- Case Study -
Green cooling

Sustainable development goals (SDGs)

Goal 8: Decent work and economic growth

Goal 9: Industry, innovation and infrastructure

Relevant concept/ issues

Green technology

Relevant sector

Heating, ventilation, and air conditioning (HVAC), food retail sector

Background

The use of refrigeration is widespread in modern society. Approximately 15 million people are employed worldwide in the refrigeration sector. The economic significance of cooling technology is notable, but difficult to assess. Global market turnover for the future cooling demand is expected to rise from $135bn in 2018 to US$170bn in 2030. Global annual sales of the refrigeration equipment amount to roughly US$500bn. Cooling is widely used in the food storage production. In low and middle-income countries, food waste in primary production is estimated to be 30-40%, while it is significantly less in the western world. Food waste is primarily caused by poor access to cooling logistics. Another significant use of cooling is in medicine distribution. In recent decades, more and more cars are equipped with AC cooled air. Cooling is also used in offices, shops, work premises and households. In countries with a warmer climate, AC use increases with stranger economies. Today, International Institute of Refrigeration (IIR) estimates the number of AC units with fixed installations to be 2.6 billion, which can be compared with the 2 billion refrigerators in households.

The traditional hydrofluorocarbon (HFC) refrigerants, which have been used in cooling apparatuses as well as for air conditioning units, refrigerators and freezers, have a very strong impact on the climate. Emissions from leaking refrigerants that directly affect the climate are 600-3800 times worse than CO_2, and the indirect emissions from the non-sustainable production of electricity. Table 1 demonstrates that phasing-out of climate impacting HFC refrigerants is of high importance if countries are to succeed in achieving set climate goals.

Impact	Measure	Total reduction of CO_2 equivalents (Gigaton leakage)
1	Refrigerant management	89.74
2	Wind turbines (onshore)	84.60
3	Reduced food waste	70.53
4	Plant-rich diet	66.11
5	Tropical forests	61.23
6	Solar farms	36.90
10	Rooftop solar	24.60

Table 1. Data from Project Drawdown – describing the impact of different measures to reduce the climate impact. These measures can be implemented within the next 30 years.

Source: http://bitly.ws/svBF

Thus, cooling technology is both one of the largest contributors to negative climate impacts, as well as being able to contribute to the significant minimization of CO_2 emissions.

What are natural refrigerants?

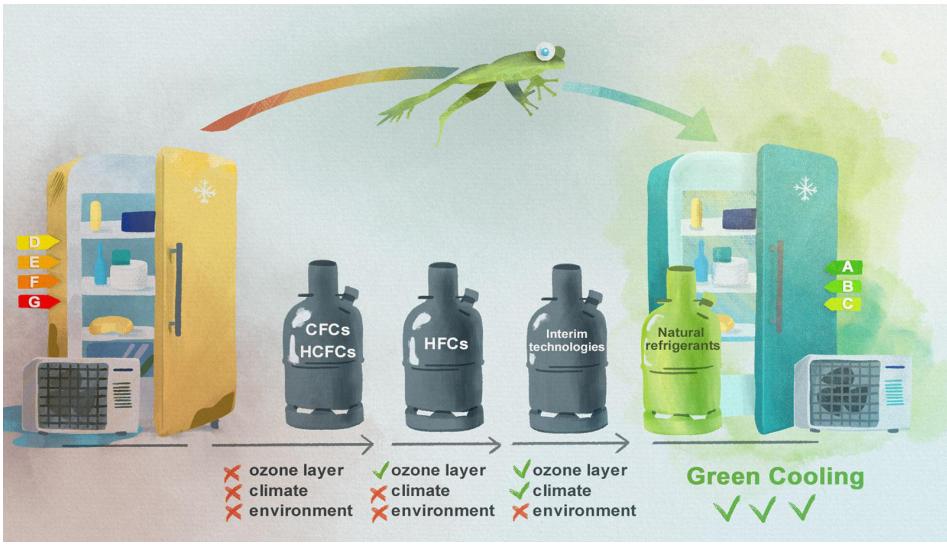

Fig. 1. Green Cooling.

Natural refrigerants are substances that exist naturally in the environment. With zero ozone depletion potential (ODP), and very low or zero global warming potential (GWP), they are considered the definitive solution to the environmental damage caused by synthetic refrigerants.

The most widespread natural refrigerants used in HVAC/R (the mechanical systems used in the heating, cooling and ventilation of indoor environments) applications today are carbon dioxide (CO_2, R-744), hydrocarbons such as propane (R-290), isobutane (R-600a), propylene (R-1270), and ammonia (NH3, R-717). Other natural refrigerants are water (H_2O, R-718) and air (R-729), used only for special applications, or sulphur dioxide (SO_2) and methyl chloride (CH_3Cl), which are no longer used.

Main characteristics of the most commonly used natural refrigerants

1. **Hydrocarbons**

   Hydrocarbons are odorless organic compounds composed of nothing more than carbon and hydrogen atoms. They are flammable and non-toxic substances, and therefore their safety classification is A3. Their ODP of 0 and extremely low GWP value mean they are harmless to the ozone layer and so to global warming. Propane (R-290), isobutane (R-600a) and propylene (R-1270) are the most common hydrocarbons currently used in HVAC/R applications.

   Hydrocarbons operate at standard working pressures and have excellent thermodynamic properties, leading to high-energy efficiency. For instance, the latent heat of evaporation of hydrocarbons is almost two times higher than that of the most common HFC refrigerants (R-134a, R-404A and R-507): this means a higher cooling/heating effect for the same refrigerant mass flow.

   The major challenge of the use of hydrocarbons as refrigerants comes from their high flammability. This requires a particular design of the system and compliance with specific requirements for flammable refrigerants defined by set standards.

2. **Carbon dioxide**

   Carbon dioxide (CO2, R-744) is a colorless fluid, heavier than air at normal conditions and odorless at low concentrations. Being a non-flammable and non-toxic substance, it is classified as A1 according to ASHRAE Standard 34.

   The effect of R-744 on the ozone layer is nill, so it has an ODP value of 0. With respect to its global warming impact, its GWP is 1, which is the reference value for comparing the direct impact of other refrigerants. However, it can be considered that R-744 does not contribute to climate change, as it is a by-product from industrial processes and would otherwise be emitted into the atmosphere.

   The major challenge for R-744 arises from the fact that the critical point is easily attainable at a temperature that is common in many climates. The critical point is the temperature at which the element is in between two states (gas and liquid). Thus, CO_2 is a little complicated to operate. Measures need to be adopted to keep pressure and temperature under control, in order to optimize heat exchange and maximize efficiency. Moreover, operating pressures are very high, and this represents the biggest challenge for the components in the installation, such as compressors, valves and piping. Nonetheless, it should be stressed that high pressure means that smaller diameter pipes can be used, and pressure drop and compression ratio are lower.

3. **Ammonia**

   Ammonia (NH3, R-717) is an alkaline and colorless chemical compound under atmospheric pressure. Being a mildly flammable and toxic substance, it is classified as B2L. R-717 is also corrosive, but its strong odor makes it easy to detect. With respect to environmental impacts, R-717 does not have any harmful effects on the ozone layer or global warming when released into the atmosphere, thus its ODP and GWP values are 0.

   R-717 is widely available on the market at a very low price. Working at standard operating pressures, its good thermodynamic properties, such as high latent heat of vaporization, position it among the refrigerants that have the highest energy efficiency for both medium and low temperature operation.

   However, the toxicity and flammability of R-717 limits its use in public places. Many advances have been made recently to minimize risks to human health, such as the development of hermetically sealed equipment or leak detection systems.

   For many years R-717 has mainly been used in industrial refrigeration, however its use is being extended to other applications, such as commercial refrigeration as a secondary fluid.

Why natural refrigerants?

Natural refrigerants are a natural, sustainable alternative to commonly used hydrofluorocarbon refrigerants (HFCs).

Natural refrigerants – including carbon dioxide, hydrocarbons, and ammonia – have zero or near-zero global warming potential (GWP), and could even reduce energy, gas, and water consumption. Transitioning to climate-friendly natural refrigerants is one of the single most effective ways to permanently reduce greenhouse gas emissions, and is considered one of the most cost-effective climate mitigation strategies.

What's more, due to their well-understood, negligible impact on the environment, natural refrigerants are a "future-proof" option for supermarkets amid increasing refrigerant regulations.

Application of natural refrigerants

1. **Rapid adoption by supermarket chains**
   Supermarkets, with their enormous cooling needs, are among the largest corporate users of HFCs. HFCs are the common refrigerants that cool our food, but also wreak havoc on our climate; they are thousands of times worse for the environment than the same quantity of CO_2. By converting to natural refrigerants, supermarkets gain energy efficiency and avoid climate-damaging emissions. It's well known that all supermarket refrigerant systems leak at some time during their lifetime, even those that are climate-friendly. The difference is a natural refrigerant system has a global warming potential (GWP) of less than 10 – more commonly 1 or 3 – whereas HFCs have GWPs in the thousands. Hence, the impact and severity of a leak is vastly mitigated when dealing with natural refrigerants instead of HFCs.

   In Europe and Japan, natural refrigerants have become the norm rather than the exception. In Europe alone, over 20,000 supermarkets use CO_2 as a refrigerant and they comprise over 90% of overall CO_2 uptake (Refrigeration world, 2020). Although the United States has made a much slower transition, the country includes some good examples. The US supermarket chain, Aldi, operates more than 320 stores using transcritical CO_2 refrigeration. Walmart uses a secondary loop refrigeration system in about 125 stores. Many of them use carbon dioxide. Whole Foods, Albertsons and Raley's have also successfully adopted ammonia/ CO_2 systems. Whole Foods has at least 20 installations. In 2015 Piggly Wiggly opened a 36,000-square-foot store in Columbus, Georgia that uses ammonia/ CO_2. It employed a 53-pound ammonia charge and a 1,400-pound CO_2 charge. This saves about 25 percent on energy, conforms to ammonia safety standards (IIAR-2, IBC, IMC, IFC, EPA and ASHRAE-15), and is approved by the local fire marshal.

   You can find the climate-friendly supermarkets around the globe here: https://www.climatefriendlysupermarkets.org/map

2. **Food giant converts**
   Global food giant Nestlé also makes extensive use of natural refrigerants. For large and medium-sized systems, and for processing, they usually use ammonia/ CO_2. Most of the Nestlé factories have now transitioned from HFCs to natural refrigerants. Nestlé also operates 21 supermarkets in Switzerland. Since 2016, the company has only used hydrocarbons in its ice cream freezers (propane R-290, isobutane R-600a, and propylene R-1270).

   Unilever, Pepsi and Coke have installed thousands of plug and play cabinets that use R290. Target, Walmart, McDonald's and Starbucks have also begun using these cabinets. In Europe, and in France in particular, tens of thousands have been deployed.

   Source: Natural refrigerants: Supermarkets moving quickly to adopt CO_2/ammonia systems (Nagy, 2020)

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