Emerson Climate Technologies at a glance

Emerson Climate Technologies is the world's leading provider of heating, ventilation, air conditioning, and refrigeration solutions for residential, industrial, and commercial applications. We combine technically superior products and services from our industry-leading divisions and brands with our global engineering, design and distribution capabilities to create reliable, energy efficient climate systems that improve human comfort, safeguard food, and protect the environment.

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Copeland Scroll heating

R410A - R407C

A Refrigerant Analysis for Air to Water Heat Pump Applications

EMERSON Climate Technologies

The perfect refrigerant choice for different heat pump systems

A theoretical comparison of R410A versus R407C

The choice of the refrigerant impacts the performance and behavior of any heat pump system. The most interesting refrigerants for heat pump applications presently are R410A and R407C.

This paper presents a theoretical comparison of these two refrigerants in order to guide the selection of the best option for different types of heat pumps.

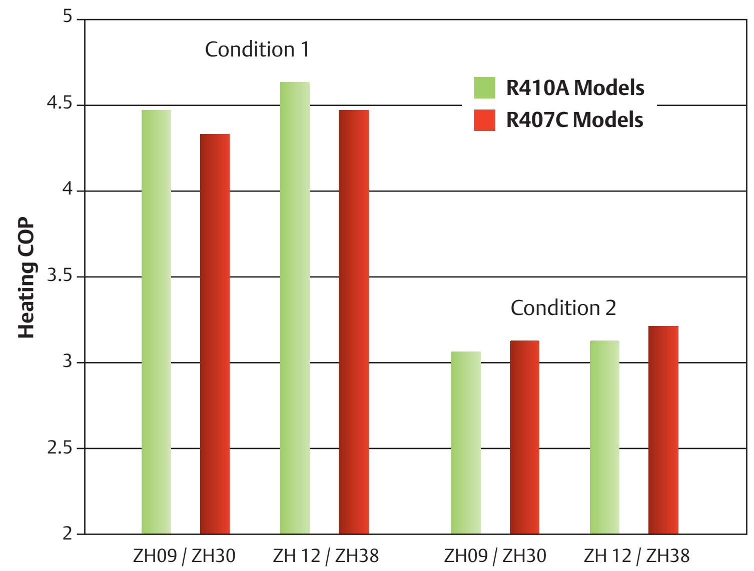
The assessment relies on a heat pump model that is based on compressor data and heat pump parameters, such as pump consumption and cycling coefficient. Further parameters like heat exchanger temperature differences and defrost impact on the efficiency are taken from representative manufacturers across Europe. The simulations focus on air to water systems that is the fastest growing market aimed in particular to retrofit applications; rating conditions and seasonal performance calculation are as per prEN14825. The prEN 14825 accounts for the domestic hot water production in the seasonal efficiency calculation.

Several Copeland Scroll™ compressors have been analyzed, both with and without enhanced vapor injection:

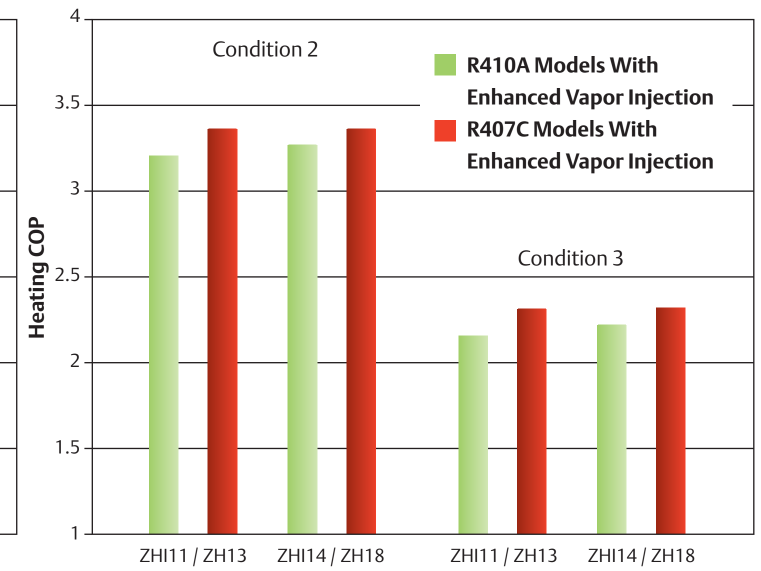
- Based on R407C refrigerant:
  Heating compressors ZH30 and ZH38
  Enhanced Vapor Injection compressors ZH13 and ZH18
- Based on R410A refrigerant:
  Heating compressors ZH09 and ZH12
  Enhanced Vapor Injection compressors ZHI11 and ZHI14
- For end-user savings, in addition, the standard air conditioning compressor ZP42 (R410A) has been analyzed.

ZHI11K1P

ZH Compressors



ZH Compressors with Enhanced Vapor Injection



ZH Compressors	Condition 1	Condition 2
Evaporating °C	-7.0	-7.0
Condensing °C	35.0	50.0
Superheat °C	5.0	5.0
Subcooling °C	4.0	4.0

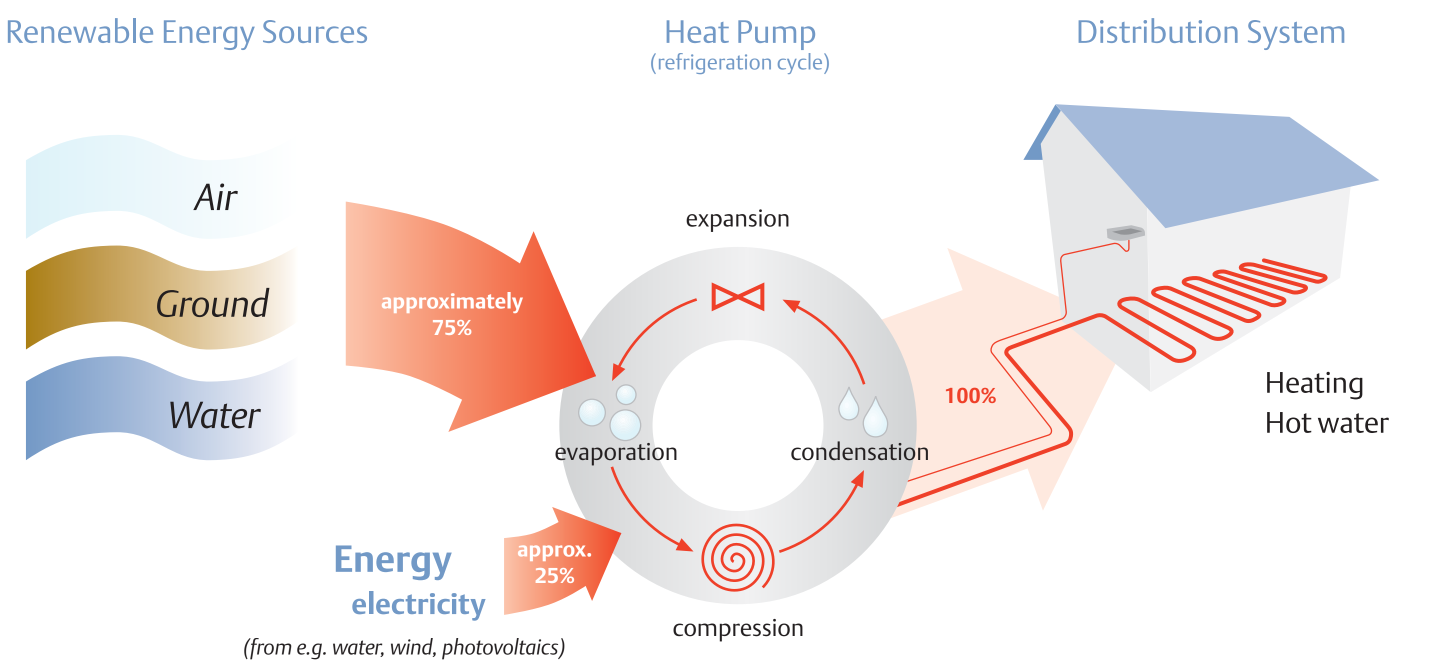
ZH Compressors with Enhanced Vapor Injection	Condition 2	Condition 3
Evaporating °C	-7.0	-15.0
Condensing °C	50.0	60.0
Superheat °C	5.0	5.0
Subcooling °C	4.0	4.0

ZH38K1P

Pure Compressor Analysis:

R410A and R407C show very similar performances with a slight advantage of R407C at higher pressure ratio, i.e. condition 2 and 3 in the above graphs.

R410A compressors operate with a higher discharge temperature and therefore utilize unique engineering solutions to feature wide operating envelopes.



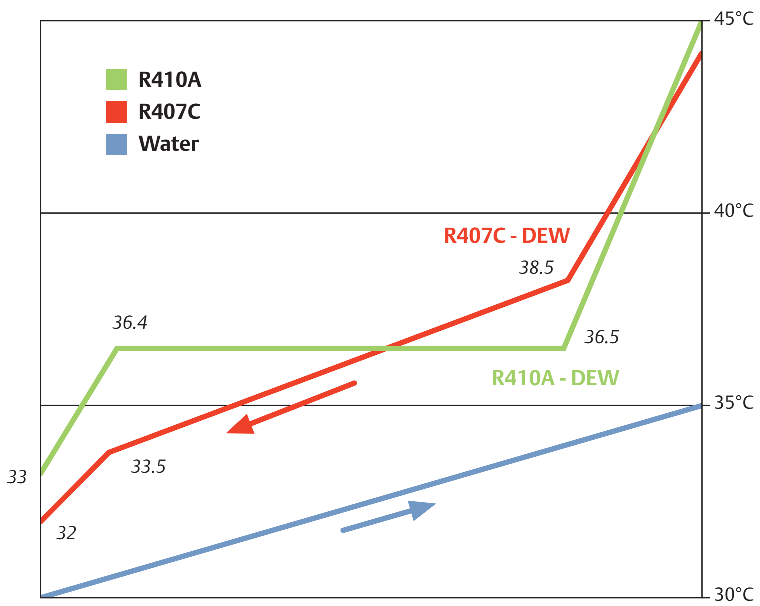
Entire System Analysis

When just considering the compressor COP, R410A does not seem to be the best solution. As soon as we extend the scope of the analysis and consider the complete heat pump system immediate advantages are highlighted. Focusing first on the condenser, where the hot water is produced, we can see, as shown in the temperature profile figure, that due to the fact that R410A has no glide the dew condensing temperature is lower than with R407C by an average of 2K, leading to higher system efficiency.

The sub-cooling effect plays an important role. R410A with zero glide is able to maintain a constant sub-cooling of 3.5K without a liquid receiver. R407C systems need a liquid receiver to keep a stable sub-cooling of 1.5K.

In the air coil the same evaporating temperature is used for R410A and R407C. One additional effect of the absence of glide is that the unit will need less defrost cycles but this effect has not been taken into account in this paper because it strongly depends on the fin and air flow design.

With the adoption of R410A, heat pump manufacturers can achieve lower unit cost, for example by reducing the air coil size because of the higher heat transfer capability of R410A and through the absence of a liquid receiver, as already mentioned.



Typical temperature profile in a brazed heat exchanger condenser

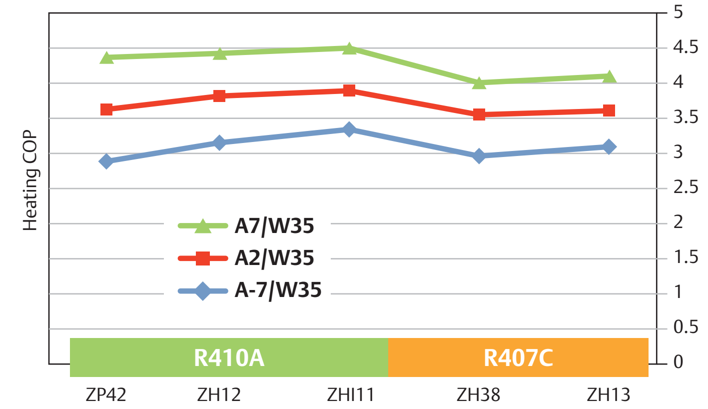
The following compressors, which are similar from a heating capacity point of view, have been used in the simulation:

- ZP42KSE – Air conditioning R410A
- ZH12K1P – New heating optimized R410A
- ZHI11K1P – New heating optimized R410A with Enhanced Vapor Injection
- ZH38K4E – Heating optimized R407C
- ZH13KVE – Heating optimized R407C with Enhanced Vapor Injection

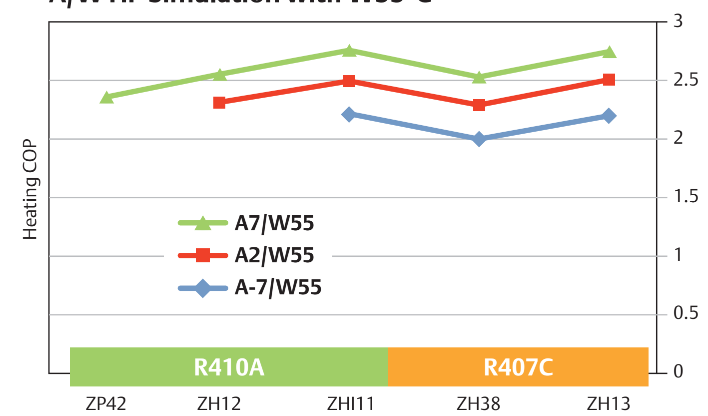
In the table on the right a summary of the different assumptions for the modeling of the heat pump system is shown and different COP result at different conditions. It can be noticed that only Enhanced Vapor Injection models can reach A-7/W55 conditions, thanks to the extended envelope. The ZP42 (typical A/C compressor) is clearly not suitable for high temperature application in general, but has been chosen as benchmark model in this analysis.

The prEN14825 has been used as reference to calculate the SCOP (Seasonal Coefficient of Performance) and to show annual running cost. Domestic Hot Water production is included calculated at a base of 20% of total annual heating requirement. This norm also divides Europe in three different climatic zones: warm, average and cold, as shown in the figure below.

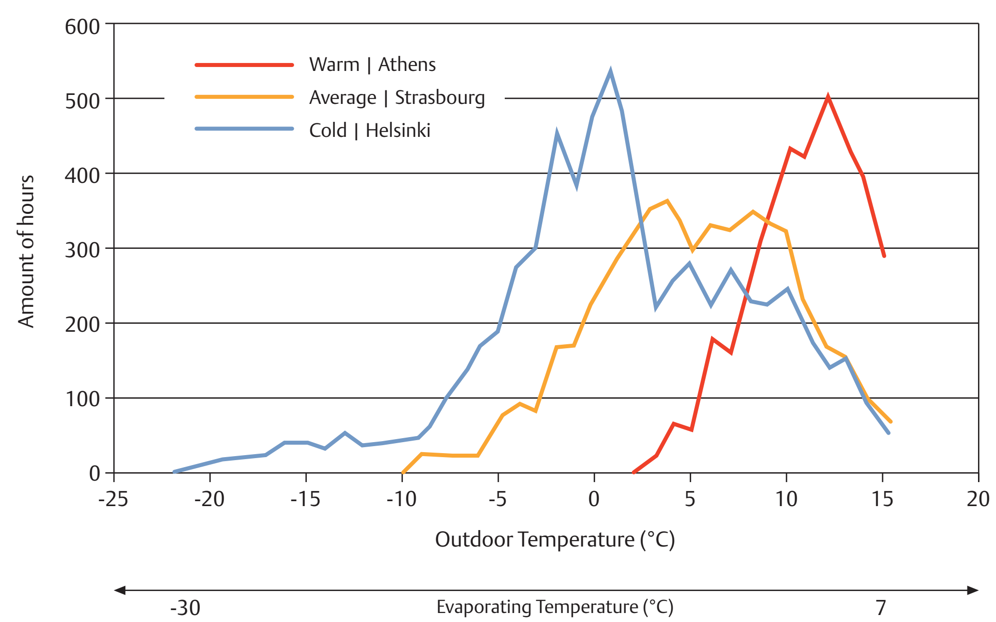
A/W HP Simulation with W35°C



A/W HP Simulation with W55°C



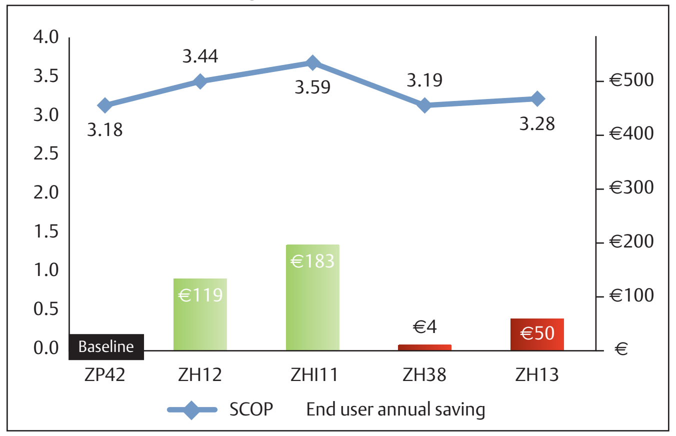
	R407C	R410A
Fan power Superheat Cycling coefficient	10% 4 K 0.9	10% 4 K 0.9
DEW - Water out Delta T Subcooling	3.5 K 1.5 K	1.5 K 3.5 K
Airside Delta T	8 K	8 K
De-frost Cap. reduction Power reduction	8% 2%	8% 2%



Seasonal Efficiency on Cold and Average Climate

To indicate/ number end-user savings and not only a pure SCOP difference a fixed 0.16/kWh electricity cost has been considered in the calculation, as a European average. As said ZP42KSE has been used as reference, except in the colder climate high temperature application, in which ZH38K4E sets the baseline.

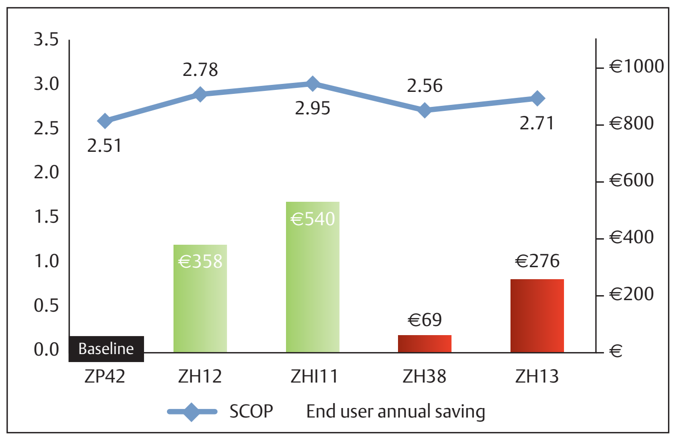
Average Climate Underfloor 35°C



Average Climate Low Temp 35°C	Ref	Vap. Inj.	SCOP	End user Ann. saving	Rank #	Comment
ZP42KSE	R410A	No	3.18	€ -	5	Baseline
ZH12K1P	R410A	No	3.44	€ 119	2	
ZHI11K1P	R410A	Yes	3.59	€ 183	1	Best
ZH38K4E	R407C	No	3.19	€ 4	4	
ZH13KVE	R407C	Yes	3.28	€ 50	3	

If we consider the colder climate, end user advantage increases. The same dwelling as the previous example in a colder climate requires 19kW building load at an outdoor temperature of -22°C.

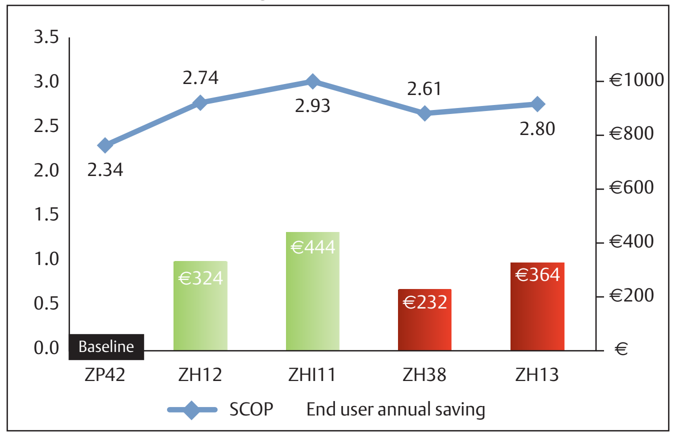
Cold Climate Underfloor 35°C



Cold Climate Low Temp 35°C	Ref	Vap. Inj.	SCOP	End user Ann. saving	Rank #	Comment
ZP42KSE	R410A	No	2.51	€ -	5	Baseline
ZH12K1P	R410A	No	2.78	€ 358	2	
ZHI11K1P	R410A	Yes	2.95	€ 540	4	
ZH38K4E	R407C	No	2.56	€ 69	1	Best
ZH13KVE	R407C	Yes	2.71	€ 276	3	

First results are shown for the average climate. The building load has been set to 13kW at an outdoor temperature of -10°C. According to the weather data profile total annual energy consumption is calculated at 26853 kWh for heating purposes and 5371 kWh for Domestic Hot Water (20%).

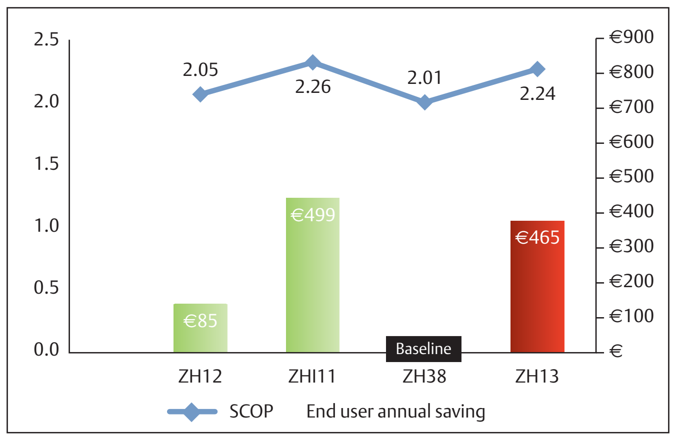
Average Climate Radiator 55°C



Average Climate High Temp 55°C	Ref	Vap. Inj.	SCOP	End user Ann. saving	Rank #	Comment
ZP42KSE	R410A	No	2.34	€ -	5	Baseline
ZH12K1P	R410A	No	2.74	€ 324	2	
ZHI11K1P	R410A	Yes	2.93	€ 444	1	Best
ZH38K4E	R407C	No	2.61	€ 232	4	
ZH13KVE	R407C	Yes	2.80	€ 364	3	

Total annual energy consumption is calculated in 46831 kWh for heating purposes and 9366 kWh for DHW (20%).

Cold Climate Radiator 55°C



Cold Climate High Temp 55°C	Ref	Vap. Inj.	SCOP	End user Ann. saving	Rank #	Comment
ZP42KSE	R410A	No	n.a.	n.a.	5	Out of range
ZH12K1P	R410A	No	2.05	€ 85	2	
ZHI11K1P	R410A	Yes	2.26	€ 499	1	Best
ZH38K4E	R407C	No	2.01	€ -	4	Baseline
ZH13KVE	R407C	Yes	2.24	€ 465	3	

With the exception of the ZP42 which is not a dedicated heating compressor, R410A systems perform better than the equivalent R407C versions.

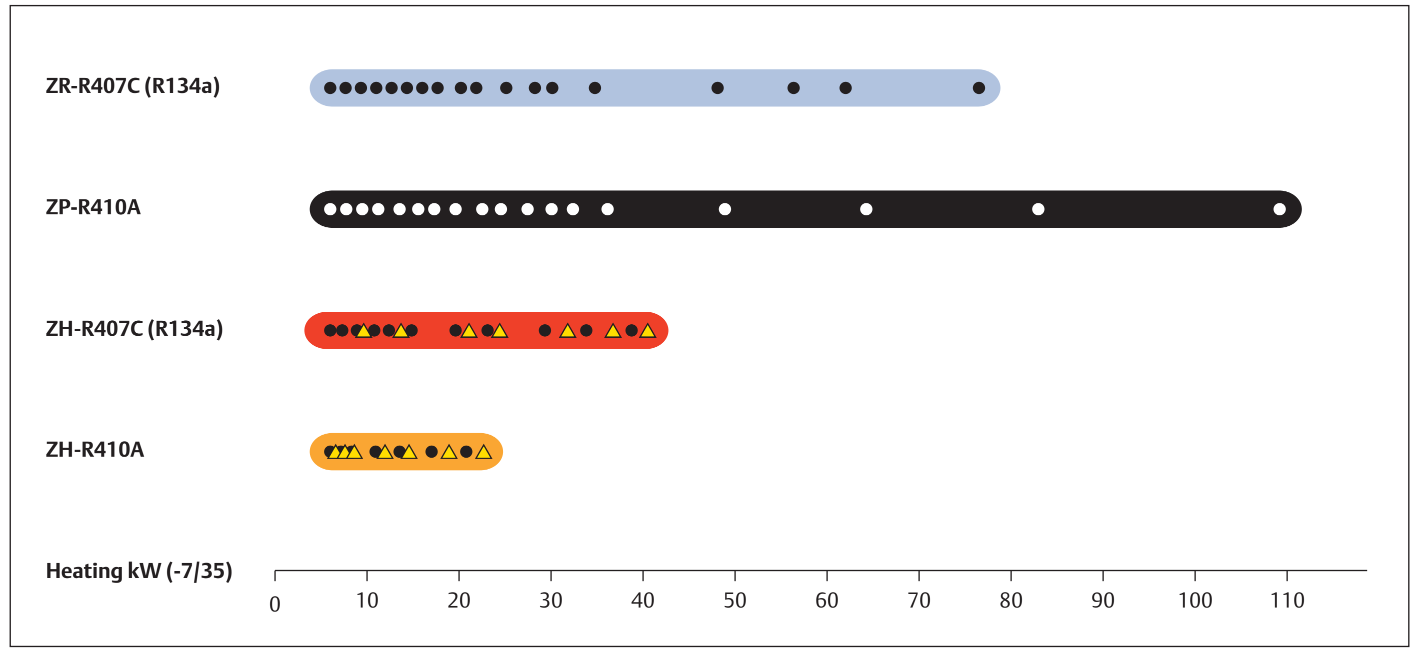
Copeland Scroll™ Residential & Commercial Line-up

Based on the assessment we summarize the following R410A advantages:

- Higher system efficiency at all climate conditions
- Lower system cost
- Significant end user savings on electricity bills

In any case Copeland Scroll™ Heating (ZH) R407C and R410A compressors provide important improvements for cold and average climates for underfloor and radiatior applications as well as Domestic Hot Water production. Enhanced Vapor Injection further increases the efficiency and operating envelope and therefore it is particularly indicated for cold climates and high water temperature heat pumps.

Standard A/C compressors might be interesting for the warmer climate and low water temperature, but more restrictive working condition limitations might lead to an excessive use of the electrical heater.



Enhanced Vapor Injection models - not available for R134a