvedt et al. (2010).

[c] Shindell et al. (2009). Three values are given: First, without aerosols, second, direct aerosol effect included, third, direct and indirect aerosol effects included. Uncertainty ranges from Shindell et al. (2009) are given for 95% confidence levels.

Table 8.A.5 | GWP and GTP for VOCs for time horizons of 20 and 100 years from the literature. Uncertainty for numbers from Fry et al. (2012) and Collins et al. (2013) refer to 1-σ. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP_{100} and GTP_{100} values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
VOC East Asia[a]	16.3 (±6.4)	5.0 (±2.1)	8.4 (±4.6)	0.7 (±0.4)
VOC EU + North Africa[a]	18.0 (±8.5)	5.6 (±2.8)	9.5 (±6.5)	0.8 (±0.5)
VOC North America[a]	16.2 (±9.2)	5.0 (±3.0)	8.6 (±6.4)	0.7 (±0.5)
VOC South Asia[a]	27.8 (±5.6)	8.8 (±1.9)	15.7 (±5.0)	1.3 (±0.5)
VOC four regions above	18.7 (±7.5)	5.8 (±2.5)	10.0 (±5.7)	0.9 (±0.5)
VOC global[b]	14	4.5	7.5	0.66

Notes:

[a] Fry et al. (2012) (updated by including stratospheric H_2O) and Collins et al. (2013).

[b] Fuglestvedt et al. (2010) based on Collins et al. (2002).

The values are given on a per kilogram of C basis.

Table 8.A.6 | GWP and GTP from the literature for BC and OC for time horizons of 20 and 100 years. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP_{100} and GTP_{100} values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
BC total, global[c]	3200 (270 to 6200)	900 (100 to 1700)	920 (95 to 2400)	130 (5 to 340)
BC (four regions)[d]	1200 ± 720	345 ± 207	420 ± 190	56 ± 25
BC global[a]	1600	460	470	64
BC aerosol–radiation interaction +albedo, global[b]	2900 ± 1500	830 ± 440		
OC global[a]	–240	–69	–71	–10
OC global[b]	–160 (–60 to –320)	–46 (–18 to –19)		
OC (4 regions)[d]	–160 ± 68	–46 ± 20	–55 ± 16	–7.3±2.1

Notes:

[a] Fuglestvedt et al. (2010).

[b] Bond et al. (2011). Uncertainties for OC are asymmetric and are presented as ranges.

[c] Bond et al. (2013). Metric values are given for total effect.

[d] Collins et al. (2013). The four regions are East Asia, EU + North Africa, North America and South Asia (as also given in Fry et al., 2012). Only aerosol-radiation interaction is included.