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Selecting and Using GWP values for Refrigerants

Summary

Refrigerant GWP values have been revised with each new IPCC Assessment Report. Regulations and guidance for the use of GWP values typically use the most up to date GWP values.

The F-Gas Regulation 517/2014 uses Fourth Assessment Report AR4 values and has measures that use GWP limits for applications and servicing. In addition, it has a cap and reduction, based on CO2 equivalents, for the HFCs that can be placed on the market, using quotas issued to producers and importers of HFCs.

The GWP values used in the F-Gas Regulation are in the downloadable logbook that can be used to meet the servicing and maintenance requirements.

The previous F-Gas Regulation 842/2006 used IPCC Third Assessment Report TAR GWP values.

All the IPPC Assessment Report values are available here. Change link to https://www.ipcc.ch/

For refrigerant users and equipment designers, the values contained in the F-Gas Regulation 817/2014 annex (IPCC Fourth Assessment Report AR4 GWP values) are the most appropriate at present.

Companies designing refrigerants should also be aware of any potential impacts from the use of AR5 values. The Commission is empowered by the F-Gas review article to update the GWPs of the substances listed in the F-Gas Regulation annexes.

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.

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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 CO2 [1].

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. 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."

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. The most commonly used HFCs are removed from the

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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.

Uncertainties of 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%, a value that has remained substantially unchanged since the Second Assessment Report (SAR). Uncertainties in refrigerant GWPs are dominated by the uncertainty in the reference gas, CO_2.

The GWPs listed in the Assessment Reports for 100-year time horizons are shown in the table for the most widely used HFCs. Also shown are the GWPs for methane and nitrous oxide.

A detailed explanation of the review undertaken for GWPs in preparation for the Fifth Scientific Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC) is in the Appendix.

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.

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The GWPs for 20, 100- and 500-year time horizons are shown in the table for the most widely used HFCs. The fifth Assessment Report (AR5) does not contain values for 500-year GWPs.

GWPs for common HFCs and other greenhouse gases (CO_2 = 1 at any time horizon) [2]

	Assessment	**AR4**			**AR5**	
	Time Horizon, years	*20*	**100**	*500*	*20*	*100*
HFC-32	CH_2F_2	*2330*	**675**	*205*	*2430*	*677*
HFC-125	CF_3CHF_2	*6350*	**3500**	*1100*	*6090*	*3170*
HFC-134a	CF_3CH_2F	*3830*	**1430**	*435*	*3910*	*1300*
HFC-143a	CF_3CH_3	*5890*	**4470**	*1590*	*6940*	*4800*
HFC-152a	CH_3CF_2H	*437*	**124**	*38*	*506*	*138*
HFO-1234yf	CH_2=$CHCF_3$	*n.a.*	*n.a.*	*n.a.*	*1*	*<1*
HFO-1234ze(E)	Trans- CF_3CH=CFH	*n.a*	*n.a*	*n.a*	*4*	*<1*
HFO-1336mzz(Z)	Cis-CF_3CH=$CHCF_3$	*n.a*	*n.a*	*n.a*	*6*	*2*
HCFO-1233zd(E)	Trans-CHCl=$CHCF_3$	*n.a*	*n.a*	*n.a*	*5*	*1*
Methane	CH_4	*72*	**25**	*7.6*	*84*	*28*
Nitrous oxide	N_2O	*289*	**298**	*153*	*264*	*265*

Using IPCC Assessment Report GWP values

Comparing technology options

The GWPs of the widely used HFC refrigerant components have changed by a maximum of 26% between the SAR values (1995) and the AR5 values (2013). 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 to UNFCCC, the Paris Agreement, compliance for Parties to the Kyoto Protocol and the Montreal Protocol

The Rio Convention (United Nations Framework Convention on Climate Change - UNFCCC) now references Fourth Assessment Report (AR4) GWP values for the purposes of national reporting of greenhouse gas emissions (national "Greenhouse Gas Inventories"). In addition to the greenhouse gases included in the 2006 IPCC Guidelines, the 2019 Refinement includes gases for which global warming potential (GWP) values are given in one of the subsequent IPCC Assessment Reports, unless the gases are covered by Annexes A through E of the Montreal Protocol. (Annex F of the Montreal Protocol lists hydrofluorocarbons, which are included in the 2019 Refinement.) The 2019 Refinement also provides estimation methods for halogenated greenhouse gases for which GWP values were not available from IPCC Assessment Reports at the time the 2019 Refinement was developed [3].

The European F-Gas Regulation (517/2014) also uses GWPs from AR4. The Montreal Protocol as a result of the Kigali Amendment includes AR4 GWP values for HFCs in its Annexes. Reporting and Review under the Paris Agreement establishes an Enhanced Transparency Framework (ETF) that builds on the current, solid measurement, reporting and verification system under the Convention [4].These are different from the values used during the first commitment period of the Kyoto Protocol to the Convention (which used GWPs from the Second Assessment Report).

It is worthwhile noting that the GWPs of two of the major GHGs - methane and nitrous oxide (N_2O) - have changed by +43% and –15% respectively between SAR and AR5.

Sources:

[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 Table 2.14 and AR5 Table 8.A.1

[3] See https://www.ipcc.ch/site/assets/uploads/2019/06/19R_V0_01_Overview_advance.pdf

[4] See https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-paris-agreement/reporting-and-review-under-the-paris-agreement

APPENDIX

Global Warming Potentials revision process in 2013

In preparation for the Fifth Scientific Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC), the published literature concerning the Radiative Efficiencies (REs) of halogen containing greenhouse gases was systematically reviewed. Revised atmospheric lifetimes for carbon dioxide were used and so resulted in changes to the global warming potentials calculated for a range of compounds.

The information here is condensed from:

> Hodnebrog, Ø., M. Etminan, J. S. Fuglestvedt, G. Marston, G. Myhre, C. J. Nielsen, K. P. Shine and T. J. Wallington (2013), Global warming potentials and radiative efficiencies of halocarbons and related compounds: A comprehensive review, Rev. Geophys., 51, doi:10.1002/rog.20013

The Global Warming Potential (GWP) of a gas is the ratio of the time-integrated radiative forcing of a pulse emission of the gas (the absolute GWP, or AGWP) relative to the radiative forcing of a similar pulse of carbon dioxide (CO_2) over the same time interval. The generally accepted time interval ("horizon") is 100 years.

$GWP = AGWP_{GHG} / AGWP_{CO2}$

The time-integrated radiative forcing takes account of the reduction in atmospheric concentration of the gas (related to its Atmospheric Lifetime) and is equal to the concentration integrated over 100 years multiplied by the Radiative Efficiency (RE).

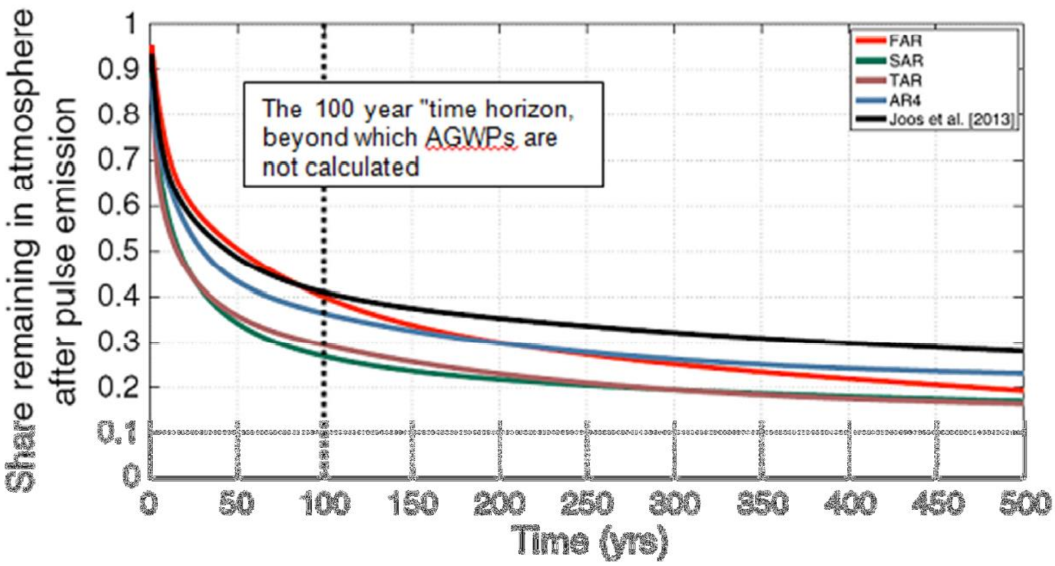

Figure 1: The decays in atmospheric concentration of a pulse emission of carbon dioxide used for the First, Second, Third and Fourth Assessment Reports (FAR, SAR, TAR and AR4, respectively) and the values from Joos et al. 2013 [1]

This relationship works for both the greenhouse gas and for carbon dioxide. But carbon dioxide has many different atmospheric loss processes, each contributing to its atmospheric lifetime. This is the subject of ongoing reassessment and Figure 1 shows the values that have been used in each of the previous Assessment Reports, together with the latest data used here. These latest data show significantly more carbon dioxide remaining in the atmosphere after an emission than had been estimated previously and the calculated AGWP of carbon dioxide is correspondingly larger. The effect is to reduce the calculated GWPs of the other greenhouse gases relative to the values given in the second, third and fourth Assessment Reports (SAR, TAR and AR4).

The paper provided a comprehensive and self-consistent set of new calculations of Radiative Efficiencies (REs) and global warming potentials (GWPs) for more than 200 compounds and claims to be the most comprehensive review of the radiative efficiencies and global warming potentials of halogenated compounds performed to date. For 49 of the compounds, the calculations yield REs significantly (> 5%) different from those in the IPCC Fourth Assessment Report and the study also presents new RE values for more than 100 gases which were not included in AR4. These revised values were adopted in the Fifth Assessment Report of IPCC (AR5).

The calculations of RE used infrared absorption spectra from:
- databases,
- individual studies,
- experimental studies and
- ab initio computational studies;

and selecting data with the highest spectral resolution.

The calculated REs were corrected to account for non-uniform distribution of the substances in the atmosphere; a particular concern for short lived gases.

In general, for HFCs the calculated GWPs are almost all the same or lower, the exceptions are HFC-143a, the GWP of which is increased from 4470 to 4800, and HFC-152a (124 increased to 138).

HFOs were not included in AR4 and have been shown by this work to have insignificantly small GWPs, in fact some with GWPs less than that of carbon dioxide. This is a direct consequence of their very short atmospheric lifetimes which result in concentrations integrated over 100 years that are tiny compared to the amount of carbon dioxide that can remain in the atmosphere after an emission.