Selecting and Using GWP values for Refrigerants

Summary and Recommendations

For refrigerant users and equipment designers, the values contained in the F-Gas Regulation annex (IPCC Third Assessment Report TAR GWP values) are the most appropriate at present.

Companies designing refrigerants should also be aware of any potential impacts from the use of AR4 values.

Companies voluntarily reporting their emissions as part of their corporate social responsibility reporting could select IPCC Second Assessment Report SAR, TAR or Fourth Assessment Report AR4 values. However it is essential that only one database is used to ensure consistency and to enable trends in emissions to be clearly seen. The source of the GWPs should be referenced. Any change in GWP source values should be noted and the emissions restated when the change is made. The use of 20 and 500 year time horizon GWPs is not recommended.

Selected Refrigerant GWPs			
HFCs	SAR 1995	**TAR 2000 Used by F-Gas**	AR4 2007
HFC-32	650	550	675
HFC-134a	1300	1300	1430
R-407A	1770	1990	2107
R-407C	1526	1653	1774
R-404A	3260	3784	3922
R-410A	1725	1975	2088
R-507	3300	3850	3985
R-422D	2232	2623	2729
R-427A	1828	2013	2138
For comparison not covered by F-Gas or Kyoto			
HCFC-22	1500	1700	1810

Global Warming Potential (GWP)

Simple Definition

The GWP of a refrigerant is its global warming impact relative to the impact of the same quantity of carbon dioxide over a 100 year period.

Complete Definition

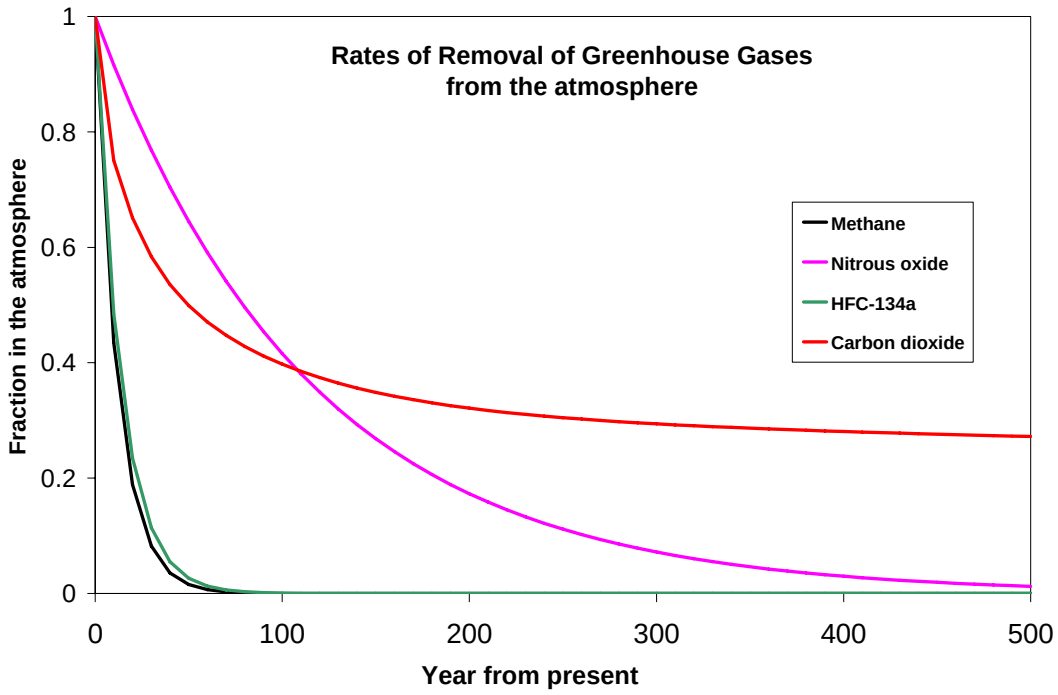
The Global Warming Potential of a refrigerant is defined as the integrated radiative forcing over a "time horizon" of 100 years following an assumed release of 1kg divided by the integrated radiative forcing over the same period from release of 1 kg of carbon dioxide. Radiative forcing is the specific increase in infrared absorption in $Wm^{-2}ppb^{-1}$ (Watts per square metre at the Earth's surface per part per billion

concentration of the material). All effects beyond 100 years are disregarded; thus Global Warming Potential captures all of the effect of an HFC but less than 40% of the total effect from CO_2.

Why are GWPs used

Basically, the intention is to put all greenhouse gas emissions onto a common scale and GWP, however imperfect, remains the recommended metric to compare future climate impacts of emissions of long-lived gases.

The adequacy of the GWP concept has been widely debated since its introduction; uncertainties and changes arise from the models used to calculate radiative forcing.



However, the main problem arises from using CO_2 as the reference gas because of the very long "tail" on its atmospheric lifetime.[1] This is shown in the chart, which compares rates of removal of greenhouse gases from the atmosphere.

The Intergovernmental Panel on Climate Change (IPCC) have concluded that "However as long as it has not been determined, neither scientifically, economically nor politically, what the proper time horizon for evaluating 'dangerous anthropogenic interference in the climate system' should be, the lack of temporal equivalence does not invalidate the GWP concept or provide guidance as to how to replace it."[2]

[1] The first 2/3 of a CO_2 emission is removed from the atmosphere relatively quickly (within 100 years or so). The other 1/3 remains for several thousand years. This affects the choice of time horizon.

[2] From IPCC AR4 Chapter 2 Changes in Atmospheric Constituents and in Radiative Forcing 2.10.1 Definition of an Emission Metric and the Global Warming Potential pages 210 and 211

The 100 year time horizon for GWPs

Wide variations in GWPs may be quoted and mis-used for HFCs. GWP values for time horizons of 20, 100 and 500 years are published by IPCC in their Assessment Reports and the values change between the reports, which are produced roughly every five years.

GWPs are calculated relative to CO_2 up to the "time horizon", with all effects beyond that time period being disregarded. Because CO_2 has an atmospheric lifetime much longer than HFCs, then a shorter time horizon results in higher GWPs for HFCs. However the most commonly used HFCs are removed from the atmosphere quickly compared to CO_2 so that short time horizons overstate their relative contribution to global warming.

This is why 100 year time horizon was selected to provide an appropriate compromise between short and long term effects.

Uncertainty for GWP Values- why they have changed over time

GWP values have been refined over the past two decades with the development of atmospheric science. As GWPs of refrigerant are relative to CO_2, any change in the calculated global warming impact (radiative forcing) of CO_2 directly affects the refrigerant GWP.

In addition, GWPs also depend on the atmospheric lifetime and infra-red absorption spectra (radiative efficiencies) of the refrigerants. Atmospheric lifetime is linked to the reaction rates for the various processes that convert the refrigerant into very low GWP breakdown products and improved knowledge about atmospheric science and radiative efficiencies for HFCs has led to revisions in their GWPs.

Uncertainty in refrigerant GWP is stated to be ±35% for both the SAR (Second Assessment Report, 1995) and TAR (Third Assessment Report, 2000). Further revisions to refrigerant GWPs were made in AR4 (Fourth Assessment Report, 2007), with reduced uncertainties compared to previously quoted values.

The GWPs for Second, Thrid and Fourth Assessment Reports for 100 year time horizon GWPs are shown in the table for the most widely used HFCs. Also shown are the GWPs for methane and nitrous oxide.

Revision of GWPs from Second to Fourth Assessment Reports					SAR to AR4
100 year GWPs		SAR 1995	TAR 2000	AR4 2007	% Change
Methane	CH4	21	23	25	19
Nitrous oxide	N2O	310	296	298	-4
HFC-32	CH2F2	650	550	675	4
HFC-125	CF3CHF2	2800	3400	3500	25
HFC-134a	CF3CH2F	1300	1300	1430	10
HFC-143a	CF3CH3	3800	4300	4470	18
HFC-152a	CH3CHF2	140	120	124	-11

How important are the differences in GWP

Time Horizon

The use of 100 year time horizons is recommended and indeed these are the only GWPs referenced in the Kyoto Protocol and F-Gas Regulation for compliance and reporting purposes.

GWPs at a 20 year time horizon are sometimes quoted to accentuate the contribution of HFCs to global warming. Using 20 year time horizons for HFCs distorts the relative contribution of CO_2 (over 90% of it is *ignored*) and does not contribute to an informed and objective assessment of the use of HFCs.

Similarly 500 year time horizon GWPs should not be used for HFCs as they do not reflect the agreed balance between short and long term effects.

It is not permissible, from scientific or legal points of view, to mix GWP time horizons or to cherry pick values from the databases in different IPCC Reports.

The GWPs for 20,100 and 500 year time horizons are shown in the table for the most widely used HFCs.

Third Assessment Report (TAR) GWPs				
		Time Horizon		
		20 years	**100 years**	*500 years*
HFC-32	CH2F2	*1800*	**550**	*170*
HFC-125	CF3CHF2	*5900*	**3400**	*1100*
HFC-134a	CF3CH2F	*3300*	**1300**	*400*
HFC-143a	CF3CH3	*5500*	**4300**	*1600*
HFC-152a	CH3CHF2	*410*	**120**	*37*

Using IPCC Assessment Report GWP values

Comparing technology options

The GWPs of the widely used HFC refrigerant components have changed by a maximum of 25% between the SAR values (1995) and the AR4 values (2007). These changes have essentially no impact on decision making when used for TEWI (Total Equivalent Warming Impact) or LCCP (Life Cycle Climate Performance) calculations, which are used to compare alternative technology options.

Reporting and Legal Requirements

The F-Gas Regulation

The F-Gas Regulation EC842/2006 uses Third Assessment Report GWP values. These were used because they were the most recent values available from IPCC at the time the F-Gas Regulation was finalised. In general, the source of GWP values has no impact on the application of the F-Gas Regulation except where it is used as a

threshold for compliance obligations. The 150 GWP sets a boundary for preparations (refrigerant blends) for the major compliance obligations. Preparations with a GWP less than 150 are excluded from the obligations except for destruction. However all individual HFCs listed in Annex I Part 1 of the Regulation are subject to all the F-Gas requirements.

It is unknown at this point whether the F-Gas review will result in the referencing of the most recent GWP values at the time of the review although this is possible according to Article 10 Review paragraph 1(k) :

> *Assess whether Community provisions concerning the global warming potential of fluorinated greenhouse gases should be amended; any changes should take account of technology and scientific developments and the need to respect industrial planning timescales.*

Reporting

The Kyoto Protocol references Second Assessment Report GWP values for the purposes of reporting and compliance. This arrangement is expected to continue until the end of 2012 (the end of the first commitment period). It is possible that different arrangements will apply from 2012 but as any reductions must be referenced back to a baseline period, any change in GWPs will require a revision of the baseline emissions. It is worthwhile noting that the GWPs of two of the major GHGs methane and nitrous oxide (N_2O) have changed by +19% and –4% respectively between SAR and AR4. These changes would also impact on any baseline revisions, so it is not just an issue for HFCs.

At present AR4 GWP values are not used in enacted legislation, but the proposed HFC legislation in the U.S.A. references AR4 values. In this case it is important to be consistent from the start as a HFC cap and phase-down (not phase-out) is proposed. In principle TAR GWP values could have been used.