

Low GWP refrigerants for heat pumps



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Heat pumps are increasingly used in building heating and cooling applications and are one of the main solutions for optimizing the energy efficiency of contemporary buildings and reducing CO₂ emissions.



The heat pump is a machine that, by using different forms of energy, is capable of extracting and transferring thermal energy.

Specifically, it is estimated that heat pumps have the potential to reduce global CO₂ emissions by at least 500 million tons by 2030, the equivalent to the annual CO₂ emissions of all cars present today in Europe (source: IEA report - December 2022).

Their main advantage is that they provide more thermal power than the electrical energy consumed.

The reduction in CO₂ emissions will be even more significant with the increase of renewable energies in the energy mix.

Regulatory framework

The new F-gas regulation (EU) 2024/573 requires that, in new air-conditioning and refrigeration systems, both commercial and industrial, the old traditional HFC refrigerants with a high GWP will be replaced by natural gases or new HFO blends with a low GWP.

These refrigerants are designed to comply with evolving regulatory requirements. The gradual reduction in the use of refrigerants with a high GWP by the refrigeration and air conditioning industry, is moving in favor of lower-GWP refrigerants.

In accordance with the Kigali Amendment and the Montreal Protocol, the goal of the new F-gas is a sharp reduction in HFCs by 2050.

Types of heat pumps

Most heat pumps operate with a vapor compression refrigeration circuit, which is based on the principles of thermodynamics.

This system consists of four main components: the compressor, which increases the pressure and temperature of the refrigerant gas; the condenser, which releases heat to the environment; the expansion device, which reduces the pressure of the refrigerant; and the evaporator, which absorbs heat from the external environment.

1. Air-to-air heat pumps

They transfer heat between the building and the outside air via the refrigerant gas. For heating and cooling, they use terminal indoor units that blow air, instead of traditional radiators. In addition, they can produce sanitary hot water by heating the water through the same system of heat exchange, without the need of a separate one.

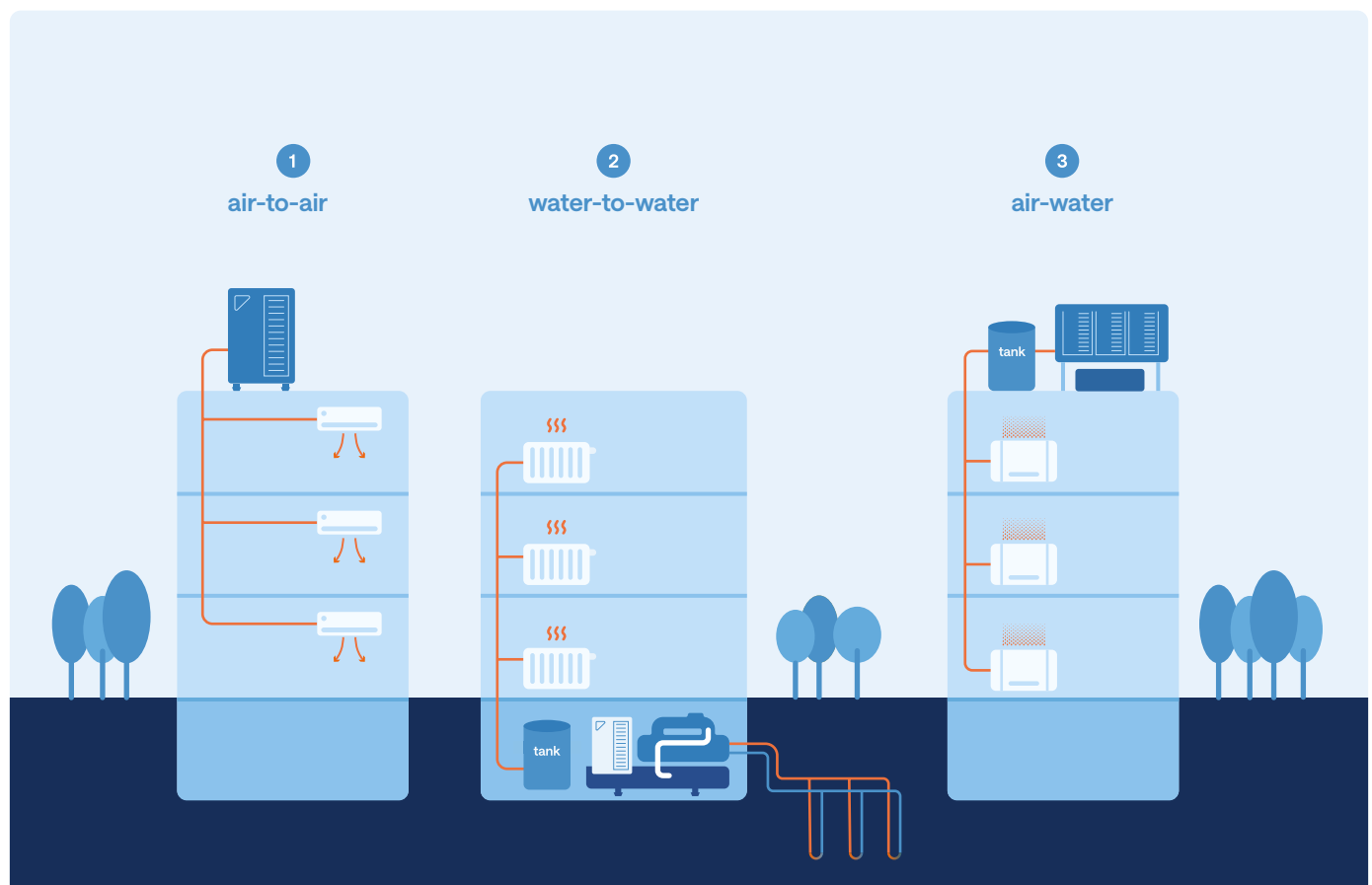
2. Water-to-water heat pumps

They transfer heat between the building and different energy sources (such as geothermal or outdoor air) using a refrigerant gas and water.

They are capable of reaching high temperatures, allowing the replacement of traditional boilers to heat radiators or supporting heating applications for industrial processes. In addition, they offer cooling capabilities and domestic hot water production, optimizing the energy efficiency of the building.

3. Air-water heat pumps

They perform a heat exchange between the building and the outside air using a refrigerant gas and water. They are capable of achieving water temperatures high enough to meet the needs of heating, cooling and sanitary hot water production, thus adapting to the majority of applications.



Nippon Sanso' Solutions

Supporting the goals of the new F-gas Regulation 2024/573 for the transition to natural and low GWP gases, Nippon Sanso' refrigerants are candidates for being a suitable option for the heat pump (RACHP) sector.



R-410A

GWP = 2,088

R-410A is a refrigerant gas consisting of a nearly azeotropic mixture of hydrofluorocarbons, not harmful to the ozone layer, non-toxic and non-flammable.

R-410A features cooling capacity suitable for a wide range of applications, enabling good performance with a low charge refrigerant. R-410A requires the use of lubricants based on synthetic polyesters (POEs) in order to ensure a complete miscibility between oil and refrigerant gas.

High pressures, high density and good heat transfer capabilities of R-410A allow the use of smaller refrigerant components, with the same achievable cooling capacity.



R-32

GWP = 675

R-32 (Difluoromethane) is a single-component HFC, which finds application in different domestic and commercial air conditioning systems.

With a GWP of one-third compared to R-410A, R-32 turns out to be a refrigerant in line with the new F-gas directives. Thanks to its excellent thermodynamic properties, it allows a lower charge in systems compared to the R-410A ones, standing as a candidate for a suitable replacement in single and multi splits for air conditioning and heat pumps.

It also has higher efficiency and about 10% more capacity than R-410A, depending on the application and system.

R-32 belongs to ASHRAE A2L safety class and is mildly flammable and non-toxic, and it requires lubricants based on synthetic polyesters (POE).



R-454B

GWP = 465

R-454B is a zeotropic mixture based on hydrofluoroolefins. With a GWP that is 78% lower than R-410A, R-454B makes its application in new installations easy and convenient, without requiring significant modifications.

In addition, R-454B exhibits excellent performances compared to R-32, particularly when it is necessary to provide higher hot water outlet temperatures at a lower room air temperature. R-454B, compared with R-32 refrigerant, has a lower discharge temperature at the compressor, ensuring higher reliability and longer compressor life.

R-454B belongs to the ASHRAE A2L safety class, which means it is classified as a non toxic and mildly flammable and should be used with lubricants based on polyesters based synthetic (POE) lubricants.



R-454C
GWP = 146

R-454C is a zeotropic mixture based on hydrofluoroolefins, mildly flammable, with a GWP of less than 150, designed for the replacement of refrigerants R-404A and R-22 in new industrial and commercial direct expansion plants operating at low and medium temperatures.

Classified as mildly flammable (Class A2L), R-454C allows much higher refrigerant charges than other more inflammable refrigerants and can be used safely in accordance with applicable codes and regulations.

It is suitable as a long-term solution suitable for use in hermetically sealed facilities, warehouses and cold rooms, R-454C should be used with lubricants based on synthetic polyesters (POEs).



R-1234ze
GWP = 1.37

A highly pure substance with very low GWP, R-1234ze is used in industrial air conditioning systems, positive temperature refrigeration and heat pumps.

Its characteristics are similar to those of R-134A but with improved energy efficiency. Although it falls into the A2L category, it is non-flammable at room temperature.

R-1234ze is suitable for positive temperature applications in cases where “non-flammability” is a requirement of overriding importance.



Propane
(R-290) GWP = 3

Propane has an ODP (Ozone Depletion Potential) of zero, as well as having excellent thermodynamic properties that allow it to be used in a wide variety of equipment in the HVAC-R world.

It is not a blend but a pure gas, so it does not present any of the glide problems found with some synthetic refrigerants. Its low density and its inherent properties allow for charge reduction and relatively low working pressures.

Following the update of EN 60335-2-89:2022, European manufacturers can sell standalone equipment with a charge of R-290 up to 500 gr.

Choosing the right refrigerant



A critical aspect in the operation of a heat pump is the choice of the refrigerant. Its thermodynamic properties are fundamental for the heat exchange, which occurs through its phase transition (from liquid to vapor and vice versa).

The refrigerant must have specific characteristics that allow good energy efficiency and heat exchange capacity.

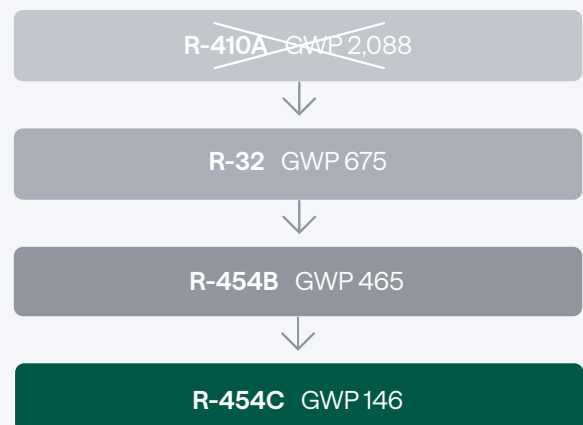
During the operating life of heat pumps powered by renewable energy, the only source of CO₂ emissions is the refrigerant. R-410A, the most common refrigerant, has a global warming potential (GWP) of 2,088, making its impact on the greenhouse effect 2,088 times greater than CO₂. A lower-GWP alternative is R-32, with a GWP of 675.

Natural refrigerants such as R-290 (propane) have a minimal GWP, as do other refrigerants with a very low GWP such as R-454C.

The performance of these systems is evaluated through the COP (coefficient of performance) indexes and EER (energy efficiency ratio), which measures efficiency in heating and cooling, respectively.

The efficiency of the heat pump in the winter season basically depends on the combination:

- outdoor air temperature
- flow temperature in the water towards the heat distribution system
- load regime, which is what the heat output actually delivers versus the maximum possible heat output



The relationship between the price of electricity and the price of gas is the factor that determines the economic advantage of using a heat pump over a gas boiler.

Whenever this EE/gas ratio is lower than the SCOP value of the heat pump, heating with the heat pump is more cost-effective.

Various theoretical studies have shown that A2L refrigerants with a low GWP could improve the efficiency of heat pump systems.

However, real world tests have shown that it is not sufficient to replace a refrigerant with a high-performance one to achieve the efficiencies theoretically expected. Every heat pump system must be designed specifically for the used refrigerant.

Many low GWP A2L refrigerants are zeotropic blends, which implies that a temperature glide must be taken into account during the design of the heat exchangers (evaporators and condensers).

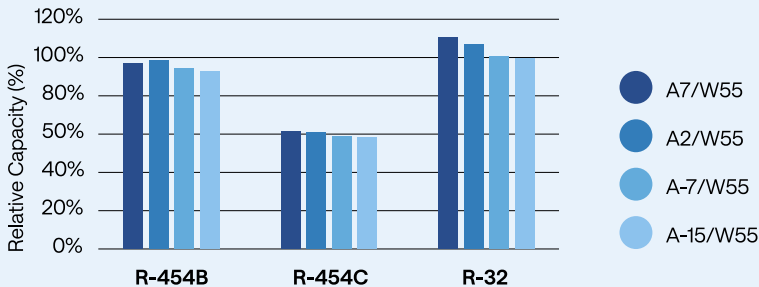
Although the behavior of these mixtures has been addressed in the past without additional cost, ignoring it can lead to non optimal solutions.

The temperature glide can be exploited favorably in evaporators to improve capacity and efficiency, but condensers must be designed differently and be slightly larger than those for azeotropic refrigerants.

To achieve a better performance, the use of compressors designed specifically for the A2L refrigerants with low GWP is essential to achieve maximum efficiency. The use of not optimized compressors for these refrigerants can reduce the capacity and efficiency of the system.

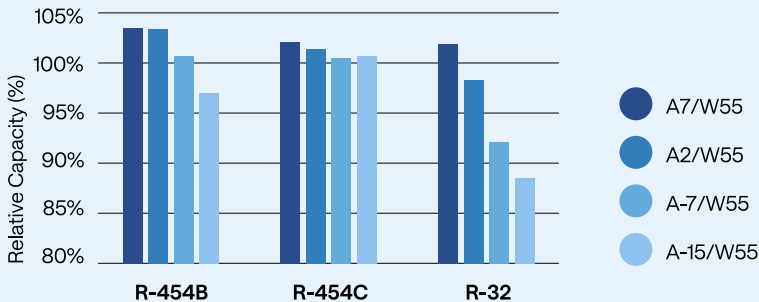
Capacity compared to R-410A

Heating capacity of different refrigerants at the A/W conditions (room air temperature/water temperature desired) for buildings under renovation (W55)



COP compared to R-410A

COP of different refrigerants at A/W conditions for buildings under renovation (W55)



Source: Opteon Heatpump whitepaper V2 15 dec 2021

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