The benefits of basing policies on the 20-year GWP of HFCs

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Overview

The intent of this paper is to reignite discussion on the benefits of basing policies on the 20-year global warming potential (GWP) of HFCs rather than on the current standard of 100-year GWP. The paper explores:

- The need for a global phase out of HFCs
- The rationale for basing policies on the 20-year GWP of HFCs
- Annex 1: Comparison of global projections of HFC emissions with 100-year GWP (GWP_{100}) and 20-year GWP (GWP_{20}) metrics
- Annex 2: Comparison of the impact of proposed HFC phase down schedules with GWP_{20} and GWP_{100} metrics

Approaching climate tipping points

2010 was one of the two hottest years on record.[1] At the same time, according to the international Energy Agency, CO_2 emissions in 2010 reached a record high of 30.6 Gt.[2]

The steady growth in extreme weather events around the world signals that human-induced climate change is happening right now. In 2010 and 2011 we have witnessed unparalleled devastation around the world from record floods, fires, droughts, more frequent and intense tornadoes and hurricanes. In some countries, millions of acres of agricultural land have been lost due to flooding, while other countries report massive declines in crop harvests due to heat and drought. In China, up to 4 million people faced shortages of drinking water due to a drought along the Yangtze River, and portions of the river were closed to navigation. Currently, due to a prolonged drought, up to 10 million people face hunger and starvation in North East Africa.

In 2009, NASA's eminent climate scientist, Dr. James Hansen, warned that the "climate is nearing dangerous tipping points… "

A 'tipping point' in the climate system implies abrupt, non-linear, unforeseen and unpredictable changes. It is reaching thresholds of no return, where human intervention has little or no capacity to restore nature's balance.

The fact is that climate 'tipping points' could be reached within a few decades. We must therefore act now to ensure that overall greenhouse gas emissions peak no later than 2015, decline rapidly thereafter, and reach as close to zero as soon as possible. We must think both long and short term, and take immediate measures that will have significant climate benefits over the next several decades. The question then becomes: What are the most available and effective steps to reduce the flow of greenhouse gas emissions in the short term while we tackle the overall challenge of weaning the world from dependence on fossil fuels?

Need to phase out HFCs

Phasing down, and eventually phasing out, HFCs is one of the preventative measures that the Montreal Protocol could undertake today to avoid unnecessary greenhouse gas emissions.

1 UN Dispatch : January 13, 2010: reporting on NASA Goddard Institute data of January 12, 2010
2 www.iea.org/index_info.asp?id=1959

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By phasing out CFCs and other ozone-depleting substances (ODSs), the Montreal Protocol was instrumental in the reduction of massive amounts of greenhouse gas emissions: reductions of nearly 135 gigatons (Gt) of CO_2e emissions between 1990 and 2010. This has delayed the effects of climate change by up to 12 years.[3] In September 2007 the Parties to the Montreal Protocol accelerated the phase-out of HCFCs by 10 years in both developed and developing countries. This long overdue agreement has the potential to prevent up to 18 Gt or more of CO_2e emissions, provided (as the Montreal Protocol's Technology and Economics Assessment Panel – TEAP - noted) that (a) HCFCs are replaced by alternatives that have zero or low global warming potential (GWP) and (b) the energy efficiency of refrigeration and air-conditioning equipment is improved.[4]

Since HFCs are primarily used as replacements for ODSs controlled by the Montreal Protocol, the Protocol is largely responsible for their massive global uptake. HCFC consumption in developing countries is expected to peak in 2013 at approximately 566 kilotonnes (kt) a year (or at 3.14 times the peak CFC consumption).[5] Should HFCs replace HCFCs in developing countries, consumption of HFCs in developing countries is projected to be 4 to 8 times greater than in developed countries by 2050.[6] HFCs must be phased out as quickly as possible and the Montreal Protocol is well positioned to make further significant short-term contributions to climate protection by bringing HFCs into its regulatory regime.

Measuring the global warming potential of HFCs

Global warming potential (GWP) measures the potency of a greenhouse gas over a specific period of time, relative to carbon dioxide (CO_2), which has a GWP of 1. It is independent of a greenhouse gas' atmospheric concentration, ie it reflects its thermodynamic properties (how good it is at being a greenhouse gas) irrespective of how much of it is in the atmosphere. An important aspect of GWP is the timescale used: there are 20-year, 100-year and 500-year GWP values for the majority of greenhouse gases.

There is high variability in the atmospheric lifetime of greenhouse gases. For example, CO_2 can be on the order of several centuries, CH_4 (methane) 12 years, SF_6 (sulfur hexafluoride) 3,200 years. Due to this variability, the GWP_{100} metric has been deemed the most appropriate tool to cross-compare the effect of different greenhouse gases.[7] While this metric may be the most appropriate across compounds with such a wide range of atmospheric lifetimes, when it comes to HFCs it has the significant drawback of not capturing the true climate impact of these chemicals. This is because the most abundant HFCs in use today have atmospheric lifetimes much less than 100 years (see Table 1).

In fact, the average lifetime of the HFCs in use today is 21.7 years and therefore better suited to the 20-year GWP metric. Their short-term climate impact is thus diluted when measured using GWP_{100} and not adequately accounted for in climate policies. The GWP_{20} metric better reflects the true potency of HFCs during their actual time in the atmosphere. Indeed, the average GWP_{20} for HFCs (at 4,582) is 94% greater than the GWP_{100} average (at 2,362) (see Table 2). As a result, the short-term ramifications of high-level HFC consumption are far greater when their global warming contribution is measured according to their 20-year GWPs (20 GWP), instead of their 100-year GWPs (100 GWP), the current reference point.

[3] Velders et al (2007). PNAS paper
[4] UNEP, TEAP (2007). Report of the Task Force Response to Decision XVIII/12, August 2007; ICF International, 2007. Changes in HCFC consumption and emissions from the US proposed adjustments for accelerating the HCFC phase out. Prepared for the US EPA by ICF International, August 2007
[5] Freedonia Group. Inc (2009). Industry study 2528: World Fluorochemicals. Cleveland, Ohio
[6] Velders et al (2009). "The large contribution of projected HFC emissions to future climate forcing."
[7] The 100 year GWP metric has also been promoted by the chemical industry as part of their marketing strategy for HFCs. On a 20 year time scale the global warming contribution of HFCs is many fold more damaging to the climate than on a 100 year scale. According to the industry : "Using 20 year time horizons for HFCs distorts the relative contribution of CO2 (over 90% of it is ignored) and does not contribute to an informed and objective assessment of the use of HFCs." (http://www.fluorocarbons.org/en/info/brchures/fact_sheet_18.html) published by the European Fluorocarbon Technical Committee (members include: Mexichem Fluor, Arkema, DuPont, Solvay Fuor, Honeywell Fluorine Products)

Table 1: List of the most commonly used HFCs, HCFCs and low GWP alternatives. (IPCCC Fourth Assessment Report- 2007): Atmospheric lifetime and GWP20 and GWP100

Substance	Application	20 Year GWP	100 Year GWP	Atmospheric lifetime
HCFC -22	Air-conditioning: most commonly used refrigerant	5,160	1,810	12
HCFC -141b	Insulation foam blowing	2,250	725	9.3
HCFC-142b	Insulation foam blowing	5,490	2,310	17.9
HFC-23	Low temperature refrigerant	12,000	14,800	
HFC-32	Blend component of refrigerants	2,330	675	4.9
HFC-125	Blend component of refrigerants	6,350	3,500	29
HFC-134a	Refrigerant in domestic refrigerators, mobile air-conditioning, stationary air-conditioning, blend component of refrigerants, foam blowing agent, aerosol propellant	3,830	1,430	14
HFC-143a	Blend component of refrigerants	5,890	4,470	52
HFC -152a	Blend component of refrigerants, foam blowing agent, possible future refrigerant	437	124	1.4
HFC-227ea	Refrigerant	5,310	3,220	
HFC-245fa	Foam blowing agent Possible future refrigerant	3,380	1030	7.6
HFC-365mfc	Foam blowing agent Possible future refrigerant	2,520	794	8.6
HFC-404a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning	6010	3922	34.2
HFC-410 a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning, transport refrigeration	4340	2088	
HFC-407c	Refrigerant blend: a leading retrofit alternative to HCFC-22 in air-conditioning, transport refrigeration	4115	1774	
CO2	Refrigerant, foam blowing agent	1	1	
Hydrocarbons	Refrigerant, foam blowing agent	<3	<3	
Ammonia	Refrigerant	0	0	

The lifetime of HFCs ranges from 1.4 years (HFC-152a) to 52 years (HFC-143a), the average lifetime is 21.7 years. The average GWP of these HFCs, calculated over 20 years is 4582, and 2362 over 100 years. [8]

Table 2: Average GWP values of HCFCs and HFCs weighted by consumption in developing countries

Substance		20-year GWP	100-year GWP	Atmospheric lifetime
HCFCs		4,299	1,502	11.4
HFCs		4,582	2,362	21.7

The data in Annex 1 documents that the absolute annual HFC emissions weighted by GWP_{20} are roughly twice as high as the absolute annual HFC emissions weighted by GWP_{100}.

- Under the BAU consumption scenario calculated by Öko-Recherche, by 2050, the annual HFC consumption in developed (A2) countries will be approximately 1.25 Gt CO_2 eq. when using GWP_{100}, and more than twice that at 2.8 Gt CO_2 eq. when using GWP_{20}
- Under the same scenario, by 2050, the annual HFC consumption in developing (A5) countries will be approximately 5 Gt CO_2 eq. using GWP_{100}, and more than twice that at 10.8 Gt CO_2 eq. when using GWP_{20}

Policy rationale for using the 20 GWP of HFCs

Which time frame is used to measure the global warming potential of substances is the result of political decision-making.

In the First IPCC Assessment Report (1990, p.58) the need for three different time frames (20, 100 and 500 years) for indicating GWP was justified as follows:

"For the evaluation of sea-level rise, the commitment to greenhouse warming over a 100 year or longer time horizon may be appropriate. For the evaluation of short-term effects, a time horizon of a few decades could be taken; for

[8] Velders et al (2009). "The large contribution of projected HFC emissions to future climate forcing", PNAS

example, model studies show that continental areas are able to respond rapidly to radiative forcing so that the relative effects of emissions on such timescales are relevant to predictions of near-term climate change." The IPCC underlines that "the choice of time horizon will depend on policy considerations" (IPCC 1994, p26).

Given that the effects of climate change are already being felt, it is prudent to base Montreal Protocol policies on the short-term climate impact of ODS alternatives. Policies based on the GWP_{20} values of HFCs highlight the benefits of climate action more accurately than policies based on the GWP_{100} values.

Given the urgency of the climate crisis, GWP_{20} better captures the political timescales that characterise national policy discussions and international negotiations. As Velders et al (2009) notes: "The climate forcing significance of a given time series of HFC emissions is highly sensitive to the time-horizon assumed because the HFC lifetimes are short compared with CO_2 lifetime...These climate-forcing comparisons, using GWPs with a 100-year time horizon yield and HFC consumption of 6.4-9.9 GtCO2-eq per year in 2050. If, instead, a 20-year time horizon is used, the consumption increases to 12.6-20 GtCO2-eq per year..."[9]

The data in Annex 2 compares the climate benefits of the two HFC phase down scenarios proposed by the Federated States of Micronesia (FSM) and North America (NA – Canada, Mexico, and the United States) using both GWP_{20} and GWP_{100} values. The GWP_{20} perspective better highlights the climate benefits of fast action on HFCs by the Montreal Protocol.

Adopting the 20-year GWP index has immediate policy ramifications.

- It would influence the level of the baseline as a GWP_{20} baseline would be higher than a GWP_{100} baseline.
- It would influence the order of how control steps are implemented, with the phase-out of substances with high GWP_{20} likely to be implemented first.
- It would redefine low GWP substances. While GWP_{100} values of some substances may seem deceptively attractive to some policy makers, the same substances measured using GWP_{20} become much less appealing. A prime example is HFC-32, with a GWP of 675 over 100 years and 2,330 over 20 years.
- It could lead to HFCs being taxed according to their climate impact across their atmospheric lifetime. The comparably high GWP_{20} values of most HFCs would result in high tax values. Fiscal instruments could thus be effective measures to significantly reduce projected HFC emissions within a very short time.

Summary

Governments in both industrialised and developing countries must set progressive restrictions on the use of HFCs, with an aim to their eventual phase-out. At the same time, they must encourage legislation and fiscal incentives (eg GWP-weighted greenhouse gas taxes), the uptake of low-climate impact technologies. This will guide industry towards natural refrigerants and foam blowing agents. These technologies are already available in most sectors and more are coming rapidly online.[10] Such measures will further encourage research and development of new HFC-free technologies.

The GWP_{20} index provides policy makers with a more accurate measure of the effect of climate action vis-à-vis HFCs over the next few decades. It should provide even greater incentive for governments to enact measures that progressively limit and phase out the use these potent greenhouse gases.

[9] Velders, Guus JM et al (2009). "The large contribution of projected HFC emissions to future climate forcing", PNAS, p4

[10] For a global survey of companies and industrial sectors working without HFCs, see the Greenpeace report: "Cool technologies: Working Without HFCs-2010"

ANNEX 1

Comparison of global projections of HFC emissions with regard to 100 year GWP and 20 year GWP metric

Prepared for Greenpeace International by Öko-Recherche, Germany, 2011

A. The scenarios considered in the comparison include:

1) Global projections by Velders et al 2009: BAU
2) Global projections by Öko-Recherche 2009: BAU

Table 3: Comparison of underlying methodologies and results of BAU scenarios by Velders et al (2009) and Öko-Recherche (2009).

	Velders et al (2009)	Öko-Recherche (2009)
Substances of interest	ODS substitutes: certain types of HFCs (HFC-134a, 152a, 245fa, 365mfc, and HFC blends: R404A, R410A)	All HFCs, PFCs, SF_6
Approach for projection	Substance based (by type of HFCs)	Sectoral approach (substances per sector)
Assumptions and data sources		
- Developed countries	2008-2020: Fixed growth rates of HFC demand (consumption) based on HFC sales data. 2020-2050: Growth rates proportional to population growth: 0.1 - 0.4%/yr.	2005-2020: Banks and emissions from IPCC/TEAP SROC report and UNEP TEAP 2009 report. 2020-2050: Sector-specific growth rates: 0 - 1%/yr.
- Developing countries	2008-2012: Trend of HCFC consumption in 2003-2007 extrapolated linearly. 2013-2050: Growth rates proportional to projected GDP: 3.8 - 6.3%/yr.	2005-2020: Banks and emissions from IPCC/TEAP SROC report and UNEP TEAP 2009 report. 2020-2050: Sector specific growth rates: 1 - 4.5%/yr.
Projected level of annual HFC emissions in 2050 (GWP100)	HFCs only: 5.5-8.8 GT CO_2 eq.	All substances: 4 GT CO_2 eq. HFCs only: 3.7 GT CO_2 eq.
Developed vs. developing countries	Consumption in developing countries exceeds consumption in developed countries by 800% by 2050.	25% of emissions from developed countries and 75% from developing countries in 2050.

The main reason for the differences of projected annual HFC emissions in 2050 between the Velders and the Öko-Recherche studies is the different long-term growth rates in developing countries (Velders: 3.8 – 6.3% vs. Öko-Recherche: 1 – 4.5%).

B. Comparison with regard to the time horizon of the GWP

<u>B.1 Öko-Recherche 2009 projections:</u>

For further comparison, only the types of HFCs considered in both the Velders and the Öko-Recherche projections are analysed (HFC-134a, 152a, 245fa, 365mfc, and HFC blends: R404A, R410A). Other additional substances included in Öko-Recherche projections are not explored further.

Table 4: Atmospheric lifetime and GWPs of HFC substances considered in both the Velders and the Öko-Recherche projections based on IPCC 4th AR and Öko-Recherche calculation of GWPs of blends:

Substance type	Lifetime (years)	GWP 20	GWP 100	GWP 500
HFC-134a	14	3,830	1,430	435
R404A	Components: 14-52	6,010	3,922	1,328
R410A	Components: 4.9 - 29	4,340	2,088	653
HFC-152a	1.4	437	124	38
HFC-245fa	7.6	3,380	1,030	314
HFC-365mfc	8.6	2,520	794	241

The following table gives the breakdown of substances in the BAU 2050 scenario. Large quantities of HFC-134a, R404A and R410A are emitted (air-conditioning and refrigeration) while emissions of HFC-152a, HFC-245fa and HFC-365mfc are rather small (foam blowing, aerosol applications). Depending on the choice of the time horizon of the GWP (GWP_{100} or GWP_{20}), the GWP-weighted emissions (MT CO_2 eq.) in 2050 differ considerably. Therefore, the contribution of each substance to total annual emissions in 2050 might vary depending on the time horizon of the GWP chosen. While the share of HFC-134a using its GWP_{100} value amounts to 20% of total HFC emissions in 2050, it climbs to 30% when using its GWP_{20} value.

Table 5: Öko-Recherche projections of share of HFC subtypes emissions in 2050

Substance type	Emitted quantities in 2050 (annual; metric kt)	GWP_{100}	Annual emissions (MT CO_2 eq) 2050 (GWP_{100})	Share of emissions by sub-types (GWP_{100})	GWP_{20}	Annual emissions (MT CO_2 eq) 2050 (GWP_{20})	Share of emissions by sub-types (GWP_{20})
HFC-134a	534.5	1,430	764	20%	3,830	2,047	30%
R404A	474	3,922	1,860	50%	6,010	2,851	42%
R410A	322.6	2,088	674	20%	4,340	1,400	21%
HFC-152a	0.14	124	0.02	negligible	437	0.06	negligible
HFC-245fa	55	1,030	56.5	1.5%	3,380	186	2.7%
HFC-365mfc	4.5	794	3.6	<1%	2,520	11.3	<1%
Other	36	-	342	ca. 8%	-	305	ca. 4%
Total	1,427		3,700	100%		6,800	100%

B.2 Velders (2009) projections:

The Velders projections need to be recalculated with GWP_{20} values in order to be compared with the GWP_{100} results. This recalculation is complicated by the fact that the Velders paper does not use metric quantities but GWP_{100}-weighted consumption and emission data. Hence the share of each type of HFC included in the projection needs to be estimated. To do this, we apply the breakdown of HFC shares from the ÖR projections (table 5) to the Velders data (low and high total emissions in 2050).

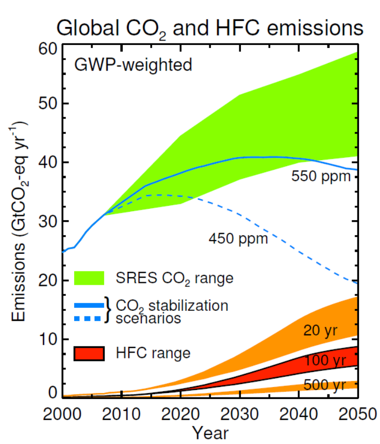
For the lower end of the Velders projections, emissions based on GWP_{20} values are equal to 10.8 GT CO_2 eq. (GWP_{100}: 5.5 GT CO_2 eq.) and for the higher end of the Velders projections, emissions based on GWP_{20} values amount to 17 GT CO_2 eq. (GWP_{100}: 8.8 GT CO_2 eq.).

Table 6: Velders low-range projections of 2050 emissions of most commonly used HFCs with GWP_{100} and GWP_{20}

Emissions 2050 (Velders low): 5.5 GT CO_2 eq.				
Substance type	Share of substance	Metric quantities (kt)	Annual emissions in 2050 GWP_{100} (MT CO_2 eq.)	Recalculated annual emissions in 2050 GWP_{20} (MT CO_2 eq.)
HFC-134a	20%	769	1,100	2,945
R404A	50%	701	2,750	4,213
R410A	20%	527	1,100	2,287
HFC-152a	2%	887	110	388
HFC-245fa	5%	267	275	902
HFC-365mfc	3%	208	165	524
Total	100%		5,500	11,259

Table 6a : Velders high-range projections of 2050 emissions of most commonly used HFCs with GWP_{100} and GWP_{20}

Emissions 2050 (Velders high): 8.8 GT CO_2 eq.				
Substance type	Share of substance	Metric quantities (kt)	Annual emissions in 2050 GWP_{100} (MT CO_2 eq.)	Recalculated annual emissions in 2050 GWP_{20} (MT CO_2 eq.)
HFC-134a	20%	1,231	1,760	4,715
R404A	50%	1,122	4,400	6,743
R410A	20%	843	1,760	3,659
HFC-152a	2%	1,419	176	620
HFC-245fa	5%	427	440	440
HFC-365mfc	3%	332	264	837
Total	100%		8,800	17,014



Graph 1: Comparison of emission projections based on GWP20, GWP100 and GWP500

These assumption-based calculations are confirmed by this graph from Velders, which compares HFC emission projections based on their GWP_{20}, GWP_{100} and GWP_{500} values[11].

Emissions projections in 2050 measured using GWP_{20} values are in the range of 11 to 17 GT CO_2 eq., which is fully in line with the results above.

[11] Based on Velders et al (2009), PNAS.

C. Overview of the comparison of HFC emission projections

The following table summarises the differences between the Velders and the Öko-Recherche projections with regard to the GWP_{20} and GWP_{100} metrics.

The share of projected HFC GWP_{20}–weighted emissions is higher in the Velders projection and varies between 16 and 24% of total projected annual GWP_{20}-weighted GHG emissions in 2050 (BAU; ie no adoption of a CO_2 stabilisation target).

Table 7: Comparison of HFC emission projections by Velders and Öko-Recherche based on GWP_{100} and GWP_{20}

	Velders et al (2009)	Öko-Recherche (2009)
GWP_{100}		
Projected level of annual HFC emissions in 2050	5.5-8.8 GT CO_2 eq.	3.7 GT CO_2 eq.
Context: GHG emissions in 2050 projected by IPCC SRES scenarios	9-22% (BAU for other GHG emissions: 40-60 GT CO_2 eq.)	5.8% (BAU for other GHG emissions: 64 GT CO_2 eq.)
GWP_{20}		
Projected level of annual HFC emissions in 2050	11.3 – 17 GT CO_2 eq.	6.8 GT CO_2 eq.
Context: GHG emissions in 2050 projected in IPCC SRES	16% - 24% (assumed BAU for other GHG emissions: 70 GT CO_2 eq.)	8.4 % (BAU for other GHG emissions: 81 GT CO_2 eq.)

D. Summary Findings

1. A general statement on the difference of applying GWP_{20} versus GWP_{100} values to a basket of HFCs has inherent uncertainties since it depends on the share of each HFC within the substance mix[12].
2. In the comparison between the Velders and Öko-Recherche projections absolute annual HFC emissions weighted by GWP_{20} are roughly about twice as high as absolute annual HFC emissions weighted by GWP_{100} in the year.
3. The atmospheric lifetimes of the HFCs considered in the comparison of projections range from 1.4 to 52 years. Therefore, the GWP_{20} metric reflects more accurately the actual global warming impact of HFCs.
4. The short-term global warming impact of HFCs becomes particularly relevant when deciding about policy measures addressing climate change in the near term.
5. Climate policies should refer to the short term global warming impact of HFCs and aim at near term HFC consumption and emission reductions. For example, tax schemes for HFCs refer to their GWPs. The use of GWP_{20} instead of GWP_{100} would lead to HFCs being taxed according to their climate impact across their atmospheric lifetime. Due to the comparably high GWP_{20} values of most HFCs, fiscal instruments could represent effective measures to significantly reduce projected HFC emissions within very short time.

[12] High shares of substances with high GWP_{20} values compared to their GWP_{100} values will result in higher total GWP_{20} weighted emissions. The SF_6 and PFCs, the other gases referred to as 'fluorinated greenhouse gases' in the Kyoto Protocol, have much longer atmospheric lifetimes – on the order of several thousand years - and very high GWPs. The appropriate metric to reflect their contribution to global warming emissions is GWP_{100} or GWP_{500} instead of GWP_{20}.

ANNEX 2

Comparison of the impact of HFC phase down schedules with regard to GWP_{20} and GWP_{100}

Prepared for Greenpeace International by Öko-Recherche in cooperation with HEAT GmbH, Germany, 2011

A. Projection for global HFC consumption (BAU)

In the early 1990s, HFCs were developed as ozone-friendly substitutes for CFCs and HCFCs, which are being phased out under the Montreal Protocol. The Montreal Protocol regime controls production and consumption of CFCs and HCFCs but the choice of alternatives is not regulated. As HFCs have been marketed as the main alternatives from the beginning, their use has increased greatly and they are now the chemicals of choice in many applications in developed countries (e.g. in commercial refrigeration, stationary and mobile air conditioning). The Montreal Protocol can thus be considered as the main driver for the use of HFCs and related HFC emissions.

The significant global warming potential of HFCs and their climate impact has caused global concerns and they are, among other fluorinated greenhouse gases such as PFCs and SF_6, controlled under the UNFCCC and the Kyoto Protocol.

The current discussion is focussed on the question of how to link the work on HFCs done under the UNFCCC with the further phase out of ODS under the Montreal Protocol more closely in order to avoid a high increase in HFC emissions. One set of responses to this discussion has been the introduction of amendments to the Montreal Protocol which would phase down HFC production and consumption.

A global model of HFC consumption has been developed on the basis of sectoral data for developed and developing countries from recent TEAP reports. In order to generate information on future HFC consumption, a business-as-usual (BAU) scenario has been calculated.

For this BAU scenario, assumptions on the growth of each sector consuming HFCs were made for developed countries (A2 countries) and developing countries (A5 countries).

The following graphs (Graph 2, Graph 3) illustrate this scenario, Tables 8 and 9 present projected consumption levels in GWP_{100} and GWP_{20} metrics.

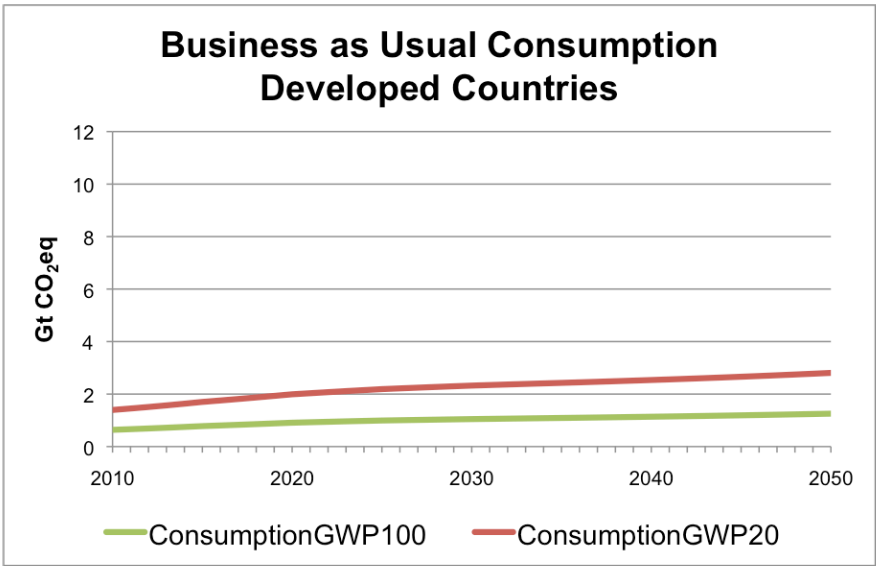
Table 8: Projections for HFC consumption (Mt CO_2 eq) in developed and developing countries in a BAU scenario expressed in GWP_{100} metrics.

Consumption BAU GWP_{100} (Mt CO_2 eq.)	2010	2020	2030	2040	2050
A2	637	909	1,047	1,137	1,253
A5	163	1,179	2,570	3,802	5,008
Global	1,016	2,088	3,617	4,939	6,261

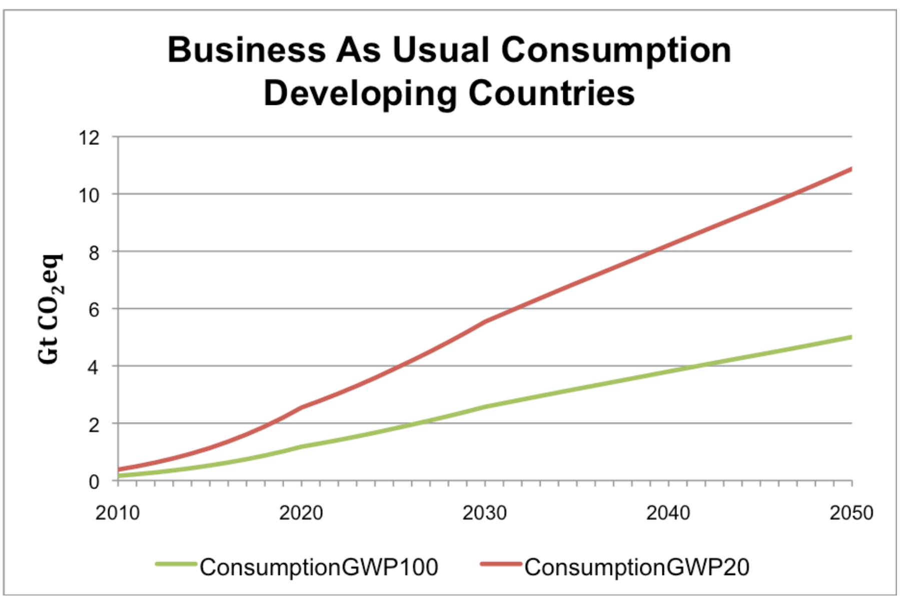
Table 9: Projections for HFC consumption (Mt CO_2 eq) in developed and developing countries in a BAU scenario expressed in GWP_{20} metrics.

Consumption BAU GWP_{20} (Mt CO_2 eq.)	2010	2020	2030	2040	2050
A2	1,395	1,992	2,323	2,537	2,807
A5	379	2,546	5,539	8,209	10,875
Global	1,558	4,538	7,862	10,746	13,182

Graph 2: HFC consumption in developed (A2) countries (2010-2050, BAU scenario)



Graph 3: HFC consumption in developing (A5) countries (2010-2050, BAU scenario)



B. How to address the projected increase in HFC consumption politically?

HFCs are produced and marketed globally, which means that HFC production often takes place in one country while HFC consumption and related emissions take place in other countries. Therefore, local or regional political action (eg the European F-gas Regulation (EC) No 842/2006) can only address the contribution of HFCs to global warming to a minor extent. Large-scale emission reductions are only achievable at the international level.

C. HFC phase down scenarios as proposed under the Montreal Protocol

The Montreal Protocol (MP) is in a unique position as it deals with all the industries and sectors that rely on HFCs while not regulating them. However, the Montreal Protocol could introduce stepwise control limits for the production and consumption of HFCs, similar to how it regulated similar ODS. Indeed, two proposals amending the Montreal Protocol to include HFCs were submitted in 2009 and re-submitted in 2010 and 2011, one by the Federated States of Micronesia (FSM) and the other by North America (NA). Both proposals call for controls on the production and consumption of HFCs. Table 10 compares these proposals.

Table 10: Comparison of the amendment proposals to the Montreal Protocol submitted in 2011. The total baseline has been estimated based on data of recent TEAP reports.

MP 2011 amendment proposals	NA				FSM			
	A2		A5		A2		A5	
Proposed Baseline	85% of HCFC plus HFC consumption		HCFC consumption		Combined HCFC and HFC consumption		HCFC consumption	
Baseline years	2005-2008		2005-2008		2004-2006		2007-2009	
Year of first control level	2015		2017		2014		2020	
Proposed first control level (freeze level)	90%		100%		85%		85%	
Final phase down level (tail)	15%		15%		10%		10%	
Year of final step down	2033		2043		2031		2036	
Total baseline (Mt CO_2 eq.; GWP100)	732		563		697		654	
Control schedule	2015	90%	2017	100%	2014	85%	2020	85%
	2017	80%	2021	80%	2017	70%	2023	70%
	2020	70%	2025	70%	2020	55%	2026	55%
	2025	50%	2029	50%	2023	45%	2029	45%
	2029	30%	2035	30%	2026	30%	2032	30%
	2033	15%	2043	15%	2029	15%	2035	15%
					2031	10%	2037	10%

The FSM proposal suggests stricter control steps and a lower remaining level of tail consumption. A long grace period could potentially allow developing countries to introduce HFC technology on a large scale before their first control step. The NA proposal, by contrast, allows higher tail consumption and the grace period for developing countries is shorter.

In order to start reducing HFC emissions as soon as possible, the grace period for developing countries should be short since high growth of HFC consumption is expected in developing countries. This is due to both the HCFC phase out and a general increase of refrigeration and air conditioning needs.

D. Effect of using the GWP_{20} metrics in phase down schedules

Using the GWP_{20} metrics would significantly influence the implementation of the proposed phase down schedules:

(a) It would influence the level of the baseline: the GWP_{20} baseline is higher than the GWP_{100} baseline.[13]

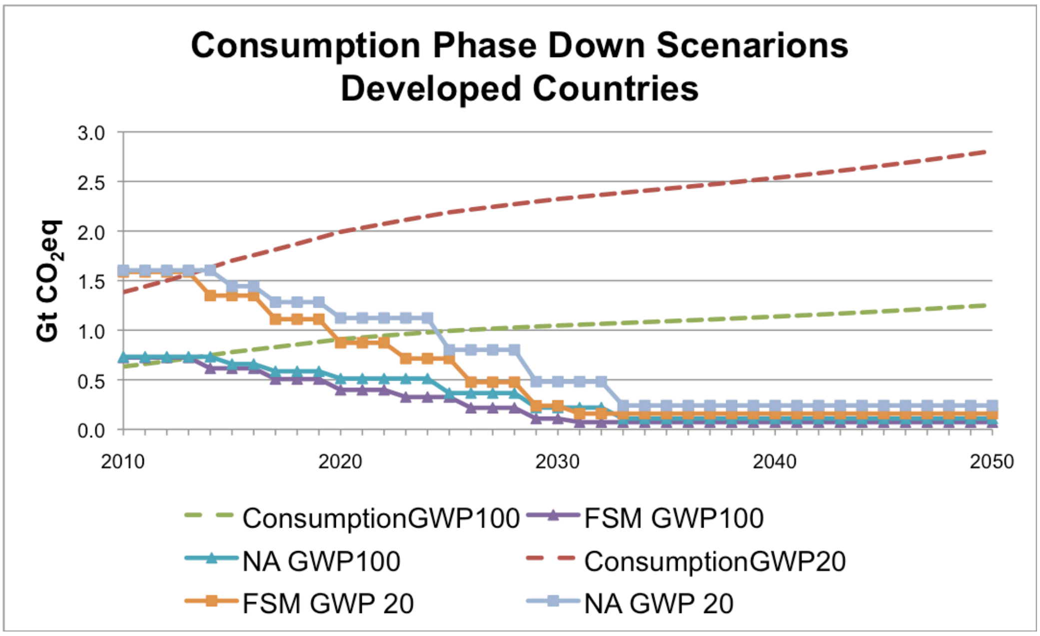
(b) It would concern the implementation of control steps: Phase out of substances with high GWP_{20} value is likely to be implemented first. Early reductions of these substances, for example HFC-134a (GWP_{100}: 1,430; GWP_{20}: 3,830), R404A (GWP_{100}: 3,922; GWP_{20}: 6,010), R410A (GWP_{100}: 2,088; GWP_{20}: 4,340), would significantly reduce HFC emissions during equipment lifetime and at end-of life within the next 10-20 years.

The use of GWP_{20} metrics would influence the choice of HCFC alternatives: Ambitious early HFC phase down targets based on GWP_{20} values would make the introduction of HFC technology and new HFC equipment much more unattractive. Additional funding by the ExCom for low GWP technologies (+25%) is likely to support the selection of non-HFC alternatives and would contribute to sustainable long-term solutions.

The following graphs (Graph 4, Graph 5) illustrate these phase down scenarios for developed and developing countries based on both, GWP_{20} and GWP_{100}. BAU consumption is included in the graphs for comparison. Underlying data on HFC consumption are given in tables 11 and 12.

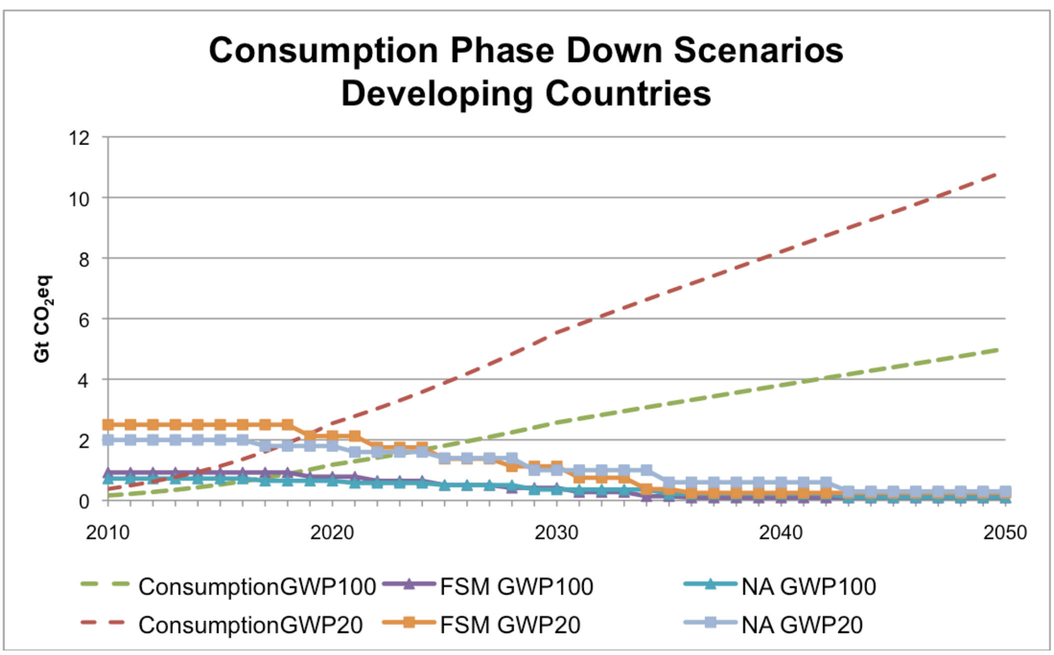
[13] A5 countries are implementing HCFC phase out schedules under the Montreal Protocol. In both proposals, the consumption baseline for developing countries combines HFC and HCFC consumption.

Graph 4: Phase down scenarios for HFC consumption in developed countries (2010-2050).



BAU consumption in 2050 is projected to increase to 1.25 Gt CO_2 eq. (GWP_{100}) and 2.8 Gt CO_2 eq (GWP_{20}) respectively. The differences between NA scenario and FSM scenario displayed along with the different steps according to GWP_{20} and GWP_{100} metrics in both scenarios.

Graph 5: Phase down scenarios for HFC consumption in developed countries (2010-2050).



BAU consumption in 2050 is projected to increase to 5 Gt CO_2 eq. (GWP_{100}) and 10.8 Gt CO_2 eq (GWP_{20}) respectively. The first control step for developing countries in the NA proposal is in 2017 (NA) or 2020 (FSM).

Table 11: HFC consumption according to phase down schedules proposed in GWP_{100} metrics.

Consumption GWP_{100} (Mt CO_2 eq.)	2010	2020	2025	2030	2035	2040	2050
NA							
A2	732	512	366	220	110	110	110
A5	563	563	394	282	196	196	85
Global	1,295	1,075	760	502	306	306	195
FSM							
A2	724	399	326	109	72	72	72
A5	654	560	458	294	98	65	65
Global	1,378	959	784	403	170	137	137
For comparison:							
BAU							
A2	637	909	993	1,047	1,090	1,137	1,253
A5	379	1,179	1,808	2,570	3,195	3,802	5,008
Global	1,016	2,088	2,801	3,617	4,285	4,939	6,261

Table 12: HFC consumption according to phase down schedules proposed in GWP20 metrics.

Consumption GWP_{20} (Mt CO_2 eq.)	2010	2020	2025	2030	2035	2040	2050
NA							
A2	1,604	1,123	802	481	240	240	240
A5	1,235	1,235	864	617	370	370	185
Global	2,839	2,358	1,666	1,098	610	610	425
FSM							
A2	1,587	873	714	238	159	159	159
A5	1,433	1,218	1,003	645	215	143	143
Global	3,020	2,091	1,717	883	374	302	302
For comparison:							
BAU							
A2	1,395	1,992	2,189	2,323	2,427	2,537	2,807
A5	379	2,546	3,879	5,539	6,894	8,209	10,875
Global	1,558	4,538	6,068	7,862	9,321	10,746	13,182

E. The relationship between the phase down of HFC production and consumption and HFC emissions

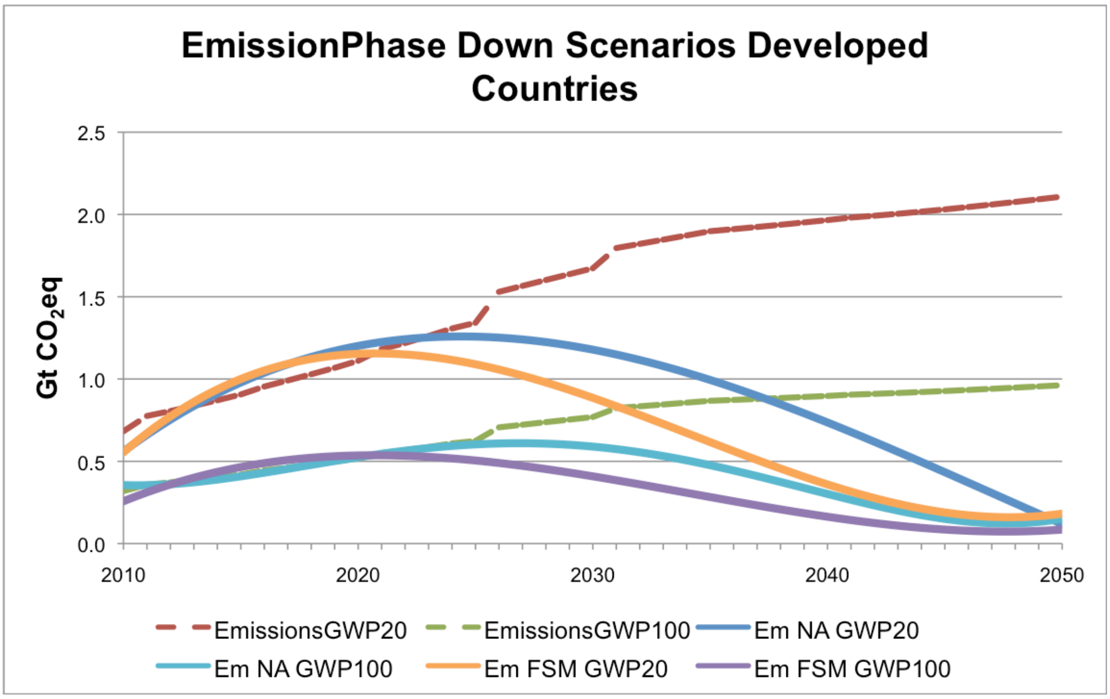
HFC consumption will lead to HFC emissions during manufacture of halocarbons and products and equipment containing HFCs (manufacturing emissions), during product life (use phase emissions) and at the end of product life (disposal emissions).

While it is technically possible to reduce emissions to some extent (eg through containment measures minimising leakage of HFC refrigerants during the lifetime of refrigeration and air-conditioning equipment; recovery and recycling of HFC refrigerants during equipment life and at end of life), such measures cannot eliminate all HFC emissions. Therefore, only a robust phase-down (and eventual phase-out) of HFCs will substantially reduce HFC emissions in the long term.

The following graphs (Graph 5, Graph 6) show remaining HFC emissions in the event that the phase down scenarios for HFC consumption suggested under the Montreal Protocol are implemented. Underlying data on HFC emissions are given in tables 13 and 14.

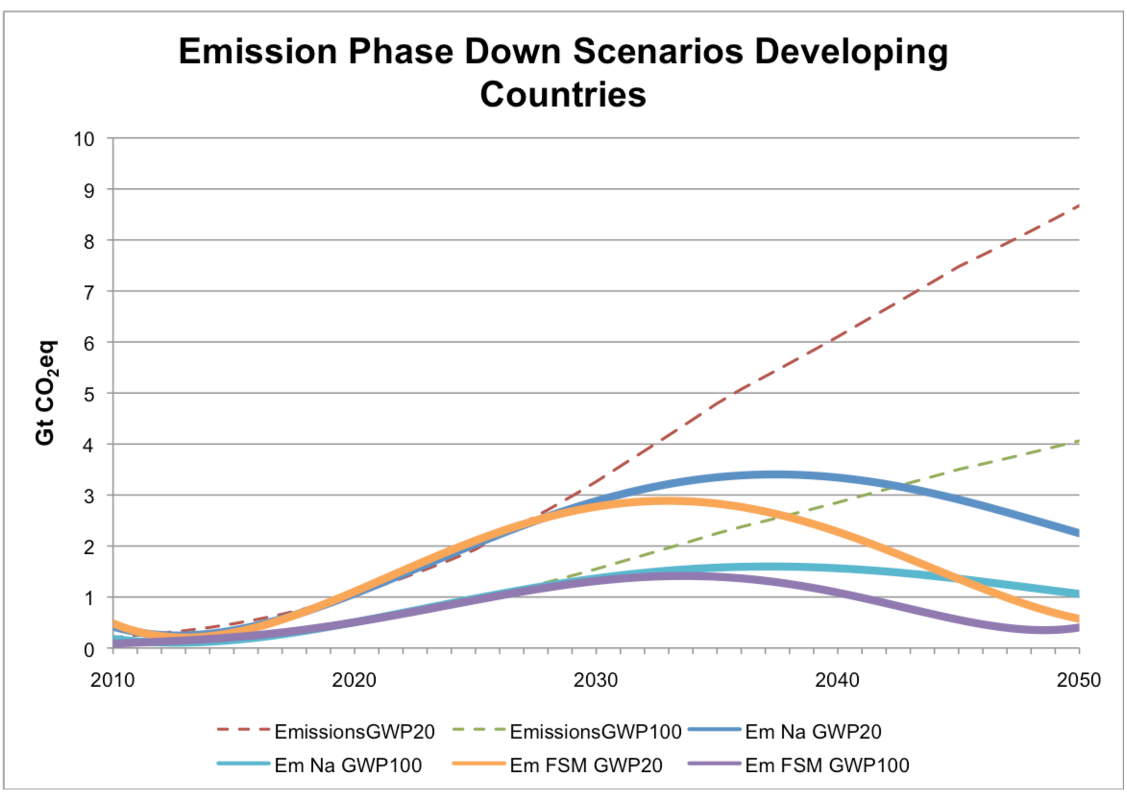
The basic assumption is made that HFC emissions are lagging 10 years behind HFC consumption. These 10 years are estimated to reflect the average lifetime of equipment containing HFCs. HFC emissions under the BAU scenario are given for comparison. HFC emissions are only likely to decrease significantly in the time horizon until 2050 when early phase-down steps are implemented in both developed and developing countries.

Graph 6: Emission phase-down scenarios in developed countries (2010-2050).



HFC emissions in developed countries after implementation of phase down of HFC consumption. HFC emissions will peak in 2025-2030 at ca. 1.2 Gt CO_2 eq. (GWP_{20})/ 0.5 Gt CO_2 eq. (GWP_{100}). Remaining HFC emissions in 2050 are around 0.2-0.3 Gt CO_2 eq (GWP_{20})/ 0.1 Gt CO_2 eq. (GWP_{100}). Under the FSM scenario, HFC emissions decrease earlier due to earlier phase down steps for A2.

Graph 7: Emission phase down scenarios in developing countries (2010-2050).



HFC emissions in developing countries after implementation of phase down of HFC consumption and production in BAU (2050: 8.7 Gt CO_2 eq (GWP_{20})/ 4 Gt CO_2 eq (GWP_{100}). In the phase-down scenarios (NA and FSM), HFC emissions will peak later in the period 2030-2040 at ca. 2.8 – 3.3 Gt CO_2 eq. (GWP_{20})/ 1.3-1.6 Gt CO_2 eq. (GWP_{100}). Remaining HFC emissions in 2050 are around 0.8-2.6 Gt CO_2 eq (GWP_{20})/ 0.4-1.2 Gt CO_2 eq. (GWP_{100}).

Table 13: Projected impact of phase down of HFC consumption according to proposed schedules on HFC emissions (illustrative values; Mt CO_2 eq). in GWP_{100} metrics.

Emissions GWP_{100} (Mt CO_2 eq.)	2010	2020	2025	2030	2035	2040	2050
NA							
A2	319	518	562	538	434	269	144
A5	84	500	927	1,395	1,574	1,427	1,219
Global	403	1,018	1,489	1,933	2,008	1,696	1,363
FSM							
A2	319	518	530	423	260	95	95
A5	84	500	927	1,317	1,237	1,284	400
Global	403	1,018	1,457	1,740	1,497	1,379	495
BAU							
A2	319	518	624	769	868	897	963
A5	84	500	927	1,550	2,248	2,853	4,063
Global	403	1,018	1,551	2,319	3,116	3,750	5,026

Table 14: Projected impact of phase down of HFC consumption according to proposed schedules on HFC emissions (illustrative values; Mt CO_2 eq) in GWP_{20} metrics.

Emissions GWP20 (Mt CO_2 eq.)	2010	2020	2025	2030	2035	2040	2050
NA							
A2	682	1,111	1,207	1,171	949	590	316
A5	203	1,055	1,934	2,936	3,356	3,051	2,602
Global	885	2,166	3,141	4,107	4,305	3,641	2,918
FSM							
A2	682	1,111	1,140	920	570	200	200
A5	203	1,055	1,934	2,773	2,790	2,746	867
Global	885	2,166	3,074	3,693	3,360	2,946	1,067
BAU							
A2	682	1,111	1,342	1,673	1,898	1,967	2,109
A5	203	1,055	1,934	3,263	4,795	6,103	8,674
Global	885	2,166	3,276	4,936	6,693	8,070	10,783

F. The share of HFC emissions out of projected total GHG emissions

Table 15 shows an assumed BAU scenario of total global GHG emissions, which implies that no CO_2 stabilization target is adopted (Bar 1).

Bar 2 refers to projected HFC emissions in 2030 and 2050 (GWP_{20}, GWP_{100}) in the BAU scenario presented earlier.

In bars 3 and 4 of the table, remaining HFC emissions after phase down of HFC consumption according to the NA proposal (“NA scenario”, paragraph 3) and the FSM proposal (“FSM scenario”, paragraph 4) shown in absolute quantities (Gt CO2 eq). Furthermore, remaining HFC emissions are compared to global GHG emissions (bar 1) and projected HFC emissions in the BAU scenario (bar 2), which results in HFC emission reductions caused by the scenarios (%; compared to BAU).

Table 15: Share of HFC emission of projected total GHG emissions based on BAU and phased-down scenarios

		2030		2050	
		GWP20	GWP100	GWP20	GWP100
1	Projected total GHG emissions in a BAU scenario (Gt CO_2 eq.)				
	Global GHG emissions	50	40	80	70
2	HFC emissions in a BAU scenario (Gt CO_2 eq.)				
	BAU	4.9	2.3	10.8	5
	HFC emissions after implementation of HFC phase down (Gt CO_2 eq.)				
3	NA scenario	4.1	1.9	2.9	1.4
	Share out of total GHG emissions (BAU in line 1: 100%)	8.2%	4.75%	3.6%	2%
	Share out of HFC em. acc to HFC BAU (line 2: 100%)	84%	83%	27%	28%
	HFC emission reductions	16%	17%	73%	72%
4	FSM scenario	3.7	1.7	1.1	0.5
	Share out of total GHG emissions (line 1: 100%)	7.4%	4.25%	1.4%	0.7%
	Share out of HFC em. acc to HFC BAU (line 2: 100%)	76%	74%	10%	10%
	HFC emission reductions	24%	26%	90%	90%

Comparison of projected total GHG emissions in a BAU scenario (bar 1), HFC emissions in a BAU scenario (bar 2) and HFC emissions after implementation of HFC phase-down in scenarios based on the amendment proposals submitted (NA scenario: bar 3; FSM scenario: bar 4) and calculated shares of remaining HFC emissions and HFC emission reductions in 2030 and 2050 in GWP_{20} and GWP_{100} metrics.

Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

The Greenpeace F-Gas Campaign aims to rapidly phase-out the global use of all ozone-depleting and global warming fluorocarbons.

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