Low GWP alternative refrigerants in heat pumps

Different refrigerants are used in various heat pump applications. CO_2 is successfully used in transcritical cycle in heat pump water heaters covering high water temperature demands. Hydrocarbons (HC-600a, HC-290) are suitable for heat pumps with low capacities of below 20 kW. Industrial heat pumps can be based on HC-600a or ammonia. The total share of natural refrigerants in the heat pump systems is approximately 2%, whereas the rest 98% are HFC refrigerants in charges of 1.5-15 kg for achieving 5 to 50 kW heating capacities[i].

HFC blends R-404A, R-407C and R-410A are the most dominant refrigerants in heat pump application. Out of them, R-410A is one of the main refrigerants used for heat pump systems in residential applications. R-410A is a near-azeotropic mixture of R-32 and R-125 with 50/50% composition. It has zero ozone depletion potential (ODP), not flammable and not toxic. R-410A has good thermal and transport properties and high volumetric capacity, but it might have unfavorable effects on the environment in case of leakage as it has relatively high global warming potential (GWP) which is 2088 times greater than that of CO_2.

It is difficult to retrofit R-410A systems with natural refrigerants, as in most cases it will require system redesign. Thus a number of synthetic refrigerants proposed as the replacements for R-410A with some of the candidates are still in the development stage. Most of the proposed refrigerants are flammable and are classified in A2L or 2L ASHRAE safety classification group. Some of them are R-32, R-1234yf, R-1234ze(E), ARM-70a, D2Y-60, DR-5, HPR1A, L-41, R-32/R-134a, R-32/R-152, R-1234ze(E)/R-32. All these refrigerants are suitable for drop-in. Other low GWP refrigerants, like CO_2 and ammonia, are also possible R-410A replacements, however require intensive re-design.

A number of the refrigerants have been suggested to substitute R-410A in the heat pump systems. R-1234yf, for instance, has very low GWP of 4 and zero ODP. The drop-in performance of R-1234yf in R-410A system in a commercially available 17,6 kW R-410A heat pump split system shows that both refrigerants have similar coefficient of performance (COP), but R-1234yf provides much lower capacity (see Figure 1)[ii]. R-1234ze(E) has similar drawback due to its lower vapour density and latent heat, hence much larger unit is required to achieve similar performance to that of R-410A[iii].

R-32 is another pure refrigerant which is suitable for heat pump applications. It has zero ODP, and offers significant GWP reduction with GWP=625. It is classified as low flammable (A2L) and might pose fire hazard which is still greater than similarly classified R-1234yf due to faster flame propagation of R-32. R-32 has higher volumetric capacity than R-410A what leads to reduced refrigerant charge whist maintaining similar system performance[iv]. Reduced refrigerant charge can also lead to additional environmental benefits in case of the refrigerant leakage. Drop-in tests show the comparable capacity and the increase in COP when using R-32 in the system designed for R-410A. Due to its high performance, R-32 can be proposed as R-410A replacement, but the flammability concerns are limiting its use. Thus, it is suggested to use R-32 in blends to mitigate its flammability while keep low GWP.

DuPont and Honeywell have proposed a number of development refrigerants to replace R-410A in heat pump applications. DuPont propose DR-4 and DR-5 R-1234yf based development refrigerants with GWP

in range of 300-500 as replacements for R-410A. In the commercially available 17,6 kW R410A heat pump split system the DR-5 outperforms R-410A showing higher COP and capacity, while DR-5 showing significantly lower capacity but higher COP (see Figure 1)[v].

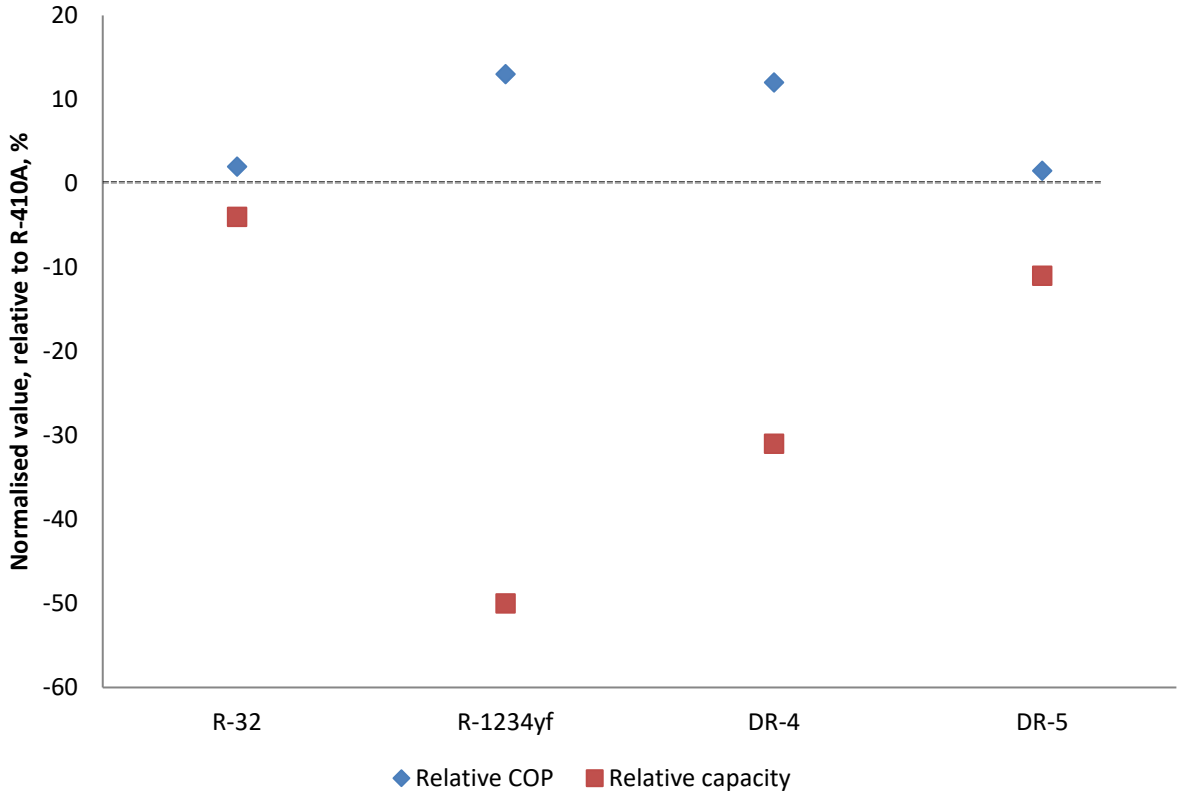

Figure 1 – Relative performance of new low GWP refrigerant in comparison to that of R-410A in heat pump application

For the similar application Honeywell investigate the applicability of mild flammable HFO-based refrigerant blend L-41. In the test, performed in heat pump unit with a nominal heating capacity of 5 kW, the L-41 show improved efficiency relative to the R-410A, however with lower capacity at drop-in conditions[vi]. Minor system modification is needed for capacity to match the baseline refrigerant.

R-32 and HFOs are the main refrigerant candidates seen to be used as R-410A replacement both in pure form and, most probably, in form of mixtures with other refrigerants. It can be concluded, that HFOs, like R-1234yf and R-1234ze(E), are not suitable for the drop-in replacement of R-410A in a heat pump systems as system modifications are required in order to keep similar performance of the heat pump system due to the low capacity of R-1234yf. This issue can be overcame by using refrigerants in the

blends with other refrigerants in order to increase the capacity, which is accompanied with GWP increase.

R-32 is suitable for the drop-in replacement of R-410A while taking into the account the safety issues due to its flammability. R-32 blends with other refrigerants can be used in order to mitigate the flammability while keeping the GWP low.

Energy conservation and environmental concerns are the main reasons for the development growth of new low GWP refrigerants. While the direct contribution of all the proposed refrigerants to global warming is lower than that of R-410A, their indirect effect is still an open question. With the majority of the refrigerants have GWP in the range of 500 and A2L flammability class it is unlikely to see inflammable very low GWP refrigerant which is suitable for drop-in replacement of used in the heat pumps today HFCs without system modifications.

---

[i] Kauffeld, "Availability of Low GWP Alternatives to HFCs. Feasibility of an Early Phase-out of HFCs by 2020."
[ii] Barve and Cremaschi, "Drop-in Performance of Low GWP Refrigerants in a Heat Pump System for Residential Applications."
[iii] Koyama, Takata, and Fukuda, "Drop-in Experiments on Heat Pump Cycle Using HFO-1234ze (E) and Its Mixtures with HFC-32."
[iv] Barve and Cremaschi, "Drop-in Performance of Low GWP Refrigerants in a Heat Pump System for Residential Applications."
[v] Biswas and Cremaschi, "Performance and Capacity Comparison of Two New LGWP Refrigerants Alternative to R-410A in Residential Air Conditioning Applications."
[vi] Spatz, Yana Motta, and Achaichia, "Low Global Warming Refrigerants for Stationary Air Conditioning Applications."