Refrigeration and Global Warming

Dr. Sheila Srivastava,

IUC Associate (March, 2018)

Abstract

For the past century, the best technology we've had for coping with heat has been the air conditioner. Air conditioners run refrigerant through coils in a loop. The refrigerant absorbs heat from inside a room as it turns from liquid to gas, then deposits heat outside as it's condensed into liquid again. Because cooler air holds less moisture, water vapor condenses on the conditioner's coils, lowering the humidity.

Now air conditioning is spreading in India. Indians bought about 5 million room ACs last year and the market is growing at 10 to 12 percent annually. Environmental costs are also significant. With its population of 1.3 billion people, India will soon pass Russia to become the third-largest source of carbon dioxide emissions. Coal and other fossil fuels dominate Indian electricity generation, so more air conditioners means increased emissions. In addition, the refrigerants used in air conditioning are themselves a potent greenhouse gas.

The impact of refrigeration and air-conditioning installations on climate change has been principally through energy consumption and the past emissions of CFCs. Now, more efficient installations and new-generation fluids such as HFCs* (Hydrofluorocarbons) contribute to a 60% reduction in the global warming impact of refrigeration. As such, the refrigeration industry is one of the sectors that has made most progress in this area. Substituting CFCs with low leakage HFC systems that have improved efficiency will mean a net reduction in the effect on the global climate. This is the result of a pragmatic and responsible approach towards sustainable refrigeration that respects both the safety of the user and the environment.

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Introduction

Analysis of Figure 1 reveals that China is the largest emitter of CO_2 in the atmosphere followed by U.S. The contribution of India is 6.8%

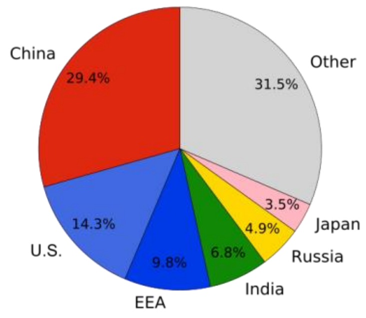


Fig. 1 Global carbon dioxide emissions

Globally, 2017 will likely end up one of the three hottest years on record. Nowhere does this matter more than India, where temperatures last year in Rajasthan reached 124 degrees Fahrenheit (51 degrees Celsius). By any measure, India is one of the hottest countries in the world. Chennai, Mumbai, Kolkata, and Delhi all rank among the top 10 hottest large cities globally, as measured by cooling degree days.

CDDs are a unit of cooling demand measured by comparing each day's average temperature to 65 degrees Fahrenheit.

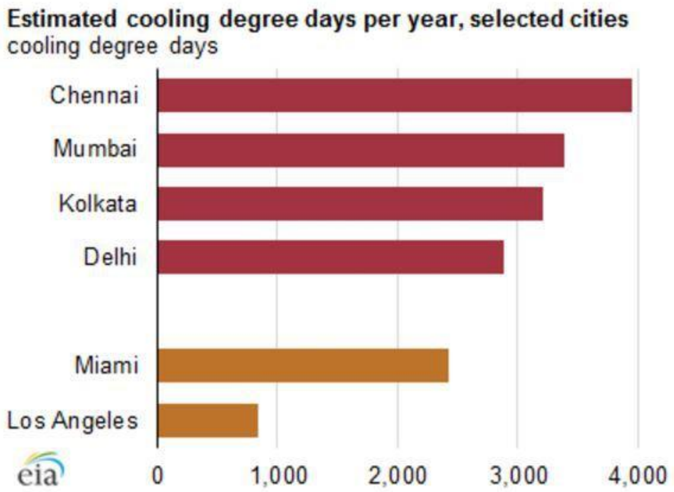


Figure 2 : This figure plots annual cooling degree days (CDDs) by city.

Source: U.S. Energy Information Administration, October 2015.

Refrigeration and air conditioning processes are now part of our way of life and it would be inconceivable for it to be any other way. They have become essential ingredients for maintaining and improving our quality of life.

- **The cooling** chain enables the storage, transport and use of food items in ideal hygienic conditions, reducing loss and waste.
- **Air conditioning**, particularly in hot countries, brings comfort in places such as homes and occupational buildings, shops and public transport and contributes to maintain hygienic conditions in hospitals
- **Refrigeration** of many medical products such as vaccines and blood is indispensable for ensuring their preservation.
- **Thermal insulation** using high-efficiency foams reduces energy consumption in buildings, refrigerated transport and cold rooms.
- Refrigeration is essential for the operation of equipment such as **large IT systems** through to the most sophisticated **medical applications.**

Using the benefits of an activity while ignoring its impact on the environment is not an option today. As citizens, industrialists or politicians we need to understand the environmental challenges. Only then can we make responsible decisions to ensure sustainable socio-economic development.

Objectively evaluating the real impact of a refrigeration system on the environment requires an understanding of effects through the whole life cycle. This is the only way to take into account more than just the effects of a part of the system on global warming.

The refrigerant absorbs the heat as energy source to evaporate in the closed space. The vapor is then compressed and re-condensed outside to release the heat. The liquefied refrigerant is ready for a new cycle.

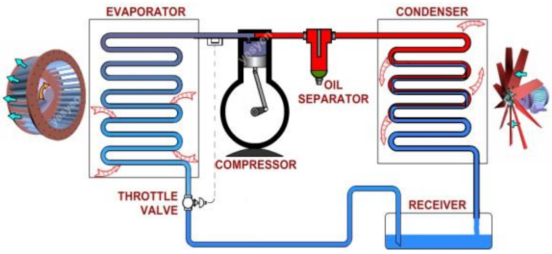


Figure 3 : The refrigeration cycle

THE WORLD OF REFRIGERATION FLUIDS

Ammonia

Ammonia was the first refrigerant to be used on a large scale. It is efficient, but it is also very **toxic and flammable**. That is why safer substitutes have often been preferred and ammonia is now generally restricted to use with supervision by skilled personnel (for example, cold stores, dairies, and breweries). However the systems to ensure safety involve a 30% to 40% cost premium compared to using less dangerous fluids.

Hydro-chlorofluorocarbons H-CFCs

HCFCS were developed in parallel with CFCs (chlorofluorocarbons) and, together, they provided the spectacular social development of **safe, cheap and effective** refrigeration. HCFCs have a small affect on the ozone layer. They were labelled "transitional substances" in 1990 and their production and use will be phased out. In 1990 their contribution to greenhouse gas emissions was only 0.5% of the total that year.

Hydrocarbons (Propane or Isobutane)

Hydrocarbons (LPG) are also efficient refrigeration fluids. However they are **very flammable**, potentially explosive, and thus dangerous. In some countries, their use is restricted or banned in public places and tall buildings. Hydrocarbons also contribute to urban pollution as they trigger the generation of tropospheric ozone in the lower atmosphere. Their global warming potential is low but safety requirements can increase **energy consumption** and CO_2 emissions.

Hydrofluorocarbons (HFCs)

HFCs are pratically non-toxic and non-flammable. They can be used in a large number of applications and equipment can be serviced and maintained by the large existing trained base of installers. HFC present **minimum risk**, even in the case of an accidental leak. They also offer very good energy performance. However, whilst they have no effect on stratospheric or tropospheric ozone, they are greenhouse gases.

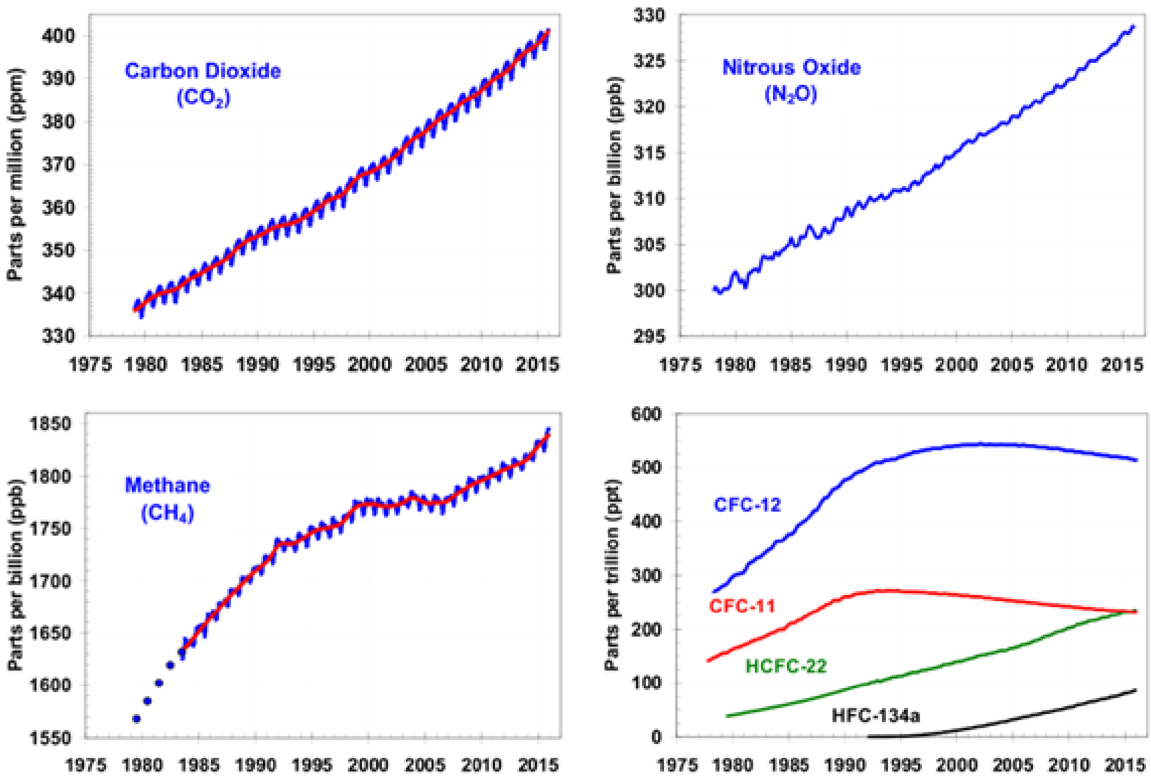


Figure 4 : Major Green-house gas trends

An analysis of the major green house gas trends, Figure 4, reveals that CO_2, N_2O and Methane contents in the atmosphere recorded regular increase since 1975. The refrigerant CFC content have reported a rising trend since 1975 to 1995, thereafter due to awareness and its reported impact as ozone layer depleter, its content has followed little downward trend. HCFC as well as HFC are attributing increasing trend since their initial use during 1980 and 1990 respectively.

THE IMPACT OF A REFRIGERATION SYSTEM ON THE GLOBAL CLIMATE

The impact of refrigeration and air conditioning systems on global warming is through both energy use and refrigerant emissions.

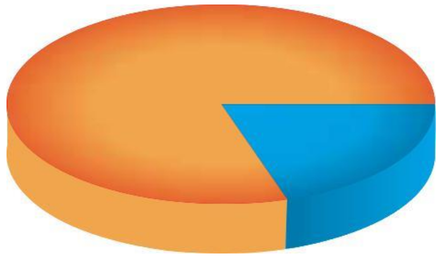
I ENERGY USE

Refrigeration equipment consumes electricity, produced in general by burning fossil fuel that emits CO_2 (carbon dioxide) into the atmosphere. This gas is the main contributor to greenhouse gas emissions that could lead to global warming and climate change. By the simple fact of consuming energy over its life cycle, any refrigeration unit contributes to climate change. This “indirect” effect can represent more than 80% of its impact.

II REFRIGERANT EMISSIONS

Poorly designed, badly maintained installations or refrigeration units abandoned at the end of their life without recovering or recycling the refrigerant fluid can lead to emissions into the atmosphere. These emissions are known as the “direct” effect. The substantial progress made in sealing modern units and in recycling fluids has brought about a considerable reduction in these emissions. The direct impact of refrigerant fluids on climate change is relatively small now and, in general, is decreasing.

INDIRECT EFFECT
Energy use
80 %



DIRECT EFFECT
Refrigerant Emissions
20 %

Reducing the indirect impact due to energy consumption is the highest priority for the management of refrigeration systems. The reduction of indirect impact of refrigeration and air-conditioning units lies essentially in the improvement of their energy use. The energy consumption is affected by three main parameters.

1. **The quality of systems**

   Matching and optimising the components which make up a refrigeration system is an essential part in the design of systems that consume less energy. It is also crucial to check system integrity so as to avoid refrigerant leaks.

2. **The quality of unit insulation**

   Good insulation maintains heat gain to refrigerated cold spaces and provides a better energy return. In blown insulation foam, it is the entrapped gas - not the polymer material - which determines the degree of insulation. Life-cycle studies show that insulation foam blown using HFCs can be more efficient and longer-lasting than that using other blowing agents such as hydrocarbons, water or CO_2.

3. **The choice of the refrigerant fluid**

   The perfect refrigerant does not exist. Refrigerant fluids are chosen for their thermodynamic efficiency to extract heat and for their safety in use. Ammonia and some hydrocarbons, whilst they are excellent refrigerants, are extremely flammable or toxic and demand maximum attention to safety and strict precautions.

For example, in the case of ammonia being used as the refrigerant in supermarket freezers, safety procedures require the use of a "double circuit" system with ammonia restricted to the circuit outside the building. This inevitably involves a loss of refrigerating efficiency, which increases the energy use. As a result, electricity consumption and associated costs are distinctly increased.

While HFC must be contained, they do not require the same safety precautions. They can be used across a wide range of application temperatures and can be more carefully selected to optimise system efficiency. HFCs are thus **far more generally used.**

HFCs HAVE A LOW IMPACT ON CLIMATE

Table 1 : Index and Quantity

Values of GWPS after 100 years		Greenhouse Gases emissions in the year 2000
Carbon dioxide (CO_2)	1	30,800,000,000 tonnes
Methane	21	350,000,000 tonnes
Nitrous Oxide (N_2O)	310	11,000,000 tonnes
ODS	**100 - 8,000**	600,000 tonnes
HFCs	**140 – 11,700**	140,000 tonnes
PFCs	**6,500 – 9,200**	20,000 tonnes
Sulphur hexafluoride (SF_6)	**23,900**	6,000 tonnes

ODS:Ozone Depleting Substances controlled under the Montreal Protocol

PFCs: perfluorocarbons

Table 2 : **Atmospheric lifetime and GWP relative to CO_2 at different time horizon for various greenhouse gases**

Gas name	Chemical formula	Lifetime (years)[22]	Global warming potential (GWP) for given time horizon		
			20-yr[22]	100-yr[22]	500-yr[39]
Carbon dioxide	CO_2	30–95	1	1	1
Methane	CH_4	12	84	28	7.6
Nitrous oxide	N_2O	121	264	265	153
CFC-12	CCl_2F_2	100	10 800	10 200	5 200
HCFC-22	$CHClF_2$	12	5 280	1 760	549
Tetrafluoromethane	CF_4	50 000	4 880	6 630	11 200
Hexafluoroethane	C_2F_6	10 000	8 210	11 100	18 200
Sulfur hexafluoride	SF_6	3 200	17 500	23 500	32 600
Nitrogen trifluoride	NF_3	500	12 800	16 100	20 700

HFCs HAVE A LOW IMPACT ON CLIMATE

This can be dealt under following three heads;

I. INDEX

Global Warming Potential (GWP)

The global Warming Potential is an index that relates the potency of a greenhouse gas to that of carbon dioxide. By convention, the calculation integrates the effect from each gas over 100 years (Table 1). On this scale, the GWP of a refrigerant such as HFC-134a is 1300, which means that an emission of one kilogram would have the same impact over 100 years as an emission of 1300 kg of CO_2. However, the GWP has to be put into perspective. The total quantity released is as important as the GWP in calculating the real environmental impact.

Clearly GWP as a measure does not satisfactorily describe the climate impact of a greenhouse gas. Despite the low GWP of CO_2, the enormous quantities emitted and its long lifetime means that it has a **far greater impact** on climate than HFCs. Currently, CO_2 emissions contribute 64% of the total greenhouse gas emissions and are rising. In contrast HFCs contribute much less than 1% today and are expected to rise to two or three percent by the end of the century.

II. QUANTITY

The quantities emitted

The atmosphere **naturally contains greenhouse gases** such as CO_2, methane and water vapour that have maintained a mean terrestrial temperature around 15°C. Humans are adding carbon dioxide into the atmosphere by burning fossil fuels for power, transportation and industry. Agriculture also leads to methane emissions. These sharp increases in greenhouse gases change the climate balance. When considering impacts, the relative quantities of greenhouse gases emitted to the atmosphere must be taken into account; HFCs are emitted in tiny quantities compared to CO_2 or methane (Table 1).

III. LIFETIME

Lifetime of greenhouse gases in the atmosphere

The longer a greenhouse gas stays in the atmosphere, the more its cumulative heating effect. Although the GWPS are calculated on a 100 years basis, lifetime becomes an important parameter for the longer term. Actually, CO_2 has a very long lifetime: it remains in the atmosphere for several thousand years and after 100 years has developed less than one quarter of its impact. In contrast, the lifetimes of HFCs are decades or less. Unlike HFCs, which are removed from the atmosphere relatively quickly, the long lifetime of CO_2 means a significant commitment for climate change long into the future. (Table 2)

SAFETY AND REFRIGERATION

In spite of all precautions being taken, an accident or some act of negligence can be translated into leaks of refrigerants. However, if it's a minor and limited accidental HFC loss, it will have no significant consequence at the global climate level. Such an event - if it concerns a toxic or explosive gas - could possibly be catastrophic for the people involved. Accidents with toxic or explosive refrigerants have already occurred with serious consequences. The risk of a fatality from ammonia refrigeration systems is estimated to be at least 1.5 per million installations per year (Source - IEA). If the **30 million** commercial and industrial refrigeration systems estimated to be in the EU were all operated on ammonia this could result in many additional fatalities each year. For larger systems, with higher refrigerant charge, risks are likely to be even higher for hydrocarbons than for ammonia because of high flammability.

A SUSTAINABLE AND RESPONSIBLE SOLUTION FOR THE FUTURE WITH HFCs: NO LONGER A CHOICE BETWEEN SAFETY AND EFFICIENCY

Managing Emissions

Managing the emissions of HFCs renders their impact insignificant. Their use in well designed, efficient refrigeration systems results in reduced environmental impact.

Even if all the HFCs used in refrigeration were to be sent into the atmosphere, their impact on global warming (even in this worst case) would, in the near future, represent no more than 1.6% of the greenhouse gas impact.

In practice, emissions on this scale will not occur and strenuous efforts continue to be made to eliminate refrigerant losses from installations.

Significant advantages

- In refrigeration, the range of HFCs and their many possible combinations means that we can choose a mixture which corresponds exactly to the level of cooling required, whether it is for domestic refrigerators, large freezer units, refrigerated storage, or air-conditioning systems.
- For **insulation**, foams blown with HFCs have demonstrated their **superior ecobalance**;
- From **the users'** and consumers' safety perspective, HFCs present **minimal risks**. They are practically non-toxic and non-flammable, providing a reliable option that minimises risk in a wide range of industrial, public, residential or transport situations.

CONCLUSION

7 Solutions for reducing Climate impact of Refrigeration & Air conditioning

The use of HFCs for efficient installations safely and significantly reduces the climate warming impact of refrigeration and air conditioning. This move towards sustainable development in the refrigeration sector is the responsible and safe way to meet a goal of full respect for our environment.

1. Focus on energy efficiency improvement in refrigeration through better design, installation and operation of equipment. This would reduce the indirect emissions that are over 80% of the contribution here
2. Focus on reduction of greenhouse gas emissions, as required by the Kyoto Protocol, not on regulation of uses

3. Maintain a choice of refrigerants for optimum performance in terms of safety, efficiency, environmental impact and cost
4. Maintain public safety as a primary consideration, there is no need to compromise existing safety levels
5. Establish a structured refrigerant recovery and recycling system, eliminating unnecessary regulatory barriers
6. Promote and support voluntary initiatives aimed at preventing greenhouse gas emissions, recognising that verification is essential to their success
7. Discourage discriminatory regulatory initiatives that have no objective benefit for the environment and safety.

Refrigeration equipment must be adapted to the global warming challenge. It needs long-term policy. The current phase-out of HCFCs, even if it requires a huge effort on the part of the refrigeration sector, provides an opportunity to design new equipment using renewables as energy sources and using technologies with good energy efficiency. Existing equipment can and must be improved. However, the progressive renewal, within about 20 years (lifespan of equipment) on the average, of refrigeration and air–conditioning equipment, using environmentally friendly technologies, is a key factor and could represent a major part of worldwide efforts for mitigating global warming until 2030.

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