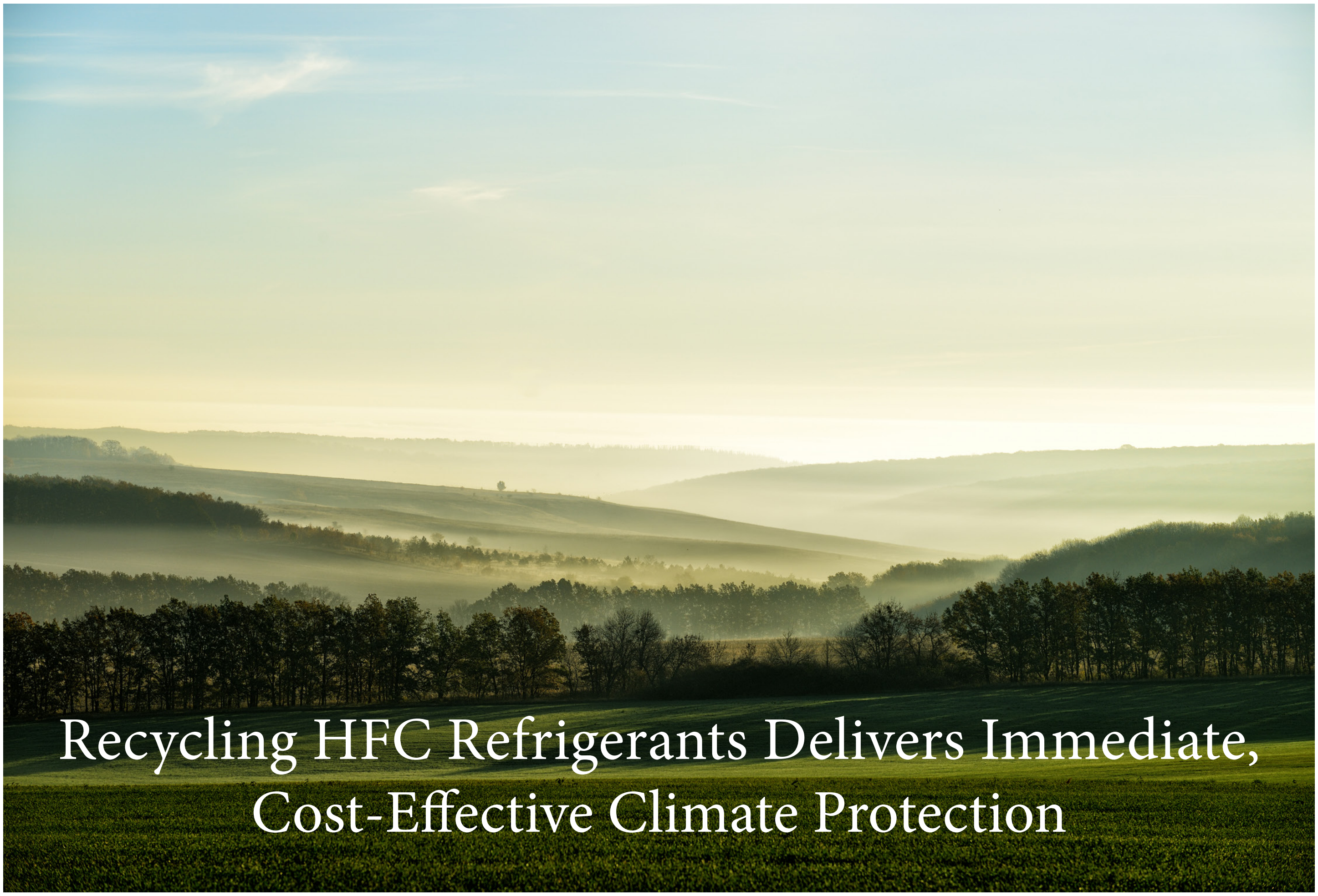

Recycling HFC Refrigerants Delivers Immediate, Cost-Effective Climate Protection

By Jeff Cohen & Joe Madden

HFCs are powerful greenhouse gases (GHGs) and are among the fastest-growing GHGs in the world[1].

Even with a global agreement to phase down production of hydrofluorocarbons (HFCs), and regulations that promote low-global warming potential (GWP) technology* in new equipment, refrigerants already produced will continue to leak powerful greenhouse gases to the atmosphere over the next several decades.

With relatively small changes in practices and little if any additional cost, HFC refrigerants can be recovered, reclaimed and re-used, potentially avoiding emissions the equivalent of 18 billion tons of carbon dioxide (CO_2) between now and 2040—a critical window to address climate change.

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*Low-GWP technologies include refrigeration and air conditioning systems and equipment that use alternative refrigerants with zero or low global warming potential such as carbon dioxide, hydrocarbons, ammonia, and hydrofluoro-olefins (HFOs).

HFCs are Potent, Fast-Growing Greenhouse Gases

Hydrofluorocarbons (HFCs) were developed as "ozone-friendly" substitutes for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) when those ozone-depleting chemicals were being phased out under the Montreal Protocol.

Although they are safe for the stratospheric ozone layer, HFCs—like CFCs and HCFCs—are powerful greenhouse gases when released to the atmosphere. Pound for pound, HFCs have global warming potentials (GWPs) hundreds to thousands times higher than CO_2.

Gas	Global Warming Potential (CO_2eq)
CO_2	1
HFC-507a	3,985
HFC-404a	3,922
HFC-407a	2,107
HFC-407c	1,774
HFC-134a	1,430
HFC-401A	970
HFC-32	675

Table 1: 100-year GWPs—Source IPCC Fourth Assessment Report

HFCs are now in widespread use in air conditioning (A/C), refrigeration, foam insulation, solvent cleaning, aerosol products, and fire suppression. They are the fastest growing greenhouse gas in much of the world, especially in developing countries where demand for refrigeration and air conditioning is rapidly increasing—in the U.S., HFC emissions increased by over 50% between 2005 and 2013.

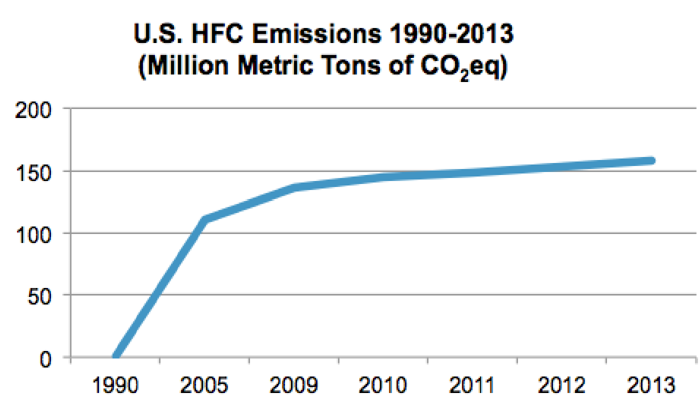


Figure 1: U.S. HFC Emissions from 1990-2013—Source: EPA (2015) Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013

Lifecycle of HFC Refrigerants

Most HFCs are used as coolants in a wide variety of refrigeration and air conditioning applications including:

- comfort cooling for automobiles, homes, office buildings, schools, and hospitals;
- industrial and commercial applications such as food manufacturing, processing and transport, pharmaceutical and chemical production, oil refining, aerospace and defense technologies, data servers, and ice rinks;
- residential refrigerator-freezers; and
- food/beverage storage in supermarkets, grocery and convenience stores.

The majority of refrigerant emissions occur from leaks in working refrigeration and air conditioning systems, and from the charging, servicing and disposal of air conditioning and refrigeration units. Under normal operating conditions, depending on the type of equipment and the location, between 1 and 50% of the refrigerant in air conditioning and refrigeration systems leaks each year.[2†]

Even with active leak detection and aggressive maintenance efforts, it is difficult to eliminate leaks completely. Consequently, to maintain proper performance, leaky equipment and systems require periodic servicing to replace the lost refrigerant. The equipment will usually be "re-charged" with "virgin" (newly produced, never previously used) HFC refrigerant.

Today, HFC Refrigerants are Produced, Used, and Mostly Emitted

This does not have to be the case. An alternative approach is to recover refrigerants from end-of-life equipment and re-use them to service existing equipment, or even to charge newly manufactured equipment.

Currently, only a small percentage (<10-15%) of HFC refrigerants are recovered, reclaimed[‡] and re-used[3]. Refrigerants are a unique resource; however, once used, they can be recovered and processed to remove impurities cost-effectively, and reused with *no compromise* in performance.

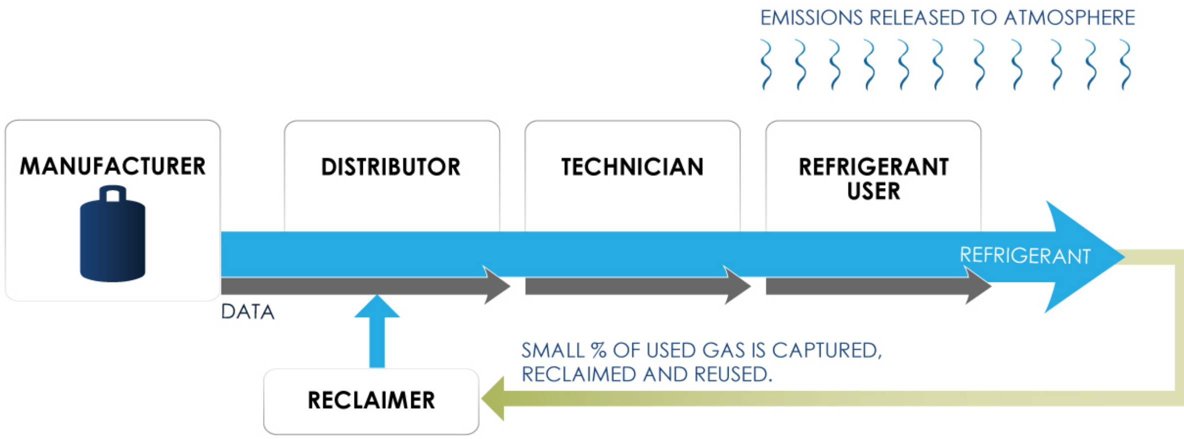
In doing so, this reduces the need to produce new HFC refrigerant, thereby reducing the total amount of HFCs that reach the atmosphere.

[†] Refrigerants can also be released during equipment servicing or when the system is decommissioned.

[‡] Reclaimed refrigerant is refrigerant restored to virgin-grade purity after recovery from equipment and removal of water, oil, and any other contaminants.

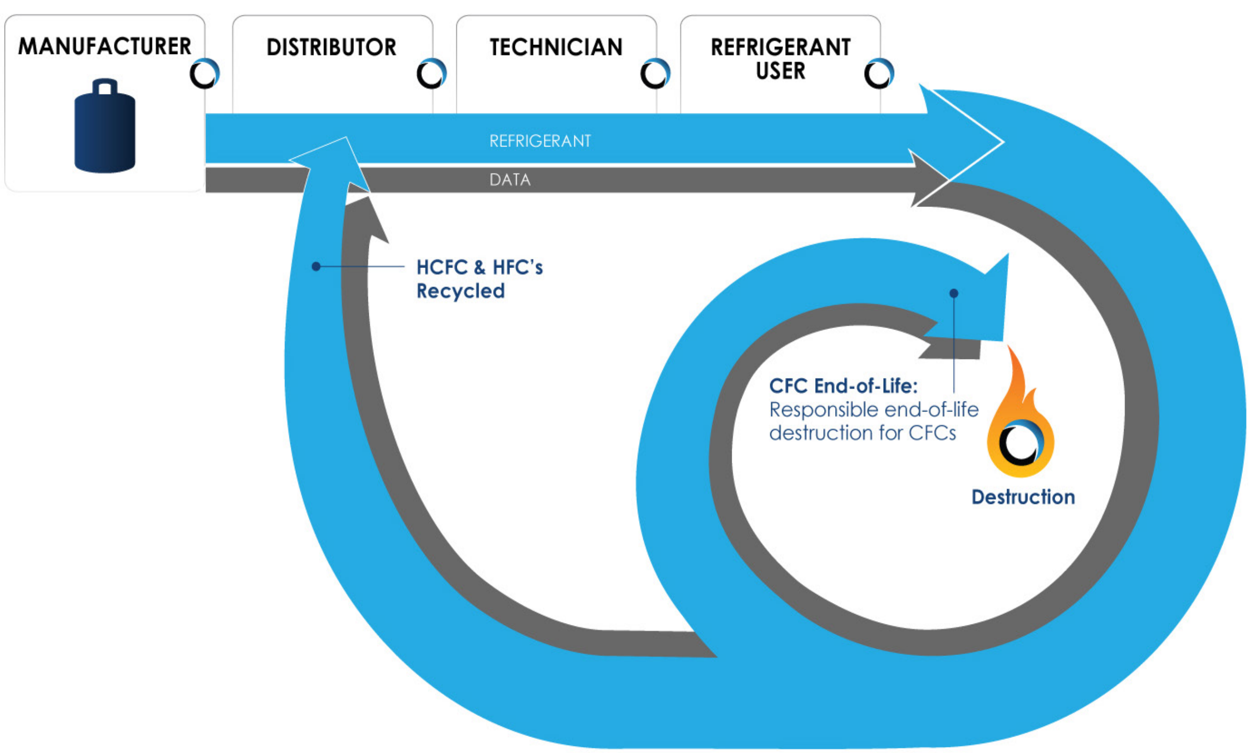
HFC Refrigerant Lifecycle Today

HFC Refrigerants are Produced, Used, and Mostly Emitted



HFC Refrigerant Lifecycle Tomorrow

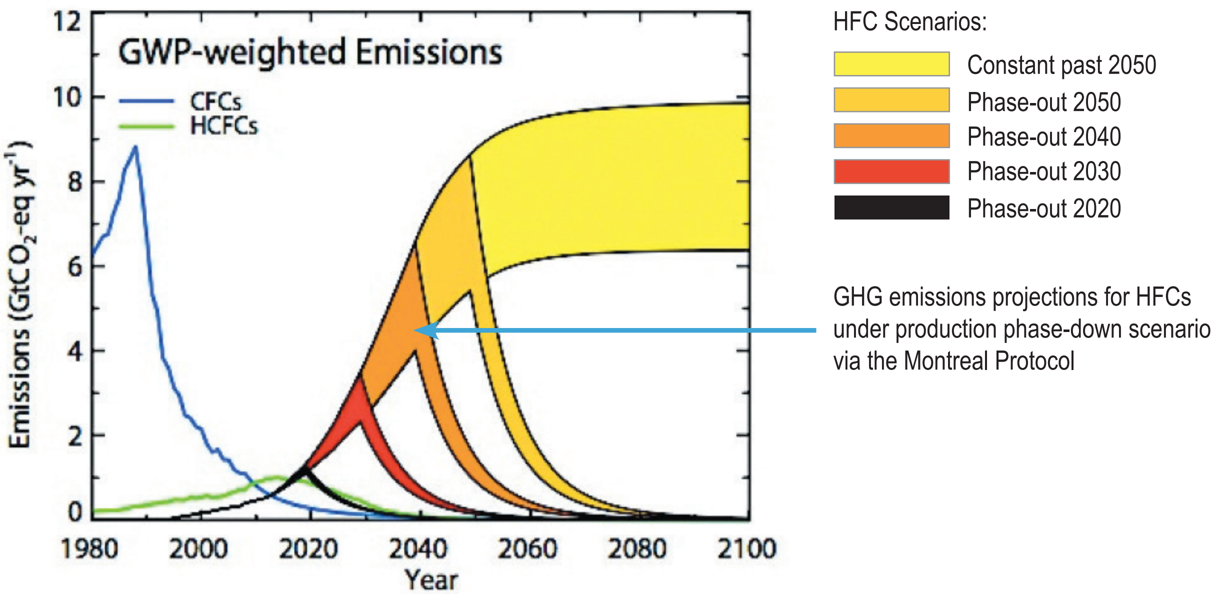
More Recycling = Less Production and Reduced Emissions



HFC Production Phasedown: Important, but Action is Needed NOW

The chart below from Velders et al. (2014) shows global GWP-weighted emissions of CFCs, HCFCs, and HFCs over time, beginning in 1980 (CFCs), and extending out with projections of HFC emissions to the end of this century. Estimates of future HFC emissions depict different scenarios, including "business-as-usual" (current consumption rate; the yellow curve) and a range of potential phaseout deadlines (2030, 2040 or 2050) under international agreement (red and orange curves).

Source: Velders et al. (2014).



Some combination of controls over HFC production is anticipated; for example, in the past 6 years, a growing coalition of countries, led by the U.S., have proposed amending the Montreal Protocol to gradually phase-down production of HFCs[4]. The latest proposal submitted by the U.S., Mexico, and Canada is a production phasedown beginning in 2018 for developing countries, culminating in a complete phase out in 2045. This is analogous to the approach the international community took on CFCs and HCFCs to protect the Earth's ozone layer via the Montreal Protocol.

However, even if the proposed amendment were adopted, the phasedown would be gradual, and would only address new production. HFC production would continue for a number of years, and emissions of HFC refrigerants from already installed refrigeration and A/C equipment would continue for decades to come[f].

[f]To illustrate, virtually all production of CFCs ended in 1995 in the U.S. Twenty years later, there is still CFC-based refrigeration and A/C equipment manufactured in that era that continues to operate.

Based on projections by Velders et al., even with a global production phaseout in 2040, cumulative HFC emissions through 2050 would still exceed 50 billion metric tons CO_2 equivalent ($mtCO_2e$).[5**]

Immediate Climate Benefits of Reclaiming/Recycling HFC Refrigerant

In addition to leak detection and repair, increasing the quantity of HFC refrigerants that are recovered and re-used presents a significant opportunity to immediately prevent emissions by eliminating unnecessary new production.

> For example: *By 2040, if 30% of HFC refrigerants are reclaimed for re-use, approximately 18 billion $mtCO_2e$ would be prevented from reaching the atmosphere over the next 25 years —that equates to 3.5 years of GHG emissions in the United States from all sources.*

Perspective on Current Climate Challenges

As the table below shows, there is scientific consensus that far more has to be done to stabilize greenhouse gas emissions worldwide to reduce the likelihood of uncontrolled and potentially catastrophic climate change. In the meantime, every pound of HFC refrigerant that is recovered and re-used increases the chance that we can avoid this outcome.

Climate Outcome	Number	Source
Scientifically "acceptable" temperature rise to allow for ~2/3 probability of avoiding "catastrophic" climate change that is "dangerous" to life on earth Climate Changes	2° C	IPCC[6]
Approximate atmospheric CO_2 + CO_2e greenhouse gas (GHG) concentration to limit global temperature rise to 2 degrees Celsius (45% probability)	450 ppm	World Energy Outlook 2012[7]
Based on atmospheric concentrations in 2010, a "Carbon Budget" for cumulative CO_2 emissions between 2011-2050 was established	565 $GtCO_2$	Carbon Tracker[8]
Projected HFC emissions through 2050, even with a global phasedown in production, with a complete phaseout in 2040	50 $GtCO_2$[**]	Velders et al. (2014)

[**]Projections include all HFC applications; refrigerants would account for roughly 70% of these totals

Solutions Today

Policymakers and the refrigerant industry are focused on reducing HFCs through a production phase-down and promoting low-GWP technologies for new equipment. In addition, advances in leak detection technologies, improved service practices, and supply chain tracking are important to deploy to contain refrigerants.

An essential component to reducing HFC refrigerant emissions is establishing the metrics that will incentivize increased re-use of HFC refrigerants. To achieve that goal, EOS Climate has authored a methodology to quantify the climate benefits of recovering, reclaiming and reusing existing HFC resources—it has also outlined the processes by which the materials themselves can be differentiated and certified. The methodology has been submitted to the American Carbon Registry (ACR)[9].

The methodology will allow crediting to organizations that recycle and/or purchase reclaimed HFCs and their environmental attributes. Policies and standards that support organizations that demonstrate climate leadership in this area will result in direct, measurable climate benefits and support the path to a sustainable future.

Conclusion

If left unchecked, HFC refrigerants will continue on the path as the world's fastest growing greenhouse gas. A simple and cost-effective way to address this problem is through recycling. However, until HFC refrigerants are tracked from production to reuse in the supply chain and metrics are established that incentivize their re-use, the likelihood of voluntary recycling will remain low.

Now is the time to act—to learn more about EOS Climate's HFC refrigerant recycling efforts, visit www.eosclimate.com/climate-solutions/.

About the Authors

Jeff Cohen and Joe Madden are co-founders of EOS Climate, a San Francisco-based company which has been a leader in delivering high quality, verified emission reductions to the California cap-and-trade program. EOS Climate's focus has been on creating market incentives for responsible life-cycle management of fluorochemical refrigerants and other commodities with high global warming potential.

References

[1] White House 2013 Climate Action Plan, https://www.whitehouse.gov/ener-gy/climate-change.

[2] IPCC/TEAP, 2006; RTOC 2010; EPA, 2014; CAR ODS Protocol 2010 – citations in the draft methodology.

[3] American Carbon Registry (2015) Emission Reduction Measurement and Monitoring Methodology for Use of Reclaimed HFC Refrigerants and Advanced Refrigeration Systems. http://americancarbonregistry.org/carbon-accounting/standards-methodologies/use-of-reclaimed-hfc-refrigerants-and-advanced-refrigeration-systems

[4] U.S. EPA (2014) Benefits of Addressing HFCs under the Montreal Protocol http://www.epa.gov/ozone/downloads/Benefits_of_Addressing_HFCs_under_the_Montreal_Protocol-July2014MASTER_REV4.pdf.

[5] Velders, G.J.M, S. Solomon, and J. Daniel (2014) Growth of climate change commitments from HFC banks and emissions. Atmos. Chem. Phys. 14:4563-4572.

[6] International Panel on Climate Change Section 2.7, https://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf.

[7] World energy outlook 2012 (International Energy Agency): Figure 8.4, page 265, http://www.iea.org/publications/freepublications/publication/world-energy-outlook-2012.html

[8] Carbon Tracker: The Carbon Bubble, http://www.carbontracker.org/wp-con-tent/uploads/2014/09/Unburnable-Carbon-Full-rev2-1.pdf.

[9] ACR (2015); see citation 3 above.