HFOs: the new generation of F-gases

Greenpeace Position Paper

July 2016

With the global phase-out of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) proceeding on schedule under the Montreal Protocol, governments are now aiming to phase-down the emissions of hydrofluorocarbons (HFCs) - the replacements for CFCs and HCFCs – by also bringing them into the regulatory regime of the Montreal Protocol.

HFCs, like their predecessors, are powerful greenhouse gases with their global warming potential[1] (GWP) being thousands of times greater than that of carbon dioxide. They are "the fastest growing greenhouse gases" increasing at a rate of 10-15% per year".[i] It is estimated that under current trajectory, if left unchecked, "by 2050 annual HFC emissions could be equivalent to 12% of annual CO_2 emissions"[ii], and that "the continued growth in HFCs will add up to 0.1^{O} C of global average temperature rise by mid-century, which will increase up to five-fold to 0.5°C by 2100 ."[iii].

Greenpeace has been against the large-scale uptake of HFCs since the early 1990s and supports the phasing out of these dangerous greenhouse gases through the auspices of the Montreal Protocol. There is now a growing consensus that HFCs need to be phased down and ultimately phased out.

To remove all incentives for the further uptake of HFCs in developing countries and speed up the phase out of HFCs in industrialized countries, Greenpeace calls for a global phase out of HFCs by 2020 in all applications where there are safer and more sustainable alternatives.

Natural Substances: sustainable alternatives to HFCs

A key question is what alternatives will replace HFCs. Greenpeace advocates the uptake of environmentally sustainable natural refrigerants such as CO_2[2], hydrocarbons, ammonia, water and air. Natural refrigerants and foaming agents, in contrast to fluorocarbons, abundantly occur in the biosphere, they maintain a steady state, and are easily absorbed by nature.

Natural substances are available and technically and economically feasible in almost all cooling applications: domestic and commercial refrigeration and air-conditioning, mobile air-conditioning, industrial processes, insulation foam blowing. For an extensive survey of companies around the world working with cooling technologies using natural substances see the interactive database www.cooltechnologies.org.

HFOs: unsustainable alternatives to HFCs

The chemical industry is promoting substances called 'Hydrofluoroolefins' or HFOs, as HFC replacements. Chemically, HFOs are a form of HFCs, but due to the negative connotations that HFCs have acquired, this new class of chemicals is being marketed under a different name. While HFOs have lower GWPs than the earlier generation of HFCs they continue to pose dangers to the environment.

---

[1] The measurement (global warming potential, or GWP) compares the potency of a greenhouse gas to carbon dioxide (CO2), which has a GWP of 1. So for example, a F-gas with a 100-year GWP of 1000 is 1000 times "better" at warming the planet over 100 years than CO2. Climate scientists can measure how effective a greenhouse gas is at warming the planet over a certain period of time. The GWP_{20} metric better reflects the true potency of HFCs during their actual time in the atmosphere. Greenpeace calls on governments to include the 20 year metric when formulating HFC phase-out climate policies.

[2] In spite of its notoriety as a greenhouse gas, CO2 has very positive characteristics as a refrigerant. It does not deplete the ozone layer and its GWP value is 1 (compared to thousands for a typical HFC). It is cheap and has good safety characteristics. Its properties permit the design of smaller components and more compact systems with its main uses being vehicle air-conditioning and supermarket refrigeration.

GREENPEACE

International

Greenpeace opposes the uptake of HFOs, the fourth generation of F-gases, for several reasons:

1. HCFCs are used to make the most prominent HFO, or so called HFC-1234yf
The chemical industry has been very secretive and proprietary about the chemical composition of HFOs. With insufficient transparency from industry, governments are basing long term policies on information provided by the fluorocarbon industry whose credibility is sorely lacking.

While the exact details of the chemical make up of HFOs are shrouded in secrecy it is known that HCFCs are a key production ingredient of the most prominent **HFO, also known as HFC-1234yf.** This means that the production of HCFCs, which are potent ozone depleting and global warming substances, will need to be maintained in perpetuity to produce HFOs. [iv] A by-product of HCFC-22 production is HFC-23, which has a GWP of 14,000, and is regularly vented into the atmosphere in production facilities that have failed to install filtering capacity

2. HFO blends have high GWP
Industry is creating HFO/HFCs blends, where the bulk of the blended compound (at least 60%), is HFC-32, with HFC-1234yf or HFC-1234ze being the minor components. **These blended compounds are marketed as HFOs**, with their implied low-GWP rating. However, upon their atmospheric dissolution, these blends will revert to their basic components and will contribute to global warming based on the higher GPW of their respective individual components. For example, the 20 year and 100 year GWP of HFC-32 is 2330 and 675 respectively.[v]

In actuality the GWP of HFO blends are relatively high GWPs compared to the GWPs of natural refrigerants. The GWP of most HFO blends range between 150 to 1800, while the GWP of natural refrigerants are 0 for ammonia, 1 for carbon dioxide, 5 for propane and less than 20 for isobutene. [vi]

Given that there is now scientific and political agreement that the global median temperature rise must be kept to no more than $1.5C^{O}$ above pre-industrial level in order to avert full-scale climate catastrophes, it is essential to avert the use of substances whose global warming contributions are higher than that of available alternatives.

3. HFOs and other HFCs produce toxic by-products upon their production and decomposition
When HFC-1234yf (commonly referred to as HFO-1234yf) breaks down in the atmosphere, it produces four to five times more trifluoroacetic acid (TFA) than the same amount of HFC-134a, the substance it is slated to replace in mobile air-conditioning.[vii viii] In high-enough concentrations, TFA is toxic to aquatic ecosystems.[ix]

This means that if HFC-1234yf (or another HFO) becomes the refrigerant of choice, the concentration of TFA in fresh water bodies around the world could increase dramatically, with unknown effects on ecosystems and human health. TFA concentrations approaching a milligram a litre may be toxic to some aquatic life forms.[x]

There are both natural and anthropogenic sources of TFA. TFA accumulation in oceans is deemed to be from natural sources, while TFA in surface fresh-waters are deemed to be from human sources.[xi]
There are several industrial sources of TFA including HFCs and HFOs.

It is expected that TFA accumulation will increase with the replacement of HFCs with HFOs, especially with the replacement of HFC-134a with (HFC-1234yf), in mobile air-conditioning and other applications. It is projected that North American HFC-1234yf production (for the mobile air-conditioning sector) will be 50 -100,000 t/year by 2050, with a total cumulative production by that year being about 3,255,000 t.[xii]

The verdict on the long-term potential harm to humans and the environment from TFA accumulation is still out. While current projections of TFA accumulation in the environment indicate that degradation of HFCs and HFOs "do not present a risk to humans and the environment" further attention to TFA formation from these sources are recommended due to the very long environmental lifetime of TFA.[xiii]

However the peak production level of HFOs is unknown. Industry will find ever-new applications for its products. There will undoubtedly be additional sources of TFA accumulation through the wide scale use of HFOs, such as HFC-1234yf in other applications.[xiv] Alarmingly, "HFO-1234yf is currently being introduced as a propellant for aerosol products."[xv]

Questions remain. What level of HFO use will result in catastrophic levels of TFA accumulation? What is the TFA accumulation tolerance level of nature? On the basis of what is already known, the precautionary principle must apply. The large scale-uptake of HFOs must be prevented until there is a full understanding of peak production levels of HFOs and their long term TFA contribution to the environment. Given these uncertainties, governments should set upper quotas on HFOs production levels.

4. Toxic Flammability of HFC-1234yf (or so called HFOs) in MACs
HFC-1234yf is flammable. When it burns, it releases hazardous substances such as hydrogen fluoride (HF). HF is very toxic and potentially lethal to humans in unventilated spaces. While the flammability of a substance is not an impediment for its use as a refrigerant, the toxic by-product of a substance when it burns is of great concern to human safety. It could greatly increase the number of casualties from car crashes, particularly in confined and poorly ventilated areas such as indoor parking lots and tunnels.

Greenpeace does not consider the flammability of a refrigerant an inherent impediment to its use. Flammable refrigerants, such as hydrocarbons, in mobile air conditioners are safe when used in equipment designed for their use, such as with secondary loop systems.

Though at the present time there are no hydrocarbon-based mobile air-conditioners sold on the world market for passenger-cars, Greenpeace estimates that globally, outside of any regulatory framework, up to 50 million cars may have been converted from CFCs and HFCs to hydrocarbons.[xvi] In such conversions hydrocarbons are applied as drop-in replacements. If hydrocarbons can be safely used as drop-in replacements in MACs on such a large scale, they could be used in equipment designed specifically for their use.

5. Higher costs of HFOs
HFC-1234yf is expected to be more than ten to twenty times (perhaps even higher) more expensive than HFC-134a. This will act as a disincentive for developing countries to phase-out of HFCs. Moreover, the high costs will provide incentives for service technicians to revert back to HFC-134a. As HFCs increasingly come under regulatory pressures (for example the EU F-gas Regulations and MAC Directive [xvii]), the high price of HFO alternatives will likely fuel an HFCs black market (as happened with CFCs in 1990s).

Conclusions

- **There is no need for HFOs.**

  HFO's do not provide long term, sustainable solutions. Natural substances are available and technically and economically feasible in almost all cooling applications: domestic and commercial refrigeration and air-conditioning, mobile air-conditioning, industrial processes, insulation foam blowing. [xviii] For an extensive survey of cooling technologies using natural substances see the interactive database www.cooltechnologies.org.

  At the present time, technologies with natural substances are primarily used in industrialized countries, but there is no reason why they cannot be used worldwide. Developing countries would greatly benefit by leapfrogging HFCs altogether, and going straight from HCFCs to the long-term solutions offered by natural refrigerants and foam blowing agents.

- **Natural refrigerants offer the most sustainable alternatives; HFO development will only delay their deployment.**

  HFOs are patented by the chemical industry, and as with previous generations of fluorocarbons developing countries will again find themselves in a technological and commercial cul-de-sac should they opt to use them. With strong international and national regulation and financing mechanisms, as well as the forward-thinking action of global corporations, the developing world can completely leapfrog HFCs (including HFOs).

- **Governments must hold the chemical industry accountable:** The chemical industry has a sorry track record with its CFC, HCFC and HFC fluorocarbon products. They have caused extensive environmental damage and endangered life on the planet. While the chemical companies have earned massive profits from the sale of these products, and from the transition from one generation of fluorocarbons to the next, they have failed to contribute towards solving the global crises their products have caused. The costs of cleaning up have been left to the public purse. Governments must not repeat this pattern. There is no credible reason for governments to accept at face value industry's claims regarding the safety and technological benefits of HFOs. Who will pay the mitigation costs should the large scale production of HFOs result in yet another global crisis?

Greenpeace calls on governments to:

(a) demand full transparency and disclosure from the manufacturers of HFOs regarding the chemical composition of these HFO substances;

(b) ban the sale of any HFO that requires feedstock whose production results in the formation of super greenhouse gases (e.g. HFC -23);

(c) set production quotas on HFOs so that industry is curtailed in its commercial aspirations for these products;

(d) immediately ban the use of HFOs as aerosols

(e) require that industry commits to paying for all mitigating costs, through a liability contract, should the large scale production of HFOs in the future result in severe damage to the environment.

(f) list HFOs in the Annex of controlled substances of the Kigali HFC Agreement. Including HFOs in the Annex will enable accurate accounting of the volume of HFOs being produced and consumed, the amount of TFA being released into the environment, and enable reporting and licensing to help prevent the illegal trade of HFCs mislabelled as HFOs.

(g) vigorously support the uptake of cooling technologies using natural substances by: enacting modern day standards and policies that reflect the current state of technology; providing financial incentives to encourage their further development and rapid uptake; applying governmental purchasing power towards cooling technologies that use natural refrigerants or other cooling methodologies that avoid the reliance on fluorocarbons.

Greenpeace calls on corporate users of refrigeration and cooling technologies to:

Greenpeace calls on multinational corporations to shift their cooling applications away from fluorocarbons, including HFOs, and to take up the use of natural substances. Such measures are being achieved by corporations (Coca Cola, PepsiCo, Red Bull, Sab Miller, and Unilever) that comprise the Refrigerants, Naturally! initiative . (http://www.refrigerantsnaturally.com/)

For more information, contact:
enquiries@greenpeace.org

Greenpeace International
Ottho Heldringstraat 5
1066 AZ Amsterdam
The Netherlands
Tel: +31 20 7182000

greenpeace.org

---

[i] Velders G. J. M, et al. (2012) Preserving Montreal Protocol Climate Benefits by Limiting HFCs, SCI. 335(6071) : 922-923.

[ii] Primer on HFCs : Institute for Governance & Sustainable Development: Working Paper: 6 July 2016: referencing Velders G.J.M, et al (2014) Growth of climate change commitments from HFC banks and emissions, ATMOS.CHEM.PHYS. DISCUSS. 14:4563, 4568

[iii] Primer on HFCs: Institute for Governance & Sustainable Development: Working Paper: 6 July 2016: referencing Xu Y., Zaelke D., Velders G.J.M., & Ramanathan V. (2013) The role of HFCs in mitigating 21st century climate change, ATMOS.CHEM.PHYS. 13:6083-6089

[iv] HCFC-225 ca (20-year GWP: 550, ODP: 0.07) and HCFC-225 cb (20-year GWP: 1700, ODP: 0.03) – US patent no. 7,470,828 B2

[v] IPCC Fourth Assessment Report

[vi] Report of the Technology and Economic Assessment Panel of the Montreal Protocol: "Further Information on Alternatives to Ozone-Depleting Substances": March 2016; pages 13-17

[vii] EPA Proposed Ruling on HFO 1234yf (2009). p. 11-12. Available at http://www.epa.gov/ozone/downloads/NPRMHFO1234yf.pdf

[viii] UNEP Environmental Effects Assessment Panel : Sources. Fates. Toxicity, and Risks of Trifluoroacetic Acid and Its Salts: Relevance to Substances Regulated Under the Montreal and Kyoto Protocols: report published in the Journal of Toxicology and Environmental Health B, 2016: DOI : p 7

[ix] Boutonnet et al. (1999). Environmental risk assessment of trifluoroacetic acid. Human and Ecological Risk Assessment, 5(1), 59–124.

[x] IPCC/TEAP Special Report on Ozone and Climate, Chapter 2, p.22

[xi] UNEP Environmental Effects Assessment Panel : Sources. Fates. Toxicity, and Risks of Trifluoroacetic Acid and Its Salts: Relevance to Substances Regulated Under the Montreal and Kyoto Protocols: report published in the Journal of Toxicology and Environmental Health B, 2016: DOI : p 5

[xii] Ibid. p. 6

[xiii] Ibid. p. 20

[xiv] KTH: Sweden Department of Energy Technology: "The potential dangers of TFA": November 01, 2015: https://www.kth.se/en/itm/inst/energiteknik/forskning/ett/projekt/koldmedier-med-lag-gwp/low-gwp-news/potentiella-faror-med-trifluorattiksyra-tfa-1.602615

[xv] Ibid. p. 7

[xvi] Estimate based on: (a) "MACs releases Refrigerant Survey Results", Mobile Air Conditioning Society Worldwide, Lansdale PA, USA, October 2002, p. 2; (b) Professor Ian Maclaine Cross of the University of New South Wales, "Usage and Risk of Hydrocarbon Refrigerants in Motor Cars for Australia and the United States", *International Journal of Refrigeration*, Vol. 27, No 4, 2004, pp.339M345; and (c) annual growth rates and direct stakeholder consultations

[xvii] http://ec.europa.eu/clima/policies/f-gas/legislation/index_en.htm

[xviii] Colbourne D (2009). Opportunities for the application of Natural Refrigerants, in the GTZ publication Natural Refrigerants; Pachai AC et al. (2009). Achieving the green dream by the use of natural refrigerants.