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Reducing the Carbon Footprint of Commercial Refrigeration Equipment

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Environmental concerns raised by high global warming potential (GWP) refrigerants have triggered a series of regulatory activities around the world to curtail the use of high GWP hydrofluorocarbons (HFCs) in air conditioning and refrigeration equipment. While the GWP of the refrigerant is a significant contributor to the overall emissions of commercial refrigeration products, it is not the only factor that requires attention. Energy efficiency, maintenance and retrofits are also significant factors that can minimize the carbon footprint of the equipment.

Introduction

The primary energy consumption of commercial refrigeration equipment in the U.S. was around 1.23 Quads[1] in 2011 [1]. This is a substantial amount of energy which represents about 4% of the total annual primary energy consumption of commercial buildings. Most of this primary energy comes from the burning of fossil fuel used to generate the electricity needed to operate the equipment. The electricity generation process at the power plant results in greenhouse gas emissions, which during the lifetime of a commercial refrigeration system (or any other product requiring electricity to function) represent the indirect contribution of the equipment to climate change. Direct emissions are a function of the GWP of the refrigerant used in the system and the amount of refrigerant leaked into the atmosphere.

The relationship between the direct and indirect emissions depends on the refrigeration system used, its application and its geographic location. Historically, the indirect emissions vary from about 60% of the total emissions for supermarket systems (which tend to leak more refrigerant) to over 90% for self-contained reach-ins (which leak much less refrigerant). **In other words, the indirect effect, which is directly related to the energy consumption of the refrigeration equipment, has been the dominant factor impacting the environment.** Current trends in the commercial refrigerant industry, particularly in retail, toward smaller, more flexible system architectures, reduced charge sizes, less piping, and lower leak rates all indicate that energy consumption will become even more dominant in determining the overall environmental footprint into the future.

Efforts are underway around the globe to phase down the use of high-GWP refrigerants. Next generation refrigerants with low GWP levels have been introduced and are readily available for use in various refrigeration systems. However, the selection of an appropriate refrigerant for a given refrigeration

[1] Quadrillion Btu or 10^{15} Btu

application should not be based on GWP alone. Other factors, including energy efficiency, proper maintenance, monitoring and potential retrofits of refrigeration systems must also be considered to minimize the total impact of the equipment on the environment. These factors are discussed in more detail below.

Energy Efficiency

As previously mentioned, the largest contribution of greenhouse gas emissions of a commercial refrigeration system comes from its energy consumption. Therefore, the impact on the environment could be significantly reduced by improving the energy efficiency of the system. Several studies have looked at the performance of low GWP alternatives in commercial refrigeration equipment [2-4]. They have shown that many low GWP alternatives perform as well or better than the refrigerants they are replacing. Though, these studies also revealed that the performance of some alternative refrigerants could be dependent on the application and the geographic location (i.e., climate zones) where the refrigeration system is installed.

For example, Target, a major retailer in the U.S., conducted an energy consumption study at two of its stores in California (55 miles apart), one operating with carbon dioxide (CO_2) and the other with a hydrofluorocarbon (HFC) blend [5]. The transcritical CO_2 system consumed on average 20% more energy per year than the HFC system. Other stores using hydrofluoroolefin (HFO) blend refrigerants in various parts of the country experienced a 3% energy consumption *reduction* per year on average compared to conventional HFC systems.

Another recent report showed a wide variety of existing supermarkets across the US achieved energy reductions on the order of 10% when converting from R-22/R-404A to low-GWP HFO blends [6] Though, a study conducted by Hannaford supermarkets in the northern part of the U.S., where annual average temperatures are relatively cool, showed that over a one year period, a transcritical CO_2 system achieved similar energy consumption to a conventional legacy HFC system [7].

These studies illustrate the importance of energy efficiency when selecting alternative solutions and the fact that focusing on the GWP of the refrigerant alone may overlook the significant environmental impact of the indirect emissions resulting from the energy consumption of the refrigeration system.

Maintenance and Monitoring

Proper maintenance is also critical to ensure the reliable and optimal operation of a refrigeration system. Some of the maintenance activities include inspecting and correcting deficiencies with:

- Evaporator and condenser coils,
- Refrigerant charge,
- All components and pipes for refrigerant leaks,
- Compressors,
- Motors,
- Door gaskets and seals, and
- Defrost system operation.

Poor maintenance can have a significant impact on the energy consumption of the refrigeration system as illustrated in Figure 1 below [8]. The figure shows the potential effects of few common maintenance issues and is by no means fully comprehensive.

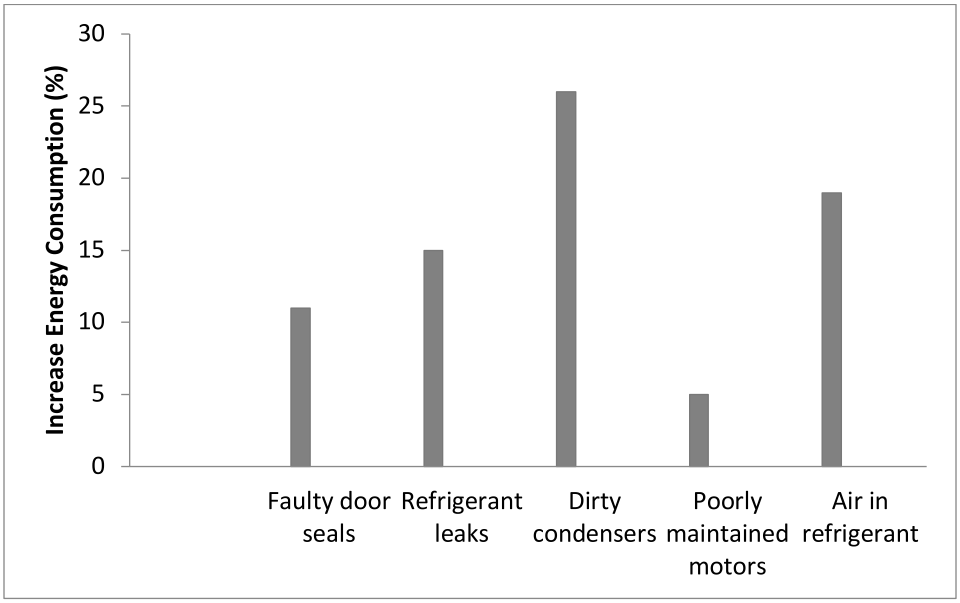

Figure 1: Increase Energy Consumption Due to Poor Maintenance [8]

Also, the percentage increase in energy consumption shown in the figure should not be taken as universally applicable to all refrigeration systems as it will vary from system to system and from one application to the next. Nevertheless, the figure illustrates how poor maintenance can significantly impact the environment if not properly addressed given that the increase in energy consumption is related to the indirect emissions of the refrigeration system. In addition, poor maintenance translates into higher operating costs, less reliable systems and longer plant downtime to bring the equipment back to its original state of operation in the case of breakdowns.

The impact of refrigerant leaks on the refrigeration system deserves attention for two main reasons. First and as previously discussed, a reduction in refrigerant charge can significantly increase the energy consumption of the equipment and therefore increase the indirect emissions of the refrigeration system. Second, the refrigerant escaping into the atmosphere through leaks contributes to the direct emissions of the refrigeration system. Consequently, refrigerant leaks must be minimized regardless of the GWP of the refrigerant and efforts are currently underway to do just that. For example, retailers participating in the EPA GreenChill programs have demonstrated through better refrigerant management plans, annual refrigerant emission rates below 15% compared to the national average of 25% [9]. Furthermore, new designs with low refrigerant charge such as distributed systems and designs without receivers have reduced considerably the amount of refrigerant in the system.

Monitoring can help users of commercial refrigeration equipment gain access to real-time information about the energy use and performance of their equipment. A large array of refrigeration equipment can be operated and maintained that way. With real-time data from a monitoring system, operators are able to recognize, pinpoint and diagnose unexpected fluctuations in performance or usage very quickly.

Because performance and usage issues can be detected and diagnosed in a timely manner, monitoring systems provide significant energy savings potential. It is estimated that on average, energy cost savings of

5% can be achieved [10]. Nowadays, fault detection and diagnosis (FDD) systems are capable of detecting performance degradation in the refrigeration equipment before it starts to drift away from its optimal operating condition [11]. These FDD systems help avoid costly breakdowns while ensuring that the refrigeration equipment always performs as originally designed, minimizing energy consumption and indirect emissions.

Retrofits

Regulatory pressures around the world are pushing retailers to consider various solutions to reduce the carbon footprint of their commercial refrigeration installations. Among the solutions available, retrofitting the exiting refrigeration equipment with a lower GWP refrigerant presents several advantages including (1) reduced energy consumption and indirect emissions, (2) reduced direct emissions, (3) reduced cost (when compared to installing a brand new system) and (4) reduced plant downtime needed to complete the conversion.

Several low GWP refrigerants have been developed over the past few years for supermarket retrofit applications. These include low-GWP HFCs and HFO/HFC blends. Other low-GWP refrigerants such as CO_2, ammonia or hydrocarbons are not suitable for retrofit into existing equipment because of high pressure, material compatibility, toxicity, or flammability issues.

However, the decision to retrofit a refrigeration system with a low-GWP refrigerant should not stop operators from fixing refrigerant leaks or problems with the equipment. In addition, other retrofit measures aimed at reducing the energy consumption of the refrigeration system should be seriously considered. Some retrofit opportunities and their respective potential energy savings are shown in Table 1 [12, 13].

Table 1: Energy Saving Opportunities from Retrofits

Retrofit Opportunity	Potential Energy Savings (%)
Refrigerant Conversion [12]	Up to 12 %
Pipe insulation [13]	15%
Transparent doors on display cases [13]	30%
Night blinds and covers [13]	6%
Intelligent defrost controls [13]	>10%
Efficient lighting (T5, LED) [13]	2%
Electronic expansion valve [13]	10%
Fans and motors [13]	4%

The potential energy savings shown in Table 1 are not additive and should not be viewed as applicable to all refrigeration systems. However, while some of the retrofit options could be expensive to implement, they are generally cost-effective, with payback periods less than 5 years [14]. Perhaps, the quickest and most cost-effective manner to reduce the total carbon emissions of commercial refrigeration equipment is to retrofit existing high-GWP systems (R-404A/R-507/R-22) with low-GWP HFCs or HFO/HFC blends. Such replacements can lower direct emissions about 70% while also reducing energy consumption by about 10%.

Summary

International regulations are pushing the refrigeration industry towards the development of more sustainable solutions. Low-GWP alternative refrigerants have been introduced and are now commercially available. However, energy consumption, which is the equipment's largest contributor to climate change, should be given full consideration.

Energy efficiency improvements, maintenance, product monitoring are all cost effective measures proven to significantly reduce the energy consumption of the equipment. The retrofit of existing commercial refrigeration systems with low-GWP HFCs and HFO/HFC blends presents a unique opportunity to quickly and cost-effectively decrease direct and indirect emissions. These energy saving measures together with the GWP of the refrigerant should be considered to reduce the carbon footprint of commercial refrigeration products.

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