2. Climate change

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2.1. Areas of protection and environmental mechanisms covered

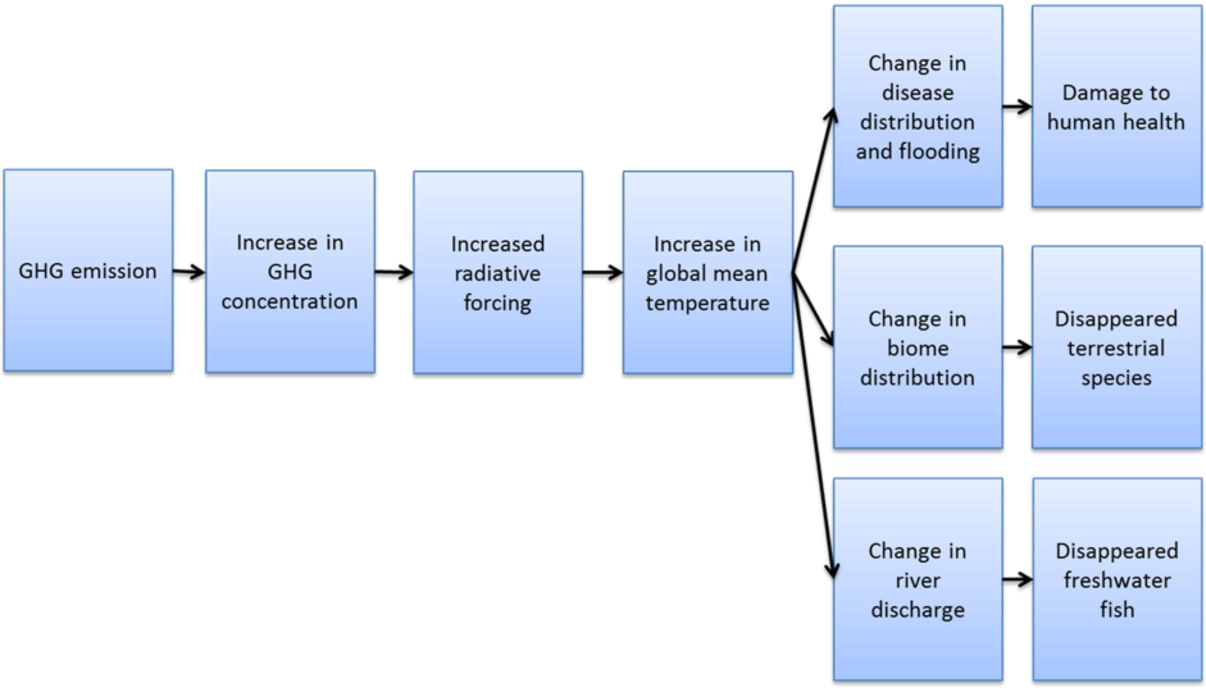

Figure 2.1: Cause and effect pathway of climate change (from Huijbregts et al., 2014)

The cause and effect pathway (Figure 2.1) of climate change starts with the emission of a greenhouse gas (GHG) to the atmosphere. The increased concentration of the GHGs causes the radiative forcing capacity of the atmosphere to increase, resulting in a larger part of the solar energy being retained in the atmosphere. This causes the global temperature to increase, thus affecting human health as well as the natural ecosystems. In this section we describe only those damages that are covered by our methodology. The areas of protection that are relevant for this environmental mechanism are human health and ecosystem quality (terrestrial and aquatic).

Human health can be affected through a shift in disease distributions. With increased temperatures certain parasites will be able to survive in areas where they previously were not able to live. Furthermore, the increased amount of energy in the atmosphere will give rise to more extreme weather in the form of coastal or inland flooding or droughts, all of which have an adverse effect on human health.

Terrestrial ecosystems will experience a shift in distribution as a result of increased temperatures. Not all species will be able to migrate quickly enough to follow the associated change in vegetation, causing them to go extinct. Freshwater ecosystems can be affected through a decrease in river discharge as a result of the changed climate. Rivers with larger discharges can sustain more different species of fish than river with lower discharges. Therefore a decrease in discharge is likely to cause a number of species to go extinct in that river system.

The climate models, which are used to predict the impact on human health, assume an increase in global temperature of 0.5 to 0.68 degrees in the year 2030 relative to the average global temperature in the reference year 2000. The 0.18 degree difference between the two scenarios is used to derive the final CF, this is a relatively small change in temperature and hence a marginal approach. A temperature change of 1-3.5 degrees is modelled for terrestrial ecosystems, while a change of 1.9 to 4.4 degrees is used for the aquatic ecosystems, making these approaches more similar to a mix between a marginal and an average approach. Ideally, one would use the same model with the same temperature increase for both human health and ecosystem damage effect factors. However, because both models have been developed independently of each other, such synchronization was not possible. Because climate change is modelled as a global increase in radiative forcing there is no need to provide location-specific emission factors. Regardless of the emissions location the impact will be the same.

2.2. Calculation of the characterization factors at endpoint level

The endpoint characterization factors for climate change that are used for damage on human health represent Disability-Adjusted loss of Life Years (DALY). This is a metric for the potential loss of life years (plus the years in which people have to live with disease, weighted with the severity of the disease) among the total world population (in the unit yr/kg GHG). The factors for ecosystem damage represent the globally potentially disappeared fraction of species over a period of time due to the emission of 1 kg of GHG (unit yr/kg GHG). In order to calculate these factors several steps are needed, starting with the prospected increase in temperature due to the release of 1 kg GHG. The following equation (equation 2.1) shows the calculation of the endpoint characterization factor CF_{end} for greenhouse gas x. GWP is the greenhouse warming potential of greenhouse gas x, *TH* is the time horizon, δTEMP is the temperature increase due to the release of 1 kg of CO_2 and *EF* is the effect factor for a given Area Of Protection (*AOP,* i.e. human health, freshwater or terrestrial ecosystems).

$$CF_{end,x,TH,AOP} = GWP_{x,TH} \cdot \partial Temp_{CO_2,TH} \cdot EF_{AOP}$$

Equation 2.1.

2.2.1. From emission to temperature increase

The International Panel on Climate Change (IPCC) provides characterization factors called Absolute Global Warming Potentials (AGWPs) which can be used to compare different GHGs (IPCC, 2013). The AGWP of a GHG represents the amount of solar radiation that is retained within the atmosphere over a period of time. When the AGWP is expressed relative to the AGWP of the reference gas CO_2 it is called the Global Warming Potential (GWP). A time horizon of 100 years is taken as the default, robust scenario and a time horizon of 100 - 1000 years represents the less robust scenario. GWPs provided by the IPCC are expressed in equivalents of 1 kg CO_2 for a 100-year time horizon. By using the radiative forcing capacity and the atmospheric life time, the AGWP and GWP for other time horizons can be calculated for all GHGs except CO_2. The approach followed here (equations 2.2 and 2.3) is equal to the midpoint calculation in the most recent ReCiPe update (Huijbregts et al., 2014).

$$AGWP_{x,TH} = RF_x \cdot\ cv_x\ \cdot LT_x\ \cdot (1 - e^{-\frac{TH}{LT_x}})$$

Equation 2.2

$$GWP_{x,TH} = \frac{AGWP_{x,TH,}}{AGWP_{CO_2,TH}}$$

Equation 2.3

"RF is the radiative efficiency (W m^{-2}/ppb), cv is the substance-specific mass to concentration conversion factor (ppb/kg), LT is the lifetime (year) of the substance x and TH is the time horizon (year) of the assessment (in this case 1000 years). RF and LT were directly available from the fifth assessment report (IPCC, 2013). Since the values for cv are not reported separately in the fifth assessment report these were calculated from the AGWPs that were reported by IPCC (2013)."
(Equations and corresponding descriptions from Huijbregts et al., 2014)

For short-lived GHGs the AGWP for a 100 year time horizon will be almost equal to the AGWP for a 1000 year horizon, because no additional effects after 100 years are to be expected. For long-lived GHGs (including CO_2 itself) however, the $AGWP_{1000}$ is much larger than the $AGWP_{100}$ because a large fraction of the captured radiation will occur during the uncertain period between 100 and a 1000 years.

2.2.2. From AGWP to temperature increase

All midpoint-to-endpoint models start with the modelling of the effects of an increase in temperature. In this study the projected increase in temperature due to 1 kg of CO_2 was taken from Joos et al. (2013). The amount of temperature increase caused by captured cumulative radiative forcing is assumed to be equal to that of CO_2 for all GHGs (Equation 2.4). This may lead to some uncertainty because the time dimension (which is important in the climate response models) is lost after the amount of radiative forcing is integrated over time.

$$\partial Temp_{x,TH} = GWP_{x,TH}\ \partial Temp_{CO_2,TH}$$

Equation 2.4

Where dTemp is the temperature change (°C/kg) and GWP is the Global Warming Potential of GHG *x* (in kg CO_2 eq), over a time horizon TH (years) and $dTemp_{CO2}$ is the temperature change caused by 1 kg of CO_2.

2.2.3. From temperature increase to endpoint damage

The effect of a temperature increase on terrestrial ecosystems and human health was derived from De Schryver et al. (2009, 2011 respectively), while the effect on freshwater ecosystems was taken from Hanafiah et al. (2011). Equations 2.5 through 2.7 show how these effect factors were calculated.

$$EF_{HH} = \sum_{i,r} Incidence_{i,r}\ \cdot Severity_{i,r}$$

Equation 2.5

Where EF_{HH} (DALY/°C) is the effect factor for human health, incidence is the additional incidence of disease/flooding event *i* (incidences/°C) and severity is the damage caused by these incidences

(DALY/incidence) in region *r* (Africa, Eastern Mediterranean, Latin American and the Caribbean, South East Asia, Western Pacific and developed countries). Please note that this factor includes both the effect (incidences) and the damage (DALY).

The effect factor for terrestrial ecosystems is shown in equation 2.6.

$$EF_{TE} = \sum_{r,g} \frac{1}{\sum S} \cdot S_{r,t} \cdot Loss_{r,t}$$

Equation 2.6

Where EF_{TE} (PDF/°C) is effect factor for terrestrial ecosystems. Species is the number of species and Loss is the percentual loss of species (%/°C) within species group t (mammals, birds, frogs, reptiles, butterflies and plants), in region *r* (Australia, Mexico, South Africa, Brazil and Europe). Equation 2.7 shows the effect factor for aquatic ecosystems.

$$EF_{FE} = \sum_{i} \frac{1}{\sum V} \cdot dQ_{mouth,i} \cdot \frac{0.4}{Q_{mouth,i}} \cdot V_i$$

Equation 2.7

Where EF_{FE} (PDF/°C) is the effect factor for freshwater ecosystems, dQ_{mouth} is the change in river discharge ($m^3\ yr^{-1}$/°C) Q_{mouth} is the total river discharge (m^3/yr) and V is the volume (m^3) of the river in river basin *i*.

The damage factors for terrestrial ecosystems (Urban 2015) represent the potentially disappeared fraction of species (PDF) per degree temperature increase. A value of 0.037 PDF/°C is reported (based on a meta analysis of different climate scenario studies). The studies that are included in the meta-analysis focus on global extinction risk for species, and the damage factor is thus in line with the rest of the impact categories. For freshwater ecosystems, Hanafiah et al. (2011) reported an effect factor of $2.04 \cdot 10^{-9}$ PDF m^3/°C; this factor was derived by taking the sum of the potentially disappeared fractions of species per river basin multiplied by the total water volume of each river basin, based on all river basins below 42°. We modified this approach by removing duplicates from the used database. Also, we estimated the number and change of fish species in each watershed based on Xenopoulos et al. (2005) for different climate scenarios (since changes may be non-marginal in some scenarios and for some watersheds). To get to a global PDF we then divide with the total number of fish species. River basins north of a latitude of 42° are not included because recent (in evolutionary terms) glaciation during ice ages has caused the number of species there to be lower than what would be expected from the discharge. Therefore the relationship between river discharge and number of fish species does not hold for these river basins. To get an average, weighted effect factor of $1.15 \cdot 10^{-2}$ PDF/°C we average across all climate scenarios.

2.3. Uncertainties

The CFs for this impact category are based on reported data from existing literature. Assessing the sensitivity of the CFs to uncertainties in the individual parameters is therefore only possible to a limited extent and is dependent on the reported data in the original reports. For the first part of the cause-and-effect chain uncertainties in the AGWP of CO_2 are provided by Joos et al. (2013). The 90% confidence interval spans from 67.9 to $117 \cdot 10^{-15}$ yr Wm^{-2} kg-CO_2^{-1} (for a 100 year time horizon) and this range becomes larger for longer time horizons. Uncertainty estimates for the GWPs of the other greenhouse gases are provided by the IPCC as 90% intervals. Note that these uncertainties are a combination of the uncertainty in the AGWP of CO_2 and the uncertainty in the AGWP of the GHG under consideration. For CH_4 an uncertainty estimate of ±40% is given (for a 100 year time horizon), for GHGs with a lifetime of a century or more a value ±30% is estimated to cover the 90% interval (for a 100 year time horizon). While for shorter-lived GHGs this interval is estimated to be ±35% (for a 100 year time horizon).

Such a detailed quantitative assessment of the other steps in the cause-and-effect chain is not available. Time integrated temperature factors are likely to be similar to the AGWP but with additional uncertainty, especially for longer time horizons were the climate feedbacks are highly relevant. Damage factors for human health are uncertain because of subjective choices (covered in section 2.4.2) as well as inherently uncertain due to limited knowledge. Assumptions related to the human health effects are listed in table 2.1 (from De Schryver et al. 2009). Most of the parameters used in these models are uncertain, so it is likely that the modelled relative risks also include a substantial amount of uncertainty. The same is true for the damage factors for terrestrial and aquatic ecosystems. For terrestrial species this is caused by uncertainty in the model that projects species extinction, which include many uncertain parameters among which the magnitude of possible dispersal per species and which species groups are included. For aquatic species there is uncertainty in the amount of discharge change caused by a rise in global temperature and the response of fish species to this change in discharge. Additionally it is not likely that the response of fish is representative of all aquatic species, therefore the level of robustness is considered low (see also section 2.4.2).

Table 2.1. Health effects considered, related assumptions and burden of disease type (from De Schryver et al. 2009).

Causes of health effects	**Assumptions**	**Burden of disease**
Malnutrition	Models of grain cereals and soybean to estimate the effects of change in temperature, rainfall and CO2 on future crop yields were used.	Nutritional deficiencies
Diarrhoea	Effects of increasing temperature on the incidence of all-cause diarrhoea were addressed, while effects of rainfall were excluded.	Diarrhoeal diseases
Heat stress	Temperature attributable deaths were calculated. The burden of disease of all cardiovascular diseases were used.	All cardiovascular diseases
Natural disasters	The increased incidence of coastal and inland flooding were assessed.	Drowning

2.4. Value choices

2.4.1. Time horizon

A prominent value choice in the modelling of the climate change is the time horizon. GHGs have widely different atmospheric lifetimes, making it important to properly state the time horizon over which impacts are considered. We calculated CFs for 100 years and 100 – 1000 years, thus the user can choose between using the more robust 100 year time horizon or the less robust and more uncertain, but more complete 1000 year time horizon.

2.4.2. Level of robustness

Other relevant value choices that are considered are:

- whether or not there is a strong potential for adaptation,
- whether future socio-economic developments are favourable

The human health and ecosystem effects were classified according to their level of robustness (Table 2.2). For the area of protection human health the expected increase in some diseases is dependent on the future socio-economic development. For some diseases, a positive socio-economic development thus prevents an increase in case occurrences. For others diseases like diarrhea and malaria, as well as for coastal flooding, an increase will occur even if the future socio-economic developments are positive. All these effects on human health are therefore considered to be health effects with a high level of robustness. In contrast, other effects may or may not occur and are therefore considered to have a low level of robustness. All effects on freshwater ecosystems were considered to have a low level of robustness because the CF was based on fish species only. It is uncertain whether these fish species are representative of the total freshwater ecosystem.

Table 2.2: Included effects in the core and extended versions of the CFs per area of protection

Area of protection	Core	Extended	Source
Time horizon (applies to all areas of protection)	100 years	100 - 1000 years	-
Human Health	Diarrhea Malaria Coastal flooding	Cardiovascular disease Malnutrition Inland flooding	De Schryver et al. (2011)
Terrestrial Ecosystems	All species included	Same species as high level	Urban (2015)
Freshwater Ecosystems	None	Fish as representative of the entire freshwater ecosystem, Based on global river basins below 42°	Hanafiah et al. (2011)

2.4.3. Characterization factors

Table 2.3: Characterization factors for human health (HH), terrestrial ecosystems (TE) and freshwater ecosystems (FE). Adding the CFs of high and low level of evidence results in the total CF over the complete time horizon and taking effects with both high and low levels of robustness into account. Substances with characterization factors of zero are very short-lived substances and are only relevant if the effects are studied over time periods shorter than a few years. Thus, over 100 years, their impacts disappear.

Substance	Human health Core (DALY/kg)	Human health Extended (DALY/kg)	Terrestrial ecosystems Core (PDF*y/kg)	Terrestrial ecosystems Extended (PDF*y/kg)	Aquatic ecosystems Core (PDF*y/kg)	Aquatic ecosystems Extended (PDF*y/kg)
Carbon dioxide (fossil)	4.28E-07	1.25E-05	1.76E-15	1.57E-14	0	4.87E-15
Methane	1.20E-05	5.96E-05	4.93E-14	7.47E-14	0	2.32E-14
Fossil methane	1.28E-05	6.13E-05	5.28E-14	7.67E-14	0	2.39E-14
Nitrous oxide	1.13E-04	9.86E-04	4.66E-13	1.24E-12	0	3.84E-13
Chlorofluorocarbons						
CFC-11	1.99E-03	1.10E-02	8.20E-12	1.37E-11	0	4.26E-12
CFC-12	4.36E-03	3.39E-02	1.80E-11	4.25E-11	0	1.32E-11
CFC-13	5.95E-03	1.59E-01	2.45E-11	1.99E-10	0	6.18E-11
CFC-113	2.49E-03	1.76E-02	1.02E-11	2.21E-11	0	6.87E-12
CFC-114	3.68E-03	4.37E-02	1.51E-11	5.47E-11	0	1.70E-11
CFC-115	3.28E-03	1.07E-01	1.35E-11	1.34E-10	0	4.18E-11
Hydrochlorofluorocarbons						
HCFC-21	6.33E-05	3.08E-04	2.60E-13	3.86E-13	0	1.20E-13
HCFC-22	7.53E-04	3.70E-03	3.10E-12	4.64E-12	0	1.44E-12
HCFC-122	2.52E-05	1.24E-04	1.04E-13	1.55E-13	0	4.83E-14
HCFC-122a	1.10E-04	5.41E-04	4.54E-13	6.77E-13	0	2.11E-13
HCFC-123	3.38E-05	1.66E-04	1.39E-13	2.08E-13	0	6.47E-14
HCFC-123a	1.58E-04	7.75E-04	6.51E-13	9.70E-13	0	3.01E-13
HCFC-124	2.25E-04	1.10E-03	9.27E-13	1.38E-12	0	4.30E-13
HCFC-132c	1.45E-04	7.08E-04	5.95E-13	8.87E-13	0	2.76E-13
HCFC-141b	3.35E-04	1.64E-03	1.38E-12	2.05E-12	0	6.38E-13
HCFC-142b	8.47E-04	4.16E-03	3.48E-12	5.21E-12	0	1.62E-12
HCFC-225ca	5.43E-05	2.67E-04	2.23E-13	3.35E-13	0	1.04E-13
HCFC-225cb	2.25E-04	1.10E-03	9.24E-13	1.38E-12	0	4.28E-13
(E)-1-Chloro-3,3,3-trifluoroprop-1-ene	4.28E-07	3.13E-06	1.76E-15	3.92E-15	0	1.22E-15
Hydrofluorocarbons						
HFC-23	5.31E-03	7.09E-02	2.18E-11	8.88E-11	0	2.76E-11
HFC-32	2.90E-04	1.42E-03	1.19E-12	1.78E-12	0	5.52E-13
HFC-41	4.96E-05	2.44E-04	2.04E-13	3.06E-13	0	9.52E-14
HFC-125	1.36E-03	6.84E-03	5.58E-12	8.56E-12	0	2.66E-12
HFC-134	4.79E-04	2.33E-03	1.97E-12	2.92E-12	0	9.08E-13
HFC-134a	5.56E-04	2.72E-03	2.29E-12	3.41E-12	0	1.06E-12
HFC-143	1.40E-04	6.88E-04	5.77E-13	8.61E-13	0	2.68E-13
HFC-143a	2.05E-03	1.14E-02	8.45E-12	1.43E-11	0	4.45E-12
HFC-152	6.85E-06	3.45E-05	2.82E-14	4.32E-14	0	1.34E-14
HFC-152a	5.90E-05	2.88E-04	2.43E-13	3.60E-13	0	1.12E-13
HFC-161	1.71E-06	7.61E-06	7.04E-15	9.52E-15	0	2.96E-15
HFC-227ca	1.13E-03	5.70E-03	4.65E-12	7.14E-12	0	2.22E-12
HFC-227ea	1.43E-03	7.60E-03	5.90E-12	9.52E-12	0	2.96E-12
HFC-236cb	5.18E-04	2.53E-03	2.13E-12	3.17E-12	0	9.86E-13
HFC-236ea	5.69E-04	2.80E-03	2.34E-12	3.50E-12	0	1.09E-12
HFC-236fa	3.45E-03	4.90E-02	1.42E-11	6.14E-11	0	1.91E-11
HFC-245ca	3.06E-04	1.50E-03	1.26E-12	1.88E-12	0	5.83E-13
HFC-245cb	1.98E-03	1.10E-02	8.13E-12	1.38E-11	0	4.29E-12
HFC-245ea	1.01E-04	4.93E-04	4.14E-13	6.17E-13	0	1.92E-13
HFC-245eb	1.24E-04	6.08E-04	5.10E-13	7.61E-13	0	2.37E-13
HFC-245fa	3.67E-04	1.80E-03	1.51E-12	2.25E-12	0	7.00E-13
HFC-263fb	3.25E-05	1.58E-04	1.34E-13	1.98E-13	0	6.16E-14
HFC-272ca	6.16E-05	3.02E-04	2.53E-13	3.78E-13	0	1.17E-13
HFC-329p	1.01E-03	5.09E-03	4.15E-12	6.38E-12	0	1.98E-12
HFC-365mfc	3.44E-04	1.69E-03	1.41E-12	2.11E-12	0	6.56E-13
HFC-43-10mee	7.06E-04	3.46E-03	2.90E-12	4.34E-12	0	1.35E-12
HFC-1132a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00
HFC-1141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00
(Z)-HFC-1225ye	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00
(E)-HFC-1225ye	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00

(Z)-HFC-1234ze	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
HFC-1234yf	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
(E)-HFC-1234ze	**4.28E-07**	**2.00E-06**	**1.76E-15**	**2.50E-15**	**0**	**7.77E-16**
(Z)-HFC-1336	**8.56E-07**	**3.52E-06**	**3.52E-15**	**4.40E-15**	**0**	**1.37E-15**
HFC-1243zf	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
HFC-1345zfc	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
Chlorocarbons and hydrochlorocarbons						
Methyl chloroform	**6.85E-05**	**3.35E-04**	**2.82E-13**	**4.20E-13**	**0**	**1.31E-13**
Carbon tetrachloride	**7.40E-04**	**3.70E-03**	**3.04E-12**	**4.64E-12**	**0**	**1.44E-12**
Methyl chloride	**5.13E-06**	**2.56E-05**	**2.11E-14**	**3.20E-14**	**0**	**9.96E-15**
Methylene chloride	**3.85E-06**	**1.87E-05**	**1.58E-14**	**2.34E-14**	**0**	**7.27E-15**
Chloroform	**6.85E-06**	**3.43E-05**	**2.82E-14**	**4.29E-14**	**0**	**1.33E-14**
1,2-Dichloroethane	**4.28E-07**	**1.88E-06**	**1.76E-15**	**2.36E-15**	**0**	**7.33E-16**
Bromocarbons, hyrdobromocarbons and Halons						
Methyl bromide	**8.56E-07**	**4.93E-06**	**3.52E-15**	**6.18E-15**	**0**	**1.92E-15**
Methylene bromide	**4.28E-07**	**2.13E-06**	**1.76E-15**	**2.66E-15**	**0**	**8.28E-16**
Halon-1201	**1.61E-04**	**7.87E-04**	**6.62E-13**	**9.86E-13**	**0**	**3.06E-13**
Halon-1202	**9.88E-05**	**4.84E-04**	**4.07E-13**	**6.07E-13**	**0**	**1.89E-13**
Halon-1211	**7.49E-04**	**3.67E-03**	**3.08E-12**	**4.60E-12**	**0**	**1.43E-12**
Halon-1301	**2.69E-03**	**1.68E-02**	**1.11E-11**	**2.10E-11**	**0**	**6.54E-12**
Halon-2301	**7.40E-05**	**3.64E-04**	**3.04E-13**	**4.55E-13**	**0**	**1.42E-13**
Halon-2311/Halothane	**1.75E-05**	**8.61E-05**	**7.22E-14**	**1.08E-13**	**0**	**3.35E-14**
Halon-2401	**7.87E-05**	**3.84E-04**	**3.24E-13**	**4.81E-13**	**0**	**1.49E-13**
Halon-2402	**6.29E-04**	**3.10E-03**	**2.59E-12**	**3.89E-12**	**0**	**1.21E-12**
Fully Fluorinated Species						
Nitrogen trifluoride	**6.89E-03**	**1.60E-01**	**2.83E-11**	**2.01E-10**	**0**	**6.24E-11**
Sulphur hexafluoride	**1.01E-02**	**4.30E-01**	**4.14E-11**	**5.39E-10**	**0**	**1.67E-10**
(Trifluoromethyl)sulfur pentafluoride	**7.45E-03**	**2.22E-01**	**3.06E-11**	**2.78E-10**	**0**	**8.63E-11**
Sulfuryl fluoride	**1.75E-03**	**9.16E-03**	**7.20E-12**	**1.15E-11**	**0**	**3.57E-12**
PFC-14	**2.84E-03**	**1.38E-01**	**1.17E-11**	**1.73E-10**	**0**	**5.36E-11**
PFC-116	**4.75E-03**	**2.23E-01**	**1.95E-11**	**2.79E-10**	**0**	**8.68E-11**
PFC-c216	**3.94E-03**	**1.67E-01**	**1.62E-11**	**2.09E-10**	**0**	**6.49E-11**
PFC-218	**3.81E-03**	**1.58E-01**	**1.57E-11**	**1.98E-10**	**0**	**6.14E-11**
PFC-318	**4.08E-03**	**1.74E-01**	**1.68E-11**	**2.18E-10**	**0**	**6.78E-11**
PFC-31-10	**3.94E-03**	**1.63E-01**	**1.62E-11**	**2.04E-10**	**0**	**6.34E-11**
Perfluorocyclopentene	**8.56E-07**	**3.91E-06**	**3.52E-15**	**4.89E-15**	**0**	**1.52E-15**
PFC-41-12	**3.66E-03**	**1.61E-01**	**1.50E-11**	**2.01E-10**	**0**	**6.25E-11**
PFC-51-14	**3.38E-03**	**1.44E-01**	**1.39E-11**	**1.80E-10**	**0**	**5.60E-11**
PFC-61-16	**3.35E-03**	**1.41E-01**	**1.38E-11**	**1.77E-10**	**0**	**5.51E-11**
PFC-71-18	**3.26E-03**	**1.38E-01**	**1.34E-11**	**1.73E-10**	**0**	**5.38E-11**
PFC-91-18	**3.08E-03**	**1.21E-01**	**1.27E-11**	**1.52E-10**	**0**	**4.72E-11**
Perfluorodecalin(cis)	**3.10E-03**	**1.22E-01**	**1.27E-11**	**1.53E-10**	**0**	**4.75E-11**
Perfluorodecalin(trans)	**2.69E-03**	**1.06E-01**	**1.11E-11**	**1.33E-10**	**0**	**4.14E-11**
PFC-1114	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
PFC-1216	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
Perfluorobuta-1,3-diene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
Perfluorobut-1-ene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
Perfluorobut-2-ene	**8.56E-07**	**3.70E-06**	**3.52E-15**	**4.63E-15**	**0**	**1.44E-15**
Halogenated alcohols and ethers						
HFE-125	**5.31E-03**	**4.58E-02**	**2.18E-11**	**5.73E-11**	**0**	**1.78E-11**
HFE-134 (HG-00)	**2.38E-03**	**1.18E-02**	**9.78E-12**	**1.48E-11**	**0**	**4.61E-12**
HFE-143a	**2.24E-04**	**1.10E-03**	**9.20E-13**	**1.37E-12**	**0**	**4.26E-13**
HFE-227ea	**2.76E-03**	**1.58E-02**	**1.14E-11**	**1.98E-11**	**0**	**6.14E-12**
HCFE-235ca2(enflurane)	**2.49E-04**	**1.22E-03**	**1.03E-12**	**1.53E-12**	**0**	**4.76E-13**
HCFE-235da2(isoflurane)	**2.10E-04**	**1.03E-03**	**8.64E-13**	**1.29E-12**	**0**	**4.00E-13**
HFE-236ca	**1.81E-03**	**8.95E-03**	**7.46E-12**	**1.12E-11**	**0**	**3.48E-12**
HFE-236ea2(desflurane)	**7.66E-04**	**3.76E-03**	**3.15E-12**	**4.70E-12**	**0**	**1.46E-12**
HFE-236fa	**4.19E-04**	**2.05E-03**	**1.72E-12**	**2.57E-12**	**0**	**7.98E-13**
HFE-245cb2	**2.80E-04**	**1.37E-03**	**1.15E-12**	**1.72E-12**	**0**	**5.33E-13**
HFE-245fa1	**3.54E-04**	**1.73E-03**	**1.46E-12**	**2.17E-12**	**0**	**6.75E-13**
HFE-245fa2	**3.47E-04**	**1.70E-03**	**1.43E-12**	**2.13E-12**	**0**	**6.62E-13**
2,2,3,3,3-Pentafluoropropan-1-ol	**8.13E-06**	**3.93E-05**	**3.34E-14**	**4.92E-14**	**0**	**1.53E-14**

HFE-254cb1	**1.29E-04**	**6.31E-04**	**5.30E-13**	**7.90E-13**	**0**	**2.45E-13**
HFE-263fb2	**4.28E-07**	**2.79E-06**	**1.76E-15**	**3.49E-15**	**0**	**1.08E-15**
HFE-263m1	**1.24E-05**	**6.17E-05**	**5.10E-14**	**7.72E-14**	**0**	**2.40E-14**
3,3,3-Trifluoropropan-1-ol	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
HFE-329mcc2	**1.31E-03**	**6.51E-03**	**5.40E-12**	**8.15E-12**	**0**	**2.53E-12**
HFE-338mmz1	**1.12E-03**	**5.53E-03**	**4.61E-12**	**6.93E-12**	**0**	**2.15E-12**
HFE-338mcf2	**3.97E-04**	**1.95E-03**	**1.63E-12**	**2.44E-12**	**0**	**7.57E-13**
Sevoflurane (HFE-347mmz1)	**9.24E-05**	**4.52E-04**	**3.80E-13**	**5.66E-13**	**0**	**1.76E-13**
HFE-347mcc3 (HFE-7000)	**2.27E-04**	**1.11E-03**	**9.33E-13**	**1.39E-12**	**0**	**4.32E-13**
HFE-347mcf2	**3.65E-04**	**1.79E-03**	**1.50E-12**	**2.24E-12**	**0**	**6.96E-13**
HFE-347pcf2	**3.80E-04**	**1.86E-03**	**1.56E-12**	**2.33E-12**	**0**	**7.25E-13**
HFE-347mmy1	**1.55E-04**	**7.61E-04**	**6.39E-13**	**9.53E-13**	**0**	**2.96E-13**
HFE-356mec3	**1.66E-04**	**8.11E-04**	**6.81E-13**	**1.02E-12**	**0**	**3.16E-13**
HFE-356mff2	**7.27E-06**	**3.52E-05**	**2.99E-14**	**4.40E-14**	**0**	**1.37E-14**
HFE-356pcf2	**3.08E-04**	**1.51E-03**	**1.27E-12**	**1.89E-12**	**0**	**5.86E-13**
HFE-356pcf3	**1.91E-04**	**9.35E-04**	**7.85E-13**	**1.17E-12**	**0**	**3.64E-13**
HFE-356pcc3	**1.77E-04**	**8.66E-04**	**7.27E-13**	**1.08E-12**	**0**	**3.37E-13**
HFE-356mmz1	**5.99E-06**	**2.86E-05**	**2.46E-14**	**3.58E-14**	**0**	**1.11E-14**
HFE-365mcf3	**4.28E-07**	**1.94E-06**	**1.76E-15**	**2.43E-15**	**0**	**7.57E-16**
HFE-365mcf2	**2.48E-05**	**1.22E-04**	**1.02E-13**	**1.53E-13**	**0**	**4.76E-14**
HFE-374pc2	**2.68E-04**	**1.31E-03**	**1.10E-12**	**1.65E-12**	**0**	**5.11E-13**
4,4,4-Trifluorobutan-1-ol	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
2,2,3,3,4,4,5,5-Octafluorocyclopentanol	**5.56E-06**	**2.70E-05**	**2.29E-14**	**3.37E-14**	**0**	**1.05E-14**
HFE-43-10pccc124(H-Galden 1040x,HG-11)	**1.21E-03**	**5.90E-03**	**4.96E-12**	**7.39E-12**	**0**	**2.30E-12**
HFE-449s1 (HFE-7100)	**1.80E-04**	**8.81E-04**	**7.41E-13**	**1.10E-12**	**0**	**3.43E-13**
n-HFE-7100	**2.08E-04**	**1.02E-03**	**8.55E-13**	**1.27E-12**	**0**	**3.96E-13**
i-HFE-7100	**1.74E-04**	**8.52E-04**	**7.16E-13**	**1.07E-12**	**0**	**3.32E-13**
HFE-569sf2 (HFE-7200)	**2.44E-05**	**1.19E-04**	**1.00E-13**	**1.49E-13**	**0**	**4.63E-14**
n-HFE-7200	**2.78E-05**	**1.35E-04**	**1.14E-13**	**1.69E-13**	**0**	**5.26E-14**
i-HFE-7200	**1.88E-05**	**9.27E-05**	**7.74E-14**	**1.16E-13**	**0**	**3.61E-14**
HFE-236ca12 (HG-10)	**2.29E-03**	**1.14E-02**	**9.42E-12**	**1.43E-11**	**0**	**4.44E-12**
HFE-338pcc13 (HG-01)	**1.25E-03**	**6.09E-03**	**5.12E-12**	**7.63E-12**	**0**	**2.37E-12**
1,1,1,3,3,3-Hexafluoropropan-2-ol	**7.79E-05**	**3.81E-04**	**3.20E-13**	**4.78E-13**	**0**	**1.48E-13**
HG-02	**1.17E-03**	**5.71E-03**	**4.80E-12**	**7.15E-12**	**0**	**2.22E-12**
HG-03	**1.22E-03**	**5.98E-03**	**5.02E-12**	**7.49E-12**	**0**	**2.33E-12**
HG-20	**2.27E-03**	**1.13E-02**	**9.33E-12**	**1.42E-11**	**0**	**4.40E-12**
HG-21	**1.66E-03**	**8.16E-03**	**6.85E-12**	**1.02E-11**	**0**	**3.18E-12**
HG-30	**3.14E-03**	**1.56E-02**	**1.29E-11**	**1.96E-11**	**0**	**6.09E-12**
1-Ethoxy-1,1,2,2,3,3,3-heptafluoropropane	**2.61E-05**	**1.27E-04**	**1.07E-13**	**1.59E-13**	**0**	**4.94E-14**
Fluoroxene	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
1,1,2,2-Tetrafluoro-1-(fluoromethoxy)ethane	**3.73E-04**	**1.83E-03**	**1.53E-12**	**2.29E-12**	**0**	**7.11E-13**
2-Ethoxy-3,3,4,4,5-pentafluorotetrahydro-2,5-bis[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]-furan	**2.40E-05**	**1.16E-04**	**9.86E-14**	**1.46E-13**	**0**	**4.52E-14**
Fluoro(methoxy)methane	**5.56E-06**	**2.63E-05**	**2.29E-14**	**3.29E-14**	**0**	**1.02E-14**
Difluoro(methoxy)methane	**6.16E-05**	**3.02E-04**	**2.53E-13**	**3.78E-13**	**0**	**1.17E-13**
Fluoro(fluoromethoxy)methane	**5.56E-05**	**2.74E-04**	**2.29E-13**	**3.43E-13**	**0**	**1.07E-13**
Difluoro(fluoromethoxy)methane	**2.64E-04**	**1.29E-03**	**1.09E-12**	**1.62E-12**	**0**	**5.03E-13**
Trifluoro(fluoromethoxy)methane	**3.21E-04**	**1.57E-03**	**1.32E-12**	**1.97E-12**	**0**	**6.13E-13**
HG'-01	**9.50E-05**	**4.64E-04**	**3.91E-13**	**5.81E-13**	**0**	**1.80E-13**
HG'-02	**1.01E-04**	**4.93E-04**	**4.15E-13**	**6.18E-13**	**0**	**1.92E-13**
HG'-03	**9.46E-05**	**4.64E-04**	**3.89E-13**	**5.81E-13**	**0**	**1.80E-13**
HFE-329me3	**1.95E-03**	**1.04E-02**	**8.01E-12**	**1.30E-11**	**0**	**4.04E-12**
3,3,4,4,5,5,6,6,7,7,7-Undecafluoroheptan-1-ol	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-Pentadecafluorononan-1-ol	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,11-Nonadecafluoroundecan-1-ol	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
2-Chloro-1,1,2-trifluoro-1-methoxyethane	**5.22E-05**	**2.56E-04**	**2.15E-13**	**3.20E-13**	**0**	**9.96E-14**
PFPMIE(perfluoropolymethylisopropyl ether)	**4.15E-03**	**1.23E-01**	**1.71E-11**	**1.55E-10**	**0**	**4.80E-11**
HFE-216	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
Trifluoromethylformate	**2.52E-04**	**1.23E-03**	**1.03E-12**	**1.54E-12**	**0**	**4.79E-13**
Perfluoroethylformate	**2.48E-04**	**1.21E-03**	**1.02E-12**	**1.52E-12**	**0**	**4.73E-13**
Perfluoropropylformate	**1.61E-04**	**7.88E-04**	**6.62E-13**	**9.87E-13**	**0**	**3.07E-13**
Perfluorobutylformate	**1.68E-04**	**8.21E-04**	**6.90E-13**	**1.03E-12**	**0**	**3.19E-13**
2,2,2-Trifluoroethylformate	**1.41E-05**	**7.01E-05**	**5.81E-14**	**8.78E-14**	**0**	**2.73E-14**
3,3,3-Trifluoropropylformate	**7.27E-06**	**3.65E-05**	**2.99E-14**	**4.58E-14**	**0**	**1.42E-14**
1,2,2,2-Tetrafluoroethylformate	**2.01E-04**	**9.84E-04**	**8.27E-13**	**1.23E-12**	**0**	**3.83E-13**

1,1,1,3,3,3-Hexafluoropropan-2-ylformate	**1.42E-04**	**6.97E-04**	**5.86E-13**	**8.73E-13**	**0**	**2.71E-13**
Perfluorobutylacetate	**8.56E-07**	**3.47E-06**	**3.52E-15**	**4.35E-15**	**0**	**1.35E-15**
Perfluoropropylacetate	**8.56E-07**	**3.63E-06**	**3.52E-15**	**4.55E-15**	**0**	**1.41E-15**
Perfluoroethylacetate	**8.56E-07**	**4.32E-06**	**3.52E-15**	**5.41E-15**	**0**	**1.68E-15**
Trifluoromethylacetate	**8.56E-07**	**4.34E-06**	**3.52E-15**	**5.43E-15**	**0**	**1.69E-15**
Methylcarbonofluoridate	**4.06E-05**	**2.00E-04**	**1.67E-13**	**2.50E-13**	**0**	**7.77E-14**
1,1-Difluoroethylcarbonofluoridate	**1.16E-05**	**5.62E-05**	**4.75E-14**	**7.04E-14**	**0**	**2.19E-14**
1,1-Difluoroethyl2,2,2-trifluoroacetate	**1.33E-05**	**6.46E-05**	**5.46E-14**	**8.09E-14**	**0**	**2.52E-14**
Ethyl 2,2,2-trifluoroacetate	**4.28E-07**	**2.88E-06**	**1.76E-15**	**3.60E-15**	**0**	**1.12E-15**
2,2,2-Trifluoroethyl2,2,2-trifluoroacetate	**3.00E-06**	**1.43E-05**	**1.23E-14**	**1.79E-14**	**0**	**5.57E-15**
Methyl 2,2,2-trifluoroacetate	**2.22E-05**	**1.10E-04**	**9.15E-14**	**1.37E-13**	**0**	**4.27E-14**
Methyl 2,2-difluoroacetate	**1.28E-06**	**6.85E-06**	**5.28E-15**	**8.58E-15**	**0**	**2.67E-15**
Difluoromethyl 2,2,2-trifluoroacetate	**1.16E-05**	**5.66E-05**	**4.75E-14**	**7.09E-14**	**0**	**2.20E-14**
2,2,3,3,4,4,4-Heptafluorobutan-1-ol	**1.45E-05**	**7.08E-05**	**5.98E-14**	**8.87E-14**	**0**	**2.76E-14**
1,1,2-Trifluoro-2-(trifluoromethoxy)-ethane	**5.31E-04**	**2.60E-03**	**2.18E-12**	**3.26E-12**	**0**	**1.01E-12**
1-Ethoxy-1,1,2,3,3,3-hexafluoropropane	**9.84E-06**	**4.89E-05**	**4.05E-14**	**6.12E-14**	**0**	**1.90E-14**
1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2,2-tetrafluoroethoxy)-propane	**2.78E-03**	**1.75E-02**	**1.14E-11**	**2.19E-11**	**0**	**6.82E-12**
2,2,3,3-Tetrafluoro-1-propanol	**5.56E-06**	**2.72E-05**	**2.29E-14**	**3.40E-14**	**0**	**1.06E-14**
2,2,3,4,4,4-Hexafluoro-1-butanol	**7.27E-06**	**3.56E-05**	**2.99E-14**	**4.46E-14**	**0**	**1.39E-14**
2,2,3,3,4,4,4-Heptafluoro-1-butanol	**6.85E-06**	**3.40E-05**	**2.82E-14**	**4.26E-14**	**0**	**1.32E-14**
1,1,2,2-Tetrafluoro-3-methoxy-propane	**4.28E-07**	**1.10E-06**	**1.76E-15**	**1.38E-15**	**0**	**4.28E-16**
perfluoro-2-methyl-3-pentanone	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
3,3,3-Trifluoropropanal	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0**	**0.00E+00**
2-Fluoroethanol	**4.28E-07**	**1.84E-06**	**1.76E-15**	**2.31E-15**	**0**	**7.17E-16**
2,2-Difluoroethanol	**1.28E-06**	**6.35E-06**	**5.28E-15**	**7.95E-15**	**0**	**2.47E-15**
2,2,2-Trifluoroethanol	**8.56E-06**	**4.18E-05**	**3.52E-14**	**5.23E-14**	**0**	**1.63E-14**
1,1'-Oxybis[2-(difluoromethoxy)-1,1,2,2-tetrafluoroethane	**2.11E-03**	**1.05E-02**	**8.66E-12**	**1.32E-11**	**0**	**4.09E-12**
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12-hexadecafluoro-2,5,8,11-Tetraoxadodecane	**1.92E-03**	**9.62E-03**	**7.90E-12**	**1.20E-11**	**0**	**3.74E-12**
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	**1.55E-03**	**7.78E-03**	**6.39E-12**	**9.74E-12**	**0**	**3.03E-12**

2.5. References

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