The Global Climate and Energy Challenge: Refrigerant Choices

By Bhupinder Godara
Director – Laboratory & Applications
Danfoss Industries (P) Ltd., Gurgaon

Introduction

In the first half of the 20th century, Chlorofluorocarbons (CFCs) became the refrigerants of choice for a wide range of applications in refrigeration and air conditioning. They were popular as blowing agents and propellants as well. Their non-toxic, odourless, non-corrosive and non-flammable properties made them a preferred choice. Later, Hydro-chloro-fluoro-carbons (HCFCs) were developed to improve energy efficiency for air conditioning applications.

Concerns about the impact of CFCs on the atmosphere emerged in 1973, and triggered a study at the University of California, USA. This study was followed by a research paper published in 1974. By the late 1970s, it became accepted that CFCs were responsible for depletion of the Earth's stratospheric ozone layer, particularly in the Polar Regions. This depletion leads to permitting high levels of ultraviolet radiation to reach the Earth's surface.

In 1985, twenty nations signed the Vienna Convention, which established a framework for negotiating international regulations to limit and phase out ozone depleting substances (ODS). The Montreal Protocol (MP) was the global vehicle established in 1987 to phase out substances with high Ozone Depleting Potential (ODP). In the words of Kofi Annan, former Secretary General of the United Nations, "Perhaps the single most successful international agreement to date has been the Montreal Protocol". Today, CFCs have been phased out in an orderly manner, and HCFCs are in the phase out process as countries prepare and execute their legally binding phase out plans.

When the Montreal Protocol was framed, the only objective of the agreement was to phase out ozone depleting substances. At that time, the Global Warming Potential (GWP) of the target substances was not an influencing factor and was not factored into the agreement. Fortunately, the alternatives developed to replace CFC had lower GWP and therefore, the impact of replacing CFCs was beneficial to the environment due to zero ODP and a lower GWP.

The HCFC replacement scenario presented challenges from a GWP perspective. Hydro-fluoro-carbons (HFCs), the alternative substances developed, have a higher GWP and are often dubbed "potent greenhouse gases". This has led to an initiative by the US, Mexico and Canada to propose an amendment to the Montreal Protocol to include within its scope an orderly phase down of HFCs, and currently this is under negotiation with member countries. While there is general consensus on the need to reduce the use of high GWP substances, there are several challenges in reaching a legally binding international agreement

About the Author

Bhupinder Godara works at Danfoss in India as Director Applications for the refrigeration and air conditioning controls division. He graduated in mechanical engineering from IIT Delhi in 1987 followed by a Masters in Thermal Engineering from the same institute in 1989. He has over 23 years' experience in refrigeration and air conditioning, managing design of products like roof mounted units for Indian Railways, special cooling and refrigeration systems for Defence, Mother Dairy and Department of Telecommunications, telecom shelters and high efficiency residential air conditioners and light commercial systems.

He was actively involved in the Energy Efficiency Program for air conditioners during its inception, as a member of the technical committee that set up the Star rating program for India. He represented India at the Asia Pacific Partnership Workshop for Standards Harmonization at Washington in 2007.

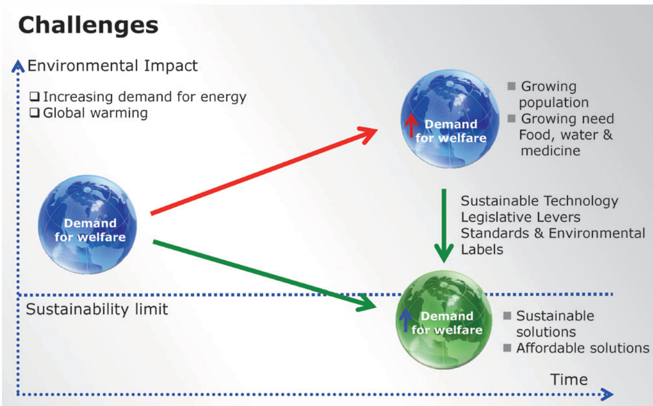

Figure 1: Challenges to an agreement on global warming potential

similar to MP. Some of the questions that need to be answered to mitigate these challenges are *(see Figure 1):*

1. Why selectively target refrigerants when there are significant other activities impacting global warming?
2. Since the terms of reference of MP were ODPs, why not create a new vehicle for GWP that is not limited to refrigerants?
3. How to arrive at a framework for negotiations that does not compromise the aspirations of millions of people in developing countries?
4. How long will it take to develop refrigerants that are safe, non-toxic and non-flammable and allow for the same or better efficiencies in air conditioning applications?

Added to the challenges in arriving at an international framework for negotiations limiting the use of high GWP substances are the following facts:

1. The climate challenge is fuelled by growth in demographics and wealth leading to an increase in energy consumption.
2. By 2050, 70% of the world's estimated 10 billion inhabitants will be part of massive urban networks.
3. Energy consumption will grow 49% by 2035.

The benefits of the reduced GWP due to CFC phase out may be offset by the higher GWP HFCs which are currently the proven options for HCFCs, as estimated in the UNEP report depicted in *Figure 2*.

Drivers for Low GWP Refrigerants

There is a combination of factors that can influence and

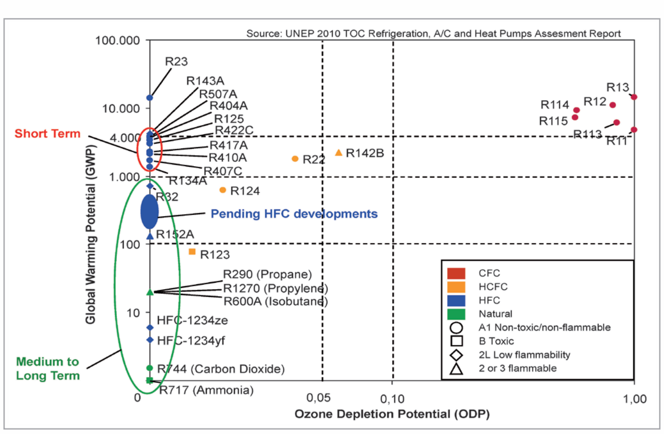

Figure 3: GWP vs. ODP map for refrigerants

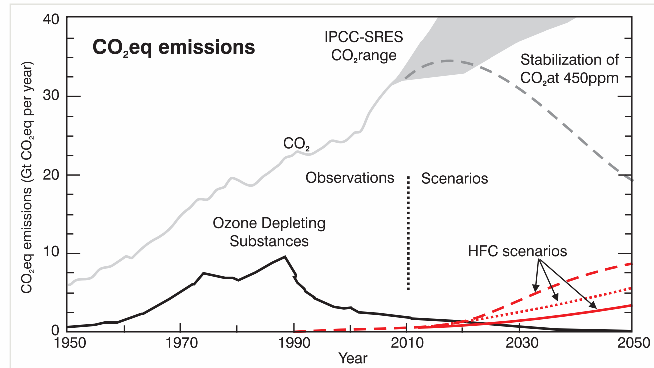

Figure 2: UNEP estimates predict the reduced GWP due to CFC phase out to be offset by the higher GWP of HFCs

incentivise the use of low GWP refrigerants. There is no single answer, as different countries choose a combination of legislation, subsidies and taxes *(see Figure 4)*.

New Refrigerant Choices

1. Air Conditioning

The only commercially available non-flammable alternative to R22 is R410a. The GWP of R410a is 2088, which is slightly higher than R22 (1810). So, a zero ODP solution to which the developed countries have already transitioned will lead to an increase in the GWP impact.

GWP of refrigerants is not entirely reflective of the true impact on global warming. GWP impact on the environment is limited to the quantity of refrigerant that leaks into the atmosphere and reaches the stratosphere. The cost of refrigerant replacement along with the associated cost of locating and repairing leaks in the field has been driving technology to improvements which lower the risk of leaks and enable early detection. Stated differently, having a leak tight system is equally effective in lowering the environmental impact of a refrigerant's GWP. With improvements in technology, systems today have lower incidence of leaks.

The direct global warming impact has also to be seen in relation to the indirect impact of the refrigerant on the system energy efficiency. To illustrate this, let us consider an example. If we use CO_2 in a trans-critical air conditioning system, the energy efficiency will drop drastically w.r.t. an R410a system. This means that the

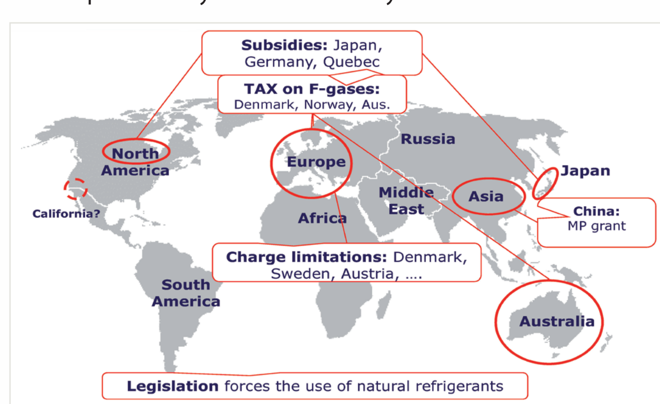

Figure 4: Different countries use different combinations of drivers to incentivise the use of low GWP substances

continued on page 46

continued from page 44

Figure 5: Some low GWP options and their relative toxicity and flammability

GWP impact due to higher energy generated at the power plant will more than offset the benefit due to GWP reduction of the refrigerant. The unfavourable impact due to a leak will occur only when the refrigerant leaks. The indirect impact will occur every hour of operation of the system for the lifetime of the air conditioners.

The objective of a lower Global Warming impact is more likely to be realized if we focus our actions on all of the following:

1. Energy efficiency of the refrigeration and air conditioning system
2. GWP of the refrigerant
3. Quantity of the refrigerant used
4. Assessment of quantity of refrigerant leaked during the lifetime of the system

Some design options that enable lowering the Global Warming Impact of refrigerants are:

1. Hermetic systems with no refrigerant charging or connections at the field level
2. Use of micro-channel and plate heat exchangers to lower the quantity of refrigerant used
3. Improved service and leak detection capability at the field and service level

An energy efficient leak free system with a low system charge is more environment-friendly than a system which only has a low GWP refrigerant with low energy efficiency.

2. Refrigeration

Refrigeration applications can be classified based on the probability of refrigerant leaks. Domestic refrigerators are manufactured under strict process control to prevent refrigerant leaks, and it is common for users to experience a leak free life span of over 10 years. The concern of a leak is therefore limited to end of life release into the atmosphere.

Supermarkets and industrial refrigerant application are more demanding, and experience shows that there is a high frequency of maintenance, with the complexity of installations resulting in a relatively high risk of undetected leaks leading to a higher incidence of refrigerant leaking into the atmosphere during the useful life of the equipment.

The climate in the region has a very significant bearing on the indirect impact due to energy efficiency. In Denmark, the climate has been ideal for making CO_2 systems a success. Fakta, a supermarket chain, has been among the first movers for adopting CO_2 systems. Today, they have more than 378 systems in operation including 61 trans-critical systems. They have, over a period, developed systems that can be lower in energy consumption than equivalent HFC refrigerant (R-404) based solutions. The average ambient monthly temperature in Denmark is lower than 17°C, and this is a key factor for the low energy consumption in these systems.

Hydrocarbons have been accepted globally as refrigerants of choice due to their low GWP and zero ODP. The recent approvals by the US Environmental Protection Agency (EPA) under their Significant New Alternatives Policy (SNAP) in December 2011 allow the use of Hydrocarbons as refrigerants in household refrigerators and stand-alone commercial freezers.

Carbon dioxide is a refrigerant of choice in cold climates where using a sub-critical refrigeration cycle is an option. The low critical point of CO_2 leads to challenges in energy efficiency for tropical climates. The solution lies in using a cascade system with CO_2 in the low temperature cycle and ammonia or propane in the high temperature cycle. If the safety and toxicity concerns for using ammonia are addressed in the application, the ammonia CO_2 cascade solution is ideal. The cascade system offers a low GWP solution that can be applied in any climate and leads to good efficiency of the system. More research needs to be undertaken to make these systems commercially acceptable for applied and operating costs.

Synthetic refrigerant manufactures have a fairly long development cycle for engineering new substances, and based on currently available information in the public domain, there is very limited visibility for low GWP and zero ODP refrigerants that have good energy efficiency.

3. Mobile Air Conditioning

The applied cost and efficiency limitations of CO_2 systems have driven the need for developing synthetic alternatives, and HFOs are an emerging choice. The challenges to developing a synthetic refrigerant meeting the safety classification A1 as per ASHRAE have so far not been met. However, the need for classification of flammable refrigerants based on the relative risk of fire has led to a new set of standards that differentiate low and high levels of flammability.

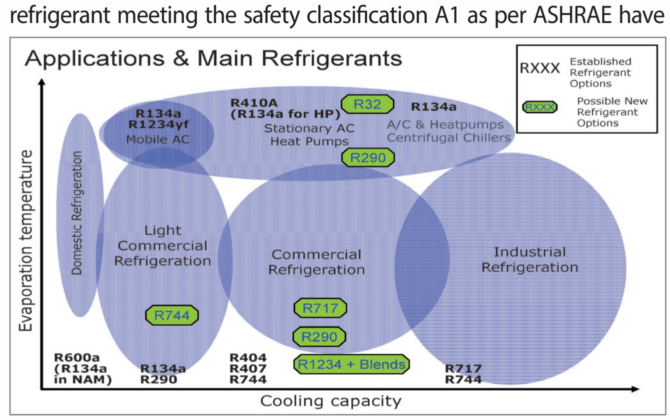

Figure 6: A summary of refrigerant options by application (mature and emerging)

Conclusion

To conclude, we show a chart (*Figure 6*) depicting the main refrigerant choices and their applications. ❖