HPT Annex 54

Heat Pump Systems with Low GWP Refrigerants

Task 4: Outlook 2030

Country Report

AUSTRIA

Edited by

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Executive Summary

The necessary reduction of greenhouse gas emissions in the area of buildings requires a move away from gas and oil heating systems, both of which are currently still widely used. The heat pump is one of the few alternatives. The last few years have already shown high growth rates. Due to the current price increases of fossil fuels and the discussion about possible supply bottlenecks, especially for natural gas (until recently, almost half of the newly installed heating systems in Austria were operated with gas), further high increases are expected until 2030. The choice of refrigerant is crucial for heat pumps - it affects the thermodynamic properties and thus also the coefficient of performance, and the global warming potential (GWP) of the refrigerant in the event of a leak (during production, operation and dismantling of the system) is also essential. The legal framework, e.g. a new version of the F-Gas regulation, might restrict common refrigerants with a high GWP such as R410A, R134a or R407C in future.

Therefore, the aim of this task was to estimate the developments of the Austrian heat pump market until 2030 with a focus on residential and commercial heat pumps. On the one hand, the total volume and, on the other hand, the breakdown of the market according to the refrigerants used are dealt with. Another essential content is the analysis of the main factors influencing these developments. In addition to a literature research, numerous Austrian experts were interviewed.

It can be seen that the heat pump market will increase from about 31,000 systems in the heating sector in 2021 to about 80,000 to 100,000 systems in 2030. In this context, the heat pump market will not be limited by demand, but by available supply. Regionally and nationally differing regulations, the lack of availability of refrigeration circuit components (especially compressors) and the increasingly evident shortage of skilled workers will play the main role here. Estimates of the market share of different refrigerants diverge so widely that it was not possible to make a meaningful forecast on this. The main reasons for the discrepancies are different assessments of future regulations concerning the permissibility of flammable refrigerants such as R290. Furthermore, the degradation product TFA is critically discussed, and here, too, there is no agreement on the legal consequences of this circumstance.

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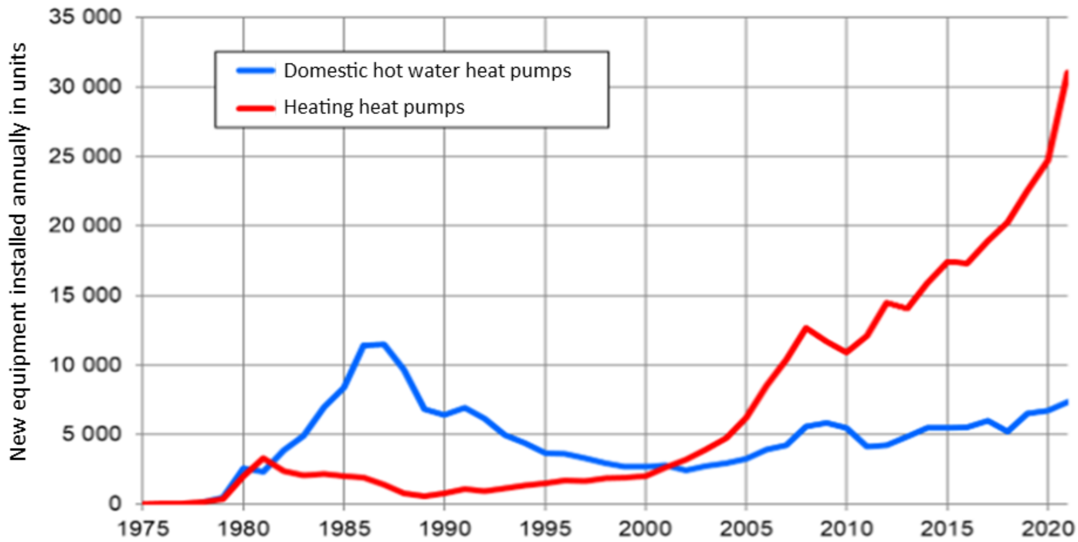
1. Heat pump market in Austria by 2030

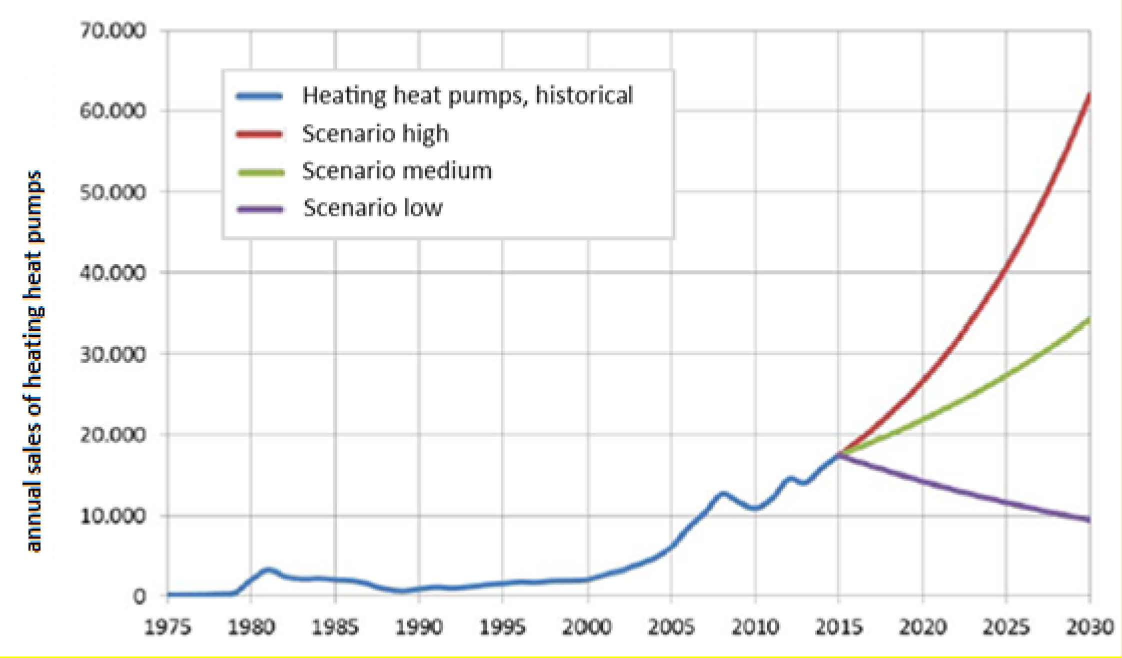
The past few years in Austria have been characterized by a sharp rise in heat pump sales figures, as can be seen in Figure 1. While in the 1980s mainly domestic hot water heat pumps were installed, now the number of heating heat pumps (partly also including hot water preparation) in particular is increasing. Until 2030 a further increase of installed heat pump systems is expected (Figure 2).

Figure 1: Annual number of heat pump systems for room heating and domestic hot water production installed in Austria



Source: Until 2006: Faninger (2007), as of 2007: Biermayr et alii (2008 ff), ENFOS (2022)

Figure 2: Annually installed heating heat pump systems in Austria until 2015 and scenarios until 2030 [02].



Source: bmvit: Österreichische Technologie-Roadmap für Wärmepumpen, 8/2016

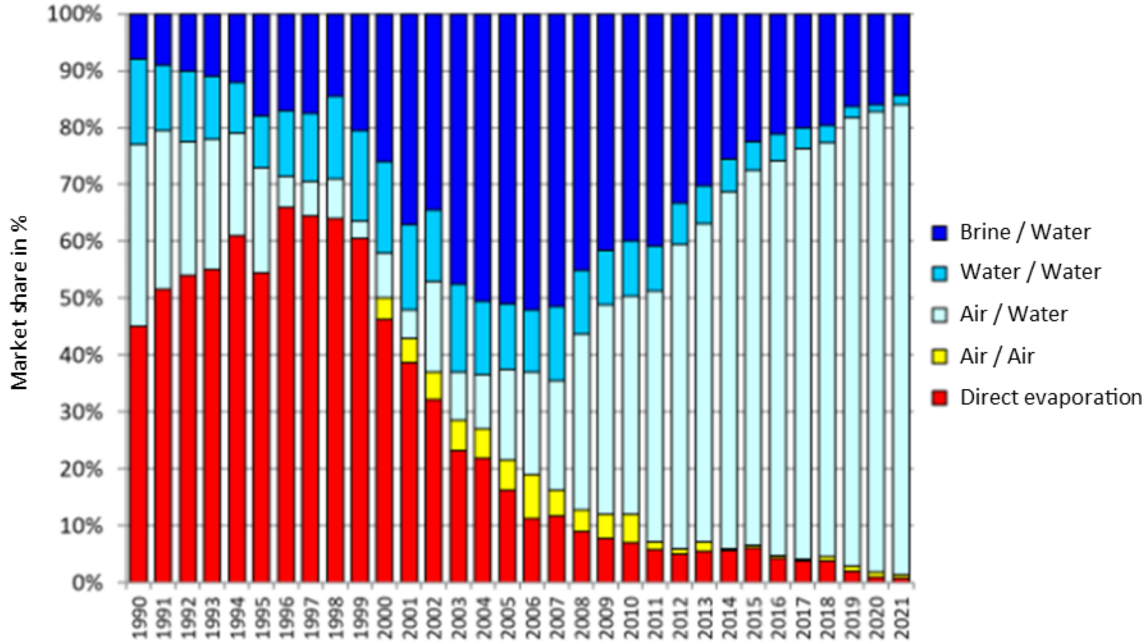
Accordingly, the 2015 scenarios for 2021 for the number of installed heating heat pumps were:

- Scenario high: 28,987 units
- Scenario medium: 22,847 units
- Scenario low: 13,674 units

The actual number for 2021 was 31,011 units, which was even higher than the Scenario High. The Scenario High resulted in a figure of 61,000 heat pumps for 2030. This means that it is likely that the figure for 2030 will also be exceeded, even more in the view of the current gas crisis and the associated even greater efforts to phase out gas, but probably also oil.

In this context, the analysis of heat pumps by construction type or heat source as depicted in Figure 3 is also interesting. While direct expansion systems played a major role in the 1990s, they have almost completely disappeared today. Because they are easier to install, especially important in renovation projects, air-to-water heat pumps now have a market share of over 80%, measured in terms of unit sales.

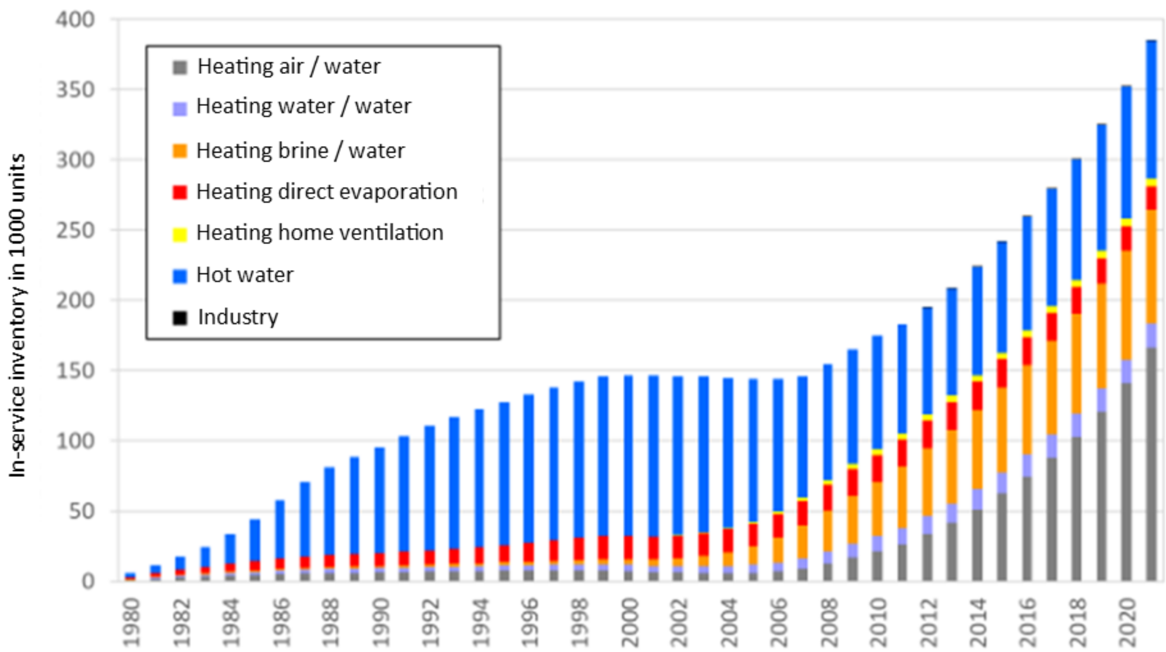
Figure 3: Breakdown of installed heating heat pumps by construction type or heat source [01].



Source: Until 2006: Faninger (2007), As of 2007: Biermayr et alli (2008 ff), ENFOS (2022)

This trend is also reflected with a delay in the inventory figures, shown in Figure 4, where air-to-water heat pumps now also account for more than 40%.

Figure 4: Inventory figures of heat pump systems in Austria by application, construction type and heat source [01].



Sources: Until 2006: Faninger (2007), As of 2007: Biermayr et alli (2008 ff), ENFOS (2022)

The forecasts of the experts surveyed on the development of sales figures for heat pumps are in line with the analysis presented earlier, namely that these will also be above the high scenario from 2015 (61,000 heating heat pumps) in 2030. All experts assume installation figures between 80,000 and 100,000 for 2030.

Even more important, however, is the analysis of the main factors influencing future developments in the heat pump market. However, the limiting factors are not demand-related anyway, but rather influenced by

- Shortage of skilled workers: The lack of appropriately trained skilled craftsmen for the installation of heat pump systems is described as the most serious and longest lasting problem. Due to necessary training periods, this shortage cannot be solved quickly. Since not only will heat pumps have to be increasingly used instead of gas heating (and many skilled tradesmen specialize in gas heating), but also the number of newly installed heating systems will have to increase overall in order to achieve the government's climate targets, this issue cannot be addressed by retraining alone (which is also costly).
- Regionally different regulations: here, above all, different interpretations of the Refrigeration Plant Ordinance (Kälteanlagenverordnung) [03] in the federal states are mentioned. The Refrigeration Plant Ordinance essentially dates back to 1969. Since then, there have been significant technical developments.
- Availability of components of the refrigeration circuit (especially compressors): Predominantly, this is seen as a temporary problem lasting a few months to a few years. Uncertain global developments such as the ongoing Corona crisis, the Ukraine crisis, possible emerging tensions between China and Taiwan, etc. hardly allow any forecasts about further developments in the production and transport of components.

Prices or availability of (low-GWP) refrigerants will not play a role in market developments, according to all experts.

It was also noted that the differentiation between heat pumps and air conditioning systems, which are also partly used for heating, creates a certain distortion in the market figures.

2. Refrigerants for heat pumps by 2030

The framework conditions for the following analyses are as follows:

- No existing heat pump systems are considered (i.e., refilling of existing systems with other refrigerants with lower GWP is not investigated).
- The focus is on the residential and commercial sectors.
- Therefore, no industrial heat pumps are investigated (which are negligible in unit numbers, but not when based on total installed capacity, as these are often large-scale systems). However, these are mostly custom solutions and therefore much more difficult to record and forecast.

Table 1 shows the heat pump models listed by KPC [04] or in the GET database [05], which is operated by the Office of the Provincial Government of Salzburg and gives a good overview of the market situation of heat pumps, among others, divided by refrigerants used. This shows that R410A is still the dominant heat pump refrigerant with a decreasing tendency, followed by R32 with a significantly lower GWP and R407C about the same. Propane (R290) as a low-GWP refrigerant and R134a follow clearly behind.

Table 1: Heat pump models available on the Austrian market by refrigerant based on [04] and [05], GWP according to [06].

Refrigerant	GWP	Class	Type of refrigerant	GET-Database 05/22		KPC 2021	KPC 2020	KPC 2019
R410A	1 924	A1	HFC-mixture	1 447	66%	69%	70%	78%
R32	677	A2L	HFC	276	13%	12%	11%	5%
R407C	1 624	A1	HFC-mixture	256	12%	13%	12%	13%
R290	3	A3	HC	73	3%	2%	2%	2%
R134a	1 300	A1	HFC	60	3%	2%	2%	1%
R454C	146	A2L	HFO/HFC-mixture	22	1%	1%	1%	0%
R417A	2 108	A1	HFC/HC-mixture	19	1%	1%	1%	1%
R404A	3 943	A1	HFC-mixture	14	1%	0%	0%	0%
R452B	676	A2L	HFC/HFO-mixture	10	0%	0%	0%	0%
R448A	1 273	A1	HFC/HFO-mixture	6	0%	0%	0%	0%
R454B	474	A2L	HFC/HFO-mixture	5	0%	0%	0%	0%
R449A	1 282	A1	HFC/HFO-mixture	4	0%	0%	0%	0%
R513A	573	A1	HFO/HFC-mixture	1	0%	0%	0%	0%
Sum				2 193	100%	100%	100%	100%

Refrigerant	GWP	Class	GET-Database 05/22		KPC 2021	KPC 2020	KPC 2019
R410A	1 924	A1	**1 447**	**66%**	**69%**	**70%**	**78%**
R32	677	A2L	**276**	**13%**	**12%**	**11%**	**5%**
R407C	1 624	A1	**256**	**12%**	**13%**	**12%**	**13%**
R290	3	A3	**73**	**3%**	**2%**	**2%**	**2%**
R134a	1 300	A1	**60**	**3%**	**2%**	**2%**	**1%**
R454c	146	A2L	**22**	**1%**	**1%**	**1%**	**0%**
R417a	2 108	A1	**19**	**1%**	**1%**	**1%**	**1%**
R404A	3 943	A1	**14**	**1%**	**0%**	**0%**	**0%**
R452b	676	A2L	**10**	**0%**	**0%**	**0%**	**0%**
R448a	1 273	A1	**6**	**0%**	**0%**	**0%**	**0%**
R454b	474	A2L	**5**	**0%**	**0%**	**0%**	**0%**
R449a	1 282	A1	**4**	**0%**	**0%**	**0%**	**0%**
R513a	573	A1	**1**	**0%**	**0%**	**0%**	**0%**
Sum			**2 193**	**100%**	**100%**	**100%**	**100%**

Sources: KPC Auflistung von Wärmepumpen, GET-Datenbank des Amtes der Salzburger Landesregierung, IPCC assessment report

The experts at the BMK note that, in principle, those heat pumps that receive subsidies are more likely to enter the market. The subsidy landscape, which in Austria is shaped not only by the federal government but also by state subsidies, thus represents a significant factor influencing future developments in the heat pump market. Currently, according to BMK, about 50% of all applications in the heating sector concern heat pumps.

As a limit for the designation of a refrigerant as "low-GWP refrigerant", the value of GWP < 150 was proposed in Task 1 [07]. However, the limit of GWP = 150 for low-GWP refrigerants is sometimes viewed critically by experts because of the restriction to natural (often flammable or restricted) refrigerants. In many cases, a limit of 750 is described as more sensible in order to be able to designate most HFOs as low-GWP refrigerants as well. According to the 4th and 5th Assessment Report of the IPCC [06], R32 would then also be covered. Especially for the higher capacity range, there are currently no units with GWP < 150. The analysis of the GET database [05] confirms this statement. The largest heat pump with R290 is currently just under 19 kW heating capacity, with R454C it is still somewhat less with 14 kW.

Low-GWP is therefore to be understood as

- GWP < 150 in the narrower sense
- GWP < 750 in the broader sense

2.1 Low GWP refrigerants pros and cons

Advantages and disadvantages of low-GWP refrigerants are oriented particularly along the following aspects:

2.1.1 Availability of components of the refrigerant circuit

For many refrigerants, the necessary components arenot yet rated. Tests required for approval take several years. However, according to the experts, research is hampered by the uncertainty of future regulatory developments. This relates above all to restrictions with regard to the two points mentioned below.

2.1.2 Safety – flammability and toxicity

Flammability is an issue with many natural refrigerants. This means that high filling volumes in particular are fundamentally problematic. This is also reflected in the fact that R290 has been used in refrigerators for a long time without any problems. In large plants, such as in industry or in heating networks, however, increased safety precautions are common and special security measures are easier to implement, so that toxic or flammable refrigerants (e.g. R717) can be handled. Partly it was also noted by the experts that heat pumps with flammable refrigerants have usually not yet reached the age where repair susceptibility or replacement play a noticeable role. Experiences in a few years could therefore negatively influence the opinion about flammable refrigerants.

2.1.3 Degradation products such as TFA - trifluoroacetic acid

Some HFOs produce TFA as a degradation product. A future revised REACH regulation may impose restrictions on refrigerants that produce TFAs. Refrigerants that have either been on the market for a long time, are currently being introduced or are still in research are affected by TFA to varying degrees [08]. While R1234yf produces 100% TFA, R1336mzz(Z) produces less than 20% TFA, R1234ze(E) less than 10%, R134a 7-20% and R1233zd(E) only 2%.

The German Federal Environment Agency states the following on the subject of TFA [08]:

- TFA represent an increasing burden on groundwater and drinking water.
- TFA is an extremely persistent substance.
- Neither natural mechanisms nor justifiable technical processes exist to remove TFA from drinking water.
- Minimization of the input of TFA into the environment is therefore necessary.

The risk of a ban on HFOs is assessed differently by the experts interviewed. The advantage of using non-combustible refrigerants with good thermodynamic properties for heat pumps, which in turn help to keep CO_2 and a number of air pollutants out of the atmosphere by burning fewer fossil fuels, must therefore be set against this potential harm.

It is also noted that there are approximately 270 million tons of TFA of natural origin dissolved in oceans (Christoph, 2002). For many applications, HFOs that produce TFA are a good refrigerant with low flammability.

2.1.4 Regulatory requirements

Regulatory requirements should reflect the aspects mentioned, such as flammability, GWP, toxicity, etc. However, since these are ultimately also political decisions, they should be treated separately.

The future F-Gas regulation [09] will have a significant impact on the choice of refrigerants for heat pumps from 2025 or 2027: The proposed regulation would ban certain stationary split air conditioners and split heat pumps:

- Beginning January 1, 2025, mono-split systems containing less than 3 kg of F-gases with a GWP of 750 or greater
- Beginning January 1, 2027: systems rated 12 kW or less that contain F-gases with a GWP of 150 or greater (except cases where safety standards can only be met by using refrigerants with higher GWP)
- As of January 1, 2027: systems rated greater than 12 kW that use F-gases with a GWP of 750 or greater (except cases where safety standards can only be met by using refrigerants with higher GWP)

In this context, R32 would be assessed according to the 4th Assessment Report [20] and therefore treated with a GWP < 750, although the current 6th Assessment Report [10] shows a value above 750. From the point of view of the BMK, this point will not change in the course of the current discussions at EU level.A major barrier for the Austrian market is seen in the still valid refrigeration plant ordinance from 1969 [03]. This does not recognize a class 2L. A revision including an appropriate differentiation into A2L, A2 and A3 refrigerants is therefore urgently needed. According to information from the BMK, a discussion process for a new version of a refrigeration plant ordinance has failed after years of effort due to the resistance of several industry representatives. According to current practice, any new draft would have to be negotiated in a social partnership and submitted for review. Experience has shown that such an undertaking can take years.

Furthermore, the sheer volume of standards and laws, some of which contradict each other according to the experts, complicates the situation for refrigerantand heat pump manufacturers in Austria. In the commercial sector, for example, the MAK value according to the Limit Values Ordinance [11] and the practical limit value according to ÖKKV [12] apply and furthermore, EN 378 [13] and IEC 60335-2-40 [14] or 89 [15].

Statements about the market shares of the refrigerants in 2030 are not possible due to the many uncertainties mentioned and the resulting strongly diverging estimates. Particularly in the case of R290, due to its flammability, estimates range widely from a ban to a market share of over 50%.

2.1.5 Natural refrigerants - areas of application, advantages and disadvantages

The following is a presentation of the advantages and disadvantages of important refrigerants from a technical and legal perspective. They are ranked according to their (estimated) maximum potential, although in some cases this is not an exact classification, but rather a rough guide, precisely because developments are unpredictable.

In the following list, most refrigerants have a GWP below 150, but there are also those with values above 150. The GWP is given according to the 5th Assessment Report of the IPCC [06].

<u>R32 (GWP = 677) A2L ("transitional refrigerant")</u>

R32 (CH_2F_2 - difluoromethane) is already used in many heat pumps, and its market share, measured by registered products in the GET database [05], is about 13%. It is also referred to as a transitional refrigerant because of its GWP, which is between that of many natural refrigerants (below 10) and the most widely used at present (around 2,000). Since the last IPCC report (AR6) [10], however, the GWP of this refrigerant is above 750 and is thus no longer a low-GWP refrigerant in the broader sense (AR4: GWP = 675, AR5: GWP = 677, AR6: GWP = 771). R32 will remain the most important refrigerant until 2027, for > 12 kW systems also beyond 2027 (here the GWP according to the 5th Assessment Report [06] applies). However, R-32 might disappear for small split heat pump systems below 12 kW output by the ban as of 01.01.2027 according to the current draft of the F-Gas Regulation [09], which would only allow refrigerants with GWP < 150 in systems rated 12 kW or less, except safety standards can only be met by using refrigerants with GWP > 150.

R32 is a well-suited, widely used substitute for R410A. Its saturated vapor pressure and volumetric cooling capacity are almost identical to R410A [07]. R32 is classified as an A refrigerant (A2L), but according to the experts, some toxicity exists. R32 does not form TFA.

<u>R290 - Propane (GWP = 3) A3</u>

R290, better known as propane ($C3H8$), is already a commonly used refrigerant for heat pumps today (about 3.5% of heat pumps in the GET database [05]). It has partly comparable thermodynamic properties to R410A, but also a 50% lower saturated vapor pressure.

The future of R290 as a refrigerant is assessed very differently. Many manufacturers are already relying on it. In some cases, R290 is seen as the low-GWP refrigerant with the highest market potential until 2030. Estimates range from 15% to over 50% market share. On the other hand, there are concerns about larger systems, especially those that are not hermetically sealed (split units) and those that are installed indoors, due to the flammability. When numerous R290 heat pumps reach an age that requires major maintenance, the issue could, according to the experts, become evident and restrictions could then be imposed, according to some experts.

According to the EN 378-1:2016 standard [17], the maximum R290 charge depends on the type of room, the location and size of the machine, and the occupancy level. Split systems and indoor systems have lower limits. There are no limits for hermetically sealed, outdoor systems, but 25 kg is often used as a voluntary limit (see Task 1 report) [07]. As a natural refrigerant, R290 also does not form TFA.

<u>R454C (GWP = 146) A2L</u>

R454C is a blend of 21.5% R32 and 78.5% R1234yf. One manufacturer offers air-to-water and brine-to-water heat pumps with this refrigerant in Austria. Partially, this refrigerant is assigned a high potential until 2030. However, there could be restrictions from a regulatory point of view due to the formation of TFA (as R1234yf produces TFA [8]). Whether these would be desirable, is not evaluated here.

<u>R454B (GWP = 474) A2L</u>

R454B is a blend of 68.9% R32 and 31.1% R1234yf. It thus contains the same components as R454C, but in a different mixing ratio. This implies a higher GWP than R454C, but it is affected by the formation of TFA to a lesser extent, since R32 does not form TFA.

R454B is the favored refrigerant for some major international heat pump manufacturers. It is already in use in large heat pumps in many areas. Five models of air-source heat pumps with this refrigerant are also offered in Austria.

<u>R1234yf (GWP < 1) A2L</u>

R1234yf has a similar saturation pressure and a comparable volumetric cooling capacity to R134a and is currently used as a refrigerant primarily in the automotive sector. It is also a possiblerefrigerant for large heat pumps. For the household sector, approval of the components is currently still lacking. R1234yf forms TFA (trifluoroacetic acid) as a decomposition product [8]. However, this aspect is seen much more critically in the case of motor vehicles than in the case of stationary systems, as there are generally greater uncontrolled refrigerant losses here. This means that a ban in stationary systems (and thus all refrigerants that produce TFA) would only be comprehensible if it were introduced for mobile systems, such as motor vehicles.

<u>R1233zd (E) (GWP = 5) A1</u>

R1233zd is used in particularly large plants up to 2 MW. The physical properties require the refrigeration cycle to operate in a vacuum. It hardly forms TFA [8].

R717 - NH_3 ammonia (GWP = 0) B2L

R717 has very good thermodynamic properties and achieves high coefficients of performance(usually better than with R290, for example). The problem is its toxicity and also its flammability. Potential is seen especially in freezing applications (< -12°C) due to its thermodynamic properties.

R744 - CO_2 (GWP = 1) A1

R744 is a good refrigerant when there is a high sink-side spread; it also performs relatively well at a large temperature swing between source and sink. Therefore, one possible application is to cool further down on the sink side, such as with ventilation heat exchangers.

The cooling circuits are relatively expensive, especially for small plants, because of the necessary technical effort due to high occurring pressures. The coefficients of performance for heating are rather low, better values are achieved for domestic hot water heat pumps. Tests have been carried out on high-temperature heat pumps, but the components have not yet been thoroughly tested. Furthermore, the use in cold stores is possible, here no transcritical process occurs.

In summary, R744 is suitable for individual plants where the temperatures fit well with the physical properties of CO_2, but not in the mass segment. Advantages are of course the incombustibility, the low GWP and compared to many HFO refrigerants the fact that no TFA is formed.

R600a - C_4H_{10} isobutane (GWP = 3) A3

R600a is currently used in domestic hot water heat pumps and in some cases also in high temperature commercial machinery (although R600 is more frequently used in this area), in addition to refrigerators. It has limited use for heating heat pumps due to thermodynamic properties.

R1234ze (GWP < 1) A2L

This refrigerant is used primarily in the industrial sector for large heat pumps. It has a lower saturated vapor pressure and volumetric cooling capacity than R134a and R1234yf. It produces about 10% TFA as a degradation product [8] and is thus less affected by this issue than some other HFO refrigerants. From today's perspective, it will not be used in the household sector.

R718 - Water (GWP = 0) A1

There is no relevant field of application for water as a refrigerant so far. There are isolated systems for office cooling that operate in the vacuum range.

R600 - C_4H_{10} Butane (GWP = 3) A3

Due to its thermodynamic properties, R600 cannot be used in heating heat pumps. A large field of application is seen in the field of high temperature heat pumps [18].

R1336mzz(Z) (GWP = 2) A1

R1336mzz(Z) is a particularly suitable refrigerant for very high temperatures (at about 160 °C). Below that, it offers no advantages over alternatives such as R1233zd, which has better volumetric refrigeration performance. Therefore, no field of application is seen in the domestic and commercial sectors.

R513A (GWP = 573) A1

R513A consists of R134a and R1234yf and is used as a replacement refrigerant for R134a. The advantage is lower GWP, and the disadvantage is higher TFA [8]. Currently, an air-source heat pump in Austria is offered with R513A [05].

3. Conclusions

The heat pump is one of the key technologies for reducing greenhouse gas emissions and phasing out fossil fuels in the building sector. The heat pump market is therefore expected to grow strongly until 2030, limited not by demand but by available supply. Here, regionally different regulations, lack of availability of components of the refrigeration circuit (especially compressors) and especially the shortage of skilled workers, which is becoming more and more evident, will play the main role. Regional, national and international (EU) policies can create the conditions for heat pumps to optimally exploit their potential for reducing fossil fuel consumption and greenhouse gas emissions in the building sector by establishing suitable funding regimes, training initiatives, securing production capacities in Europe as well, information campaigns and (uniform) legal requirements.

The thermodynamic advantages and disadvantages of the refrigerants as well as current and technically possible areas of application are known. However, no reliable statements can be made primarily because of completely conflicting assessments of the development of the legal situation (e.g. with regard to flammability and the degradation product TFA). The challenge facing policymakers here is to ensure clear, uniform and predictable regulations in the long term, taking the aspects mentioned above into account as far as possible. In addition to bans, however, subsidies are also an effective means of inducing desired steering effects in the market, especially in the first phase of a transformation.

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5. Abbrevations

AR Assessment Report

BMK Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology

BMVIT Federal Ministry of Transport Innovation and Technology

CO_2 Carbon dioxide

EN European Norm

EU European Union

F-Gas Fluorinated greenhouse gas

GET Building and energy technology

GWP Global Warming Potential

HFO Hydrofluorolefin

IEA International Energyagency

IEC International Electrotechnical Commission

IPCC Intergovernmental Panel on Climate Change

KFZ Motor vehicle

KPC Kommunalkredit Public Consulting

MAK Maximum workplace concentration

MW Megawatt

ÖGKT Austrian Society of Refrigeration

ÖKKV Austrian Refrigeration and Air Conditioning Association

REACH Registration, Evaluation, Authorisation and Restriction of Chemicals

TFA Trifluoroacetic acid

VO Regulation