Derogation request for refrigerant R-474A for electric vehicles under the PFAS restriction proposal

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Contents

1. Executive summary

Daikin Chemical Europe welcomes the opportunity to submit comments to the REACH restriction proposal on all PFAS. Regarding automobile air conditioning, the PFAS restriction dossier affects refrigerants in the thermal system. This contribution relates to refrigerant R-474A for use in Battery Electric Vehicles (BEVs). R-474A contains R-1234yf, which is under the scope of the REACH restriction proposal, and for this reason is at risk of ban under the current restriction report.

From a regulatory point of view, the European Union (EU) recently adopted a decision to ban most combustion engine vehicles from 2035 onwards. Consequently, the framework conditions have been set that lead us to expect that BEVs will have the major share in future vehicle fleets.

The acceptance of electrified vehicles by the market and the customers is essentially dependent on their everyday usability of BEVs in aspects such as achievable driving range or speed of charging. In order to maximize the usability of BEVs, their energy efficiency becomes more important. With internal combustion engines, waste heat from the engine is available to heat the passenger compartment. BEVs have to generate this heat electrically at the expense of the driving range. Heat pump systems are the most efficient method using the energy of the ambient temperature and the waste heat from the electric powertrain.

The new automotive refrigerant blend R-474A enables the thermal system to deliver high capacity at great efficiency across all conditions. It allows to expand the operation conditions in the heat pump (HP) mode at very low ambient temperatures up to high temperatures in air conditioning (AC) mode, helping to reduce the vehicle’s carbon footprint and global warming impact.

The non-PFAS refrigerants R-744, R-152a or R-290 have essential demerits in regards of efficiency and capacity. Their use would result in limitations in vehicle usability, higher energy consumption of the thermal system, and consequently, higher CO_2-equivalent emissions over the life cycle and higher use costs. In addition, these refrigerants raise safety concerns for workers in the supply chain as well as car users, due to their high toxicity in case of leakage or their high flammability. Finally, significant socio-economic impacts are to be expected from the loss of competitiveness of the European automotive industry.

For those reasons, we believe a ban of R-474A is not appropriate. Given the importance of the BEV acceptance for the future of European mobility, we support a time-unlimited derogation for R-474A. Please note that a second contribution will be submitted later that will include additional evidence, in particular the outcome of our current field-testing program and an LCCP analysis.

2. The basic of the thermal management

BEV HVAC systems require a high level of performance in terms of cooling and heating across a wide range of temperatures. As an example, a typical HVAC system for an internal combustion engine (ICE) vehicle delivers a maximum cooling capacity of around 5kW. For BEVs, use cases such as fast charging, battery thermal management and cabin heating raise the required maximum capacity to 15kW and beyond. Therefore, the efficiency of the thermal system (the energy required to deliver or remove such quantities of heat) has a large impact on the total energy efficiency of the vehicle. The refrigerant impacts the system efficiency based on its thermodynamic properties that both increase the capacity and the coefficient of performance (COP) independent of the demand for either cooling or heating.

Currently, there is no refrigerant fluid on the market that can satisfy such requirements for BEVs: R-1234yf-based systems show limitations in heating performance, whereas R-744-based systems have significant efficiency drawbacks at external temperatures above +25°C and are not practicable when external temperatures rise over +35ºC upon the performance reduction at supercritical operations. Therefore, there are multiple efforts globally where automotive OEMs and/or authorities are looking at refrigerant alternatives. For example, a large group of OEMs has launched a Cooperative Research Program (CRP) at the Society of Automotive Engineers (SAE) in the USA to look at new refrigerant alternatives. R-474A is currently being evaluated under the SAE CRP. Similarly, the China Automotive Technology Research Center (CATARC) is running a refrigerant evaluation program sponsored by the Chinese authorities.

A proper thermal management of the electrical power train, including battery, power electronics and electrical motors is essential for the lifespan of these components. This is a fundamental difference compared to ICE vehicles which neither have a temperature sensitive energy source nor electricity driven powertrain demanding a certain cooling capacity during the operation.

Batteries are temperature sensitive. Overheating reduces irreversibly the capacity of Lithium-Ion-Batteries (LIB). Shuia et.al.[1] reported a 25% capacity loss after 25 cycles at +120°C. Overheating during charging increases the internal resistance which may lead to self-ignition or even explosions in some cases (R. Spotnitz et.al.[2]). The Umweltbundesamt (UBA[3]) quantifies the efficiency under ideal conditions (+25°C) of 90%. At high ambient temperatures (+40°C) the efficiency varies between 77% to 90%. All losses are transformed into additional heat, and it must be noted that fast charging results in additional losses. Hence, a proper removal of the heat is essential, done with the on-board AC unit. The charging losses create heat at a rate up to 40kW which has to be removed with a high efficient, high capacity AC unit. Current systems based on R-1234yf, have a maximum capacity of 10kW[4] which is limited by the packaging of the car. The AC capacity is linked with system size. High capacity refrigerants maximize the removable heat while minimizing the system size. They are key to minimize the impact on system design as well as to ensure the system performance and efficiency.

[1] Shuai Ma et.al.: "Temperature effect ant thermal impact in lithium-ion batteries: A review", Progress in Natural science: Material science, p.657, Elsevier, 2018
[2] R. Spotnitz et.al.: "Abuse behaviour of high-power lithium-ion cells", Journal of Power Sources, Elsevier, 2003
[3] H. Helms et.al.: "Energieverbrauch von Elektrofahrzeugen (BEV)", Texte 160/2022, p.49, Umweltbundesamt, Dessau
[4] "CoolEV – Entwicklung eines Kühlsystems zur Optimierung von Schnellladevorgängen und Antrieben in Elektrofahrzeugen", Research Project, Hochschule Esslingen, 2020-2022

3. Existing regulations for refrigerants in Europe

Refrigerants in mobile air conditioning (MAC) applications are required to comply with the MACs directive[5] (GWP<150 under AR4) and various safety requirements regarding the toxicity and the flammability.

In addition, the F-Gas regulation[6] is regulating and limiting the amount of gas brought into the European market via the CO_2-based quota system and a continuous Phase-Down scheme. In the long term, the EU "Fit for 55" program targets the reduction of GHG emissions by 55% in 2030 and a GHG neutrality in 2050. The availability of high GWP F-Gases over quota systems will be drastically reduced in future.

4. The technical properties of R-474A

R-474A is a refrigerant blend consisting of 77% R-1234yf and 23% R-1132(E). The HFO molecule R-1132(E) is non-PFAS as the molecular formula CHF=CHF does not contain any CF3 bond relevant for the categorization as PFAS. Table 1 is showing the thermodynamic properties of R-1132(E) as blend component of R-474A.

[5] DIRECTIVE 2006/40/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC

[6] REGULATION (EC) No 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on certain fluorinated greenhouse gases

Table 1. R-1132(E) properties

Thermodynamic properties of R-1132E		
Molecular formula	CHF=CHF	[-]
Molecular weight	64.0	[g/mol]
Critical temperature	75.7 [1)]	[degC]
Critical pressure	5.17 [1)]	[MPaA]
Boiling point (101.3kPa)	-52.5 [1)]	[degC]
Vapor pressure at 25 degC	1,666 [1)]	[kPa]
Vapor density at 25 degC	56.4	[kg/m3]
Liquid density at 25 degC	938	[kg/m3]
Latent heat at 25 degC	213.7	[kJ/kg]
Lower flammability limit	4.4	[vol%]
Burning velocity	30.2	[cm/s]
GWP	0.0052 [2)]	[-]

[1)] Measured by Kyushu University NEXT-RP [2)] Measured by AIST

The resulting blend R-474A offers the right thermophysical properties regarding the boiling point (see Figure 1) and the saturation pressure curve (see Figure 2) to be the ideal refrigerant fluid for BEVs.

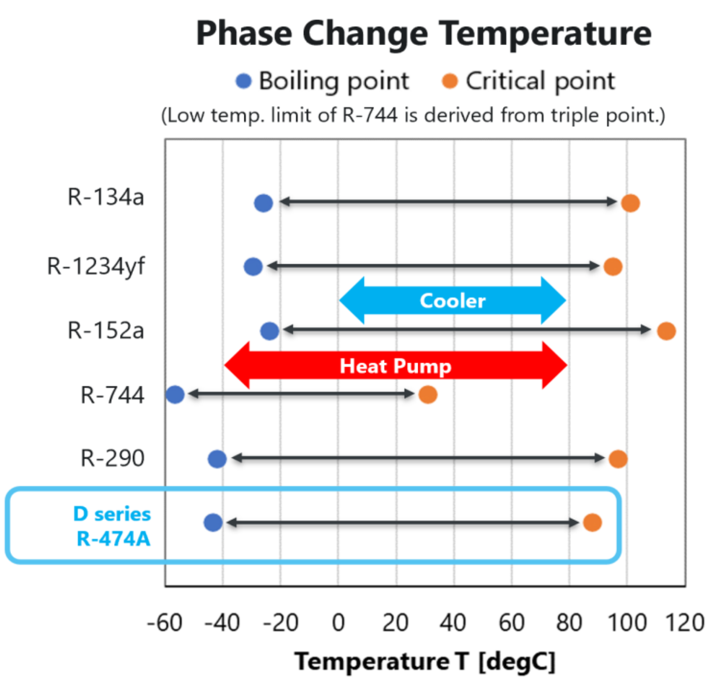

Figure 1. Temperature range between boiling point and critical point for various refrigerants

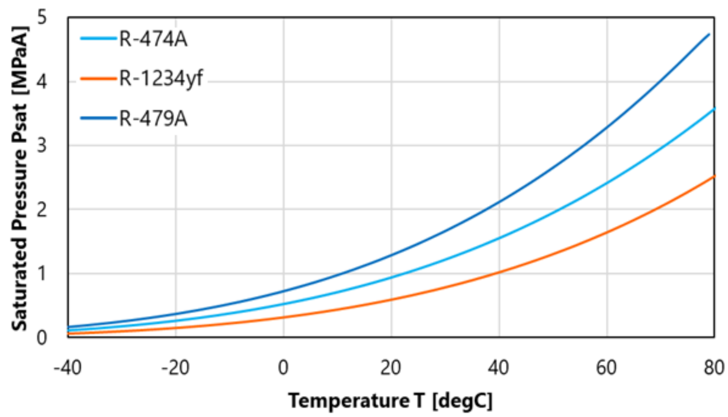

Figure 2. Saturated pressure of R-474A compared to R-1234yf

The overall properties of R-474A can be seen in Table 2. The GWP of R-474A is lower than the GPW of R-1234yf due to the ultra-low GWP of the R-1132(E) molecule further reducing the environmental impact.

Table 2. Physical properties of refrigerants for BEVs

Refrigerant		R-744	R-290	R-152a	R-1234yf	R-474A
GWP (AR4)		1	3	124	4	<4
Temperature in NBP	[°C]	-56.6[1]	-42.1	-24.0	-29.5	-43.4
Critical Temperature	[°C]	31.0	96.7	113	94.7	87.8
Critical Pressure	[MPa]	7.38	4.25	4.52	3.38	4.05
Pressure at 20°C	[MPa]	5.73	0.84	0.51	0.59	0.94
ISO817 Class	[-]	A1	A3	A2	A2L	A2L
LFL	[vol%]	-	2.1	4.8	6.2	5.5
Burning Velocity	[cm/s]	-	43	23	1.5	2.9

R-1234yf is a substantial component of the R-474A blend. The presence of R-1234yf at a concentration of 77% means that R-474A can be adopted in available series R-1234yf systems with minor modifications. This is important as BEVs have a more complex thermal management compared to ICEs. Essential components have to be tempered in a defined temperature range to deliver the optimal capacity and highest efficiencies. For example, LIB shows capacity losses of more than 20% at ambient temperatures of -15°C vs. +25°C. Furthermore, under hot conditions overheating of the battery has to be avoided.

Considering the wide ambient temperature range from -30°C to +50°C and needed efficiencies, only a compression refrigeration cycle can provide the requested capacities of up to 15kW. As weight reduction and packaging is of general concern in BEVs, the best refrigerant solution shall work in direct expansion systems that enable refrigerant-to-air heat exchanges. All in all, it shall offer the following characteristics: high pressure with a normal boiling point NBP below -40°C, subcritical temperature (t_crit) higher than +70°C. Furthermore, as regards safety, refrigerants should meet the flammability safety level of A1, A2L or A2 for direct expansion following existing risk assessments. Those safety group classifications are defined by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The ASHRAE Standard 34 describes the toxicity as well as the flammability related to the burning velocity as key criterion. All those criteria are fulfilled by the refrigerant solution R-474A.

The evaluation of R-474A has been performed on component level, thermal system level as well as on vehicle level to identify the full potential of the refrigerant. Both the stationary and the dynamic tests showed a clear picture of higher performance of about 40% compared to R-1234yf and higher COP while matching cooling and heating capacity targets. It is important to mention that R-474A is able to provide significantly higher capacity compared to R-1234yf without any compromises on the efficiency across all temperature conditions. This allows the system designer and the car manufacturer to enable the overall thermal management fulfilling any demand for cabin cooling, battery cooling, and cooling of other important systems in the vehicle.

Comparisons of R-474A with equivalent R-744 systems show an advantage in capacity and efficiency for cooling in AC mode. The higher efficiency of R-474A compared to R-744 can be delivered throughout the complete temperature range above 0°C whereas above the ambient temperature of +30°C required energy for R-744 air conditioning systems is strongly increasing. At the same time, looking at the heating in Heat Pump mode, our measurements indicate that there is no performance disadvantage for R-474A compared to R-744 (known for its good ability at low ambient temperatures). The described results of compressor evaluation tests can be seen in Figure 3 while the test conditions can be seen in Table 3.

Table 3. Test conditions for compressor component evaluation

Cooling Points

Test condition		R-1234yf	R-474A	R-744
Discharge pressure	[MPaA]	1.50	2.00	10.5
Suction pressure	[MPaA]	0.30	0.41	3.50

Heating Points

Test condition		R-1234yf	R-474A	R-744
Discharge pressure	[MPaA]	1.50	2.00	10.5
Suction pressure	[MPaA]	0.20	0.27	2.64

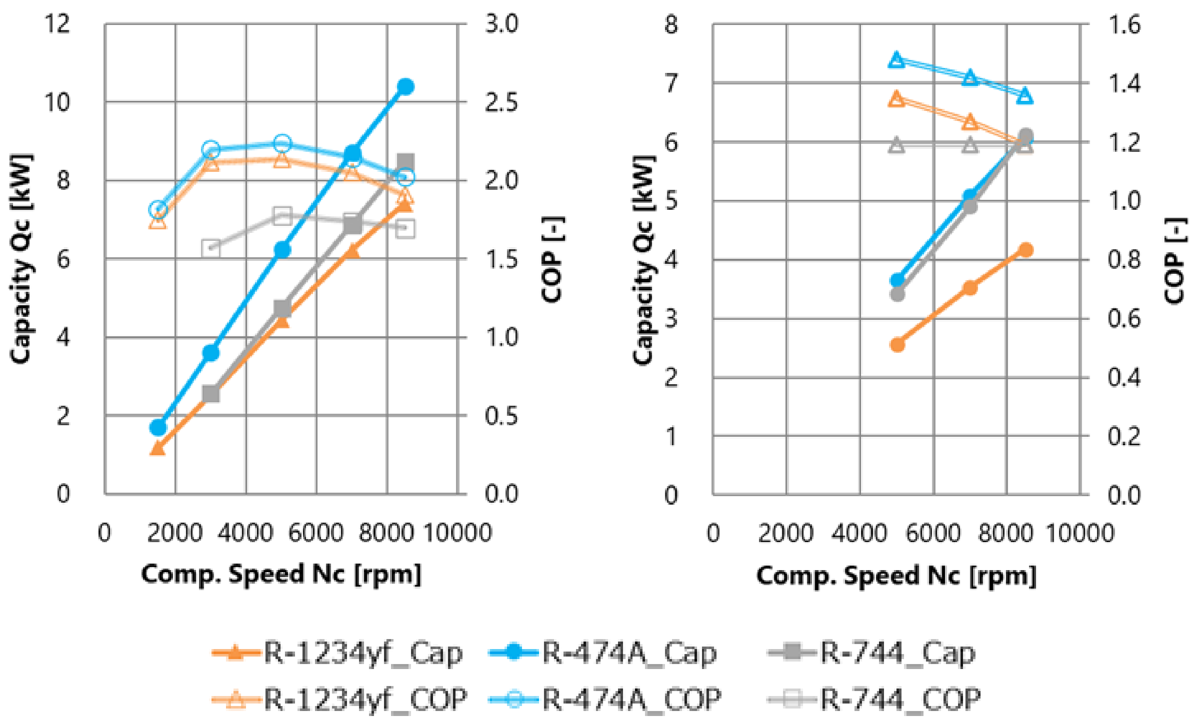

Figure 3. Compressor capacity tests R-474A vs. R-1234yf and R-744 in AC + HP mode

The necessity of high capacity is especially required at critical use cases for BEVs. This includes super-fast charging and the related demand to keep the battery at a certain temperature level also during this phase where the waste heat of high energy charging needs to be covered by the vehicle's thermal management. This is even more important for the case when passengers are sitting in the vehicle while super-fast charging at very high ambient temperatures. Such a case is also safety related as the thermal management must avoid any harm due to excessive heat in the cabin while keeping the battery cool. Otherwise, the battery will heat-up leading to malfunctioning and even a fire hazard.

Another important use case is the scenario of a heavy traffic jam in regions with very low ambient temperatures where any increase of heating capacity or efficiency can avoid harm to passengers or the shut-down of electric vehicles due to empty batteries caused by too high heating demand that must be covered by inefficient electric heaters covering the lack of heating capacity of the thermal system.

We performed a first set of driving vehicle tests using R-474A refrigerant as a drop-in for the series R-1234yf AC/HP system in collaboration with an OEM. The results confirm the increase in capacity (up to 40%) and COP compared to the R-1234yf baseline, but cannot be shared due to confidentiality commitments. We are currently running our own set of vehicle tests, and we expect to be able to share the results in our second submission to this consultation process.

5. Assessment of alternatives

5.1 Overview of alternatives already in use or in development

The PFAS restriction dossier discusses several alternatives to R-1234yf refrigerant. Those alternatives are R-744, R-152a and R-290. Each of those alternatives can be considered only as a compromise to the current refrigerant technology with regard to the parameters GWP, cooling/heating performance, required system modifications, thermal management efficiency, and use potential for a global strategy. They are also either not available in the market, or only with very limited availability. We understand that they would also put European automotive manufacturers in a position of disadvantage versus other global OEMs in other markets.

5.2 R-744 as alternative

R-744 (CO_2) is currently used by only one European OEM in series for the optional heat pump system for the European market.

We are assessing the performance of R-744 compared to our best-in-class R-474A refrigerant. For that purpose, we ran benchmark tests on system benches using the two versions of the VW ID.3 vehicle. We tested according to the SAE J2765 test matrix. The SAE J2765 matrix describes stationary measurement points with different ambient temperatures and wind velocities at the heat exchanger, in order to replicate real-life conditions. Test conditions can be divided into "maximum load" points and "efficiency at low load" points.

This scenario of maximum system load is also described in the SAE J2765 matrix, and we have tested the three refrigerants accordingly. In this case, the capacity advantage of R-474A versus both R-1234yf and R-744 was significant, R-474A being the only fluid capable of meeting the temperature targets at the cabin and battery. The limitations of R-744 became more visible under these conditions: The refrigerant R-744 has limited cooling capacity at high temperatures above +25°C due to the critical temperature (t_crit) at +31°C and the lower condensation ability above this point (see Figure 4).

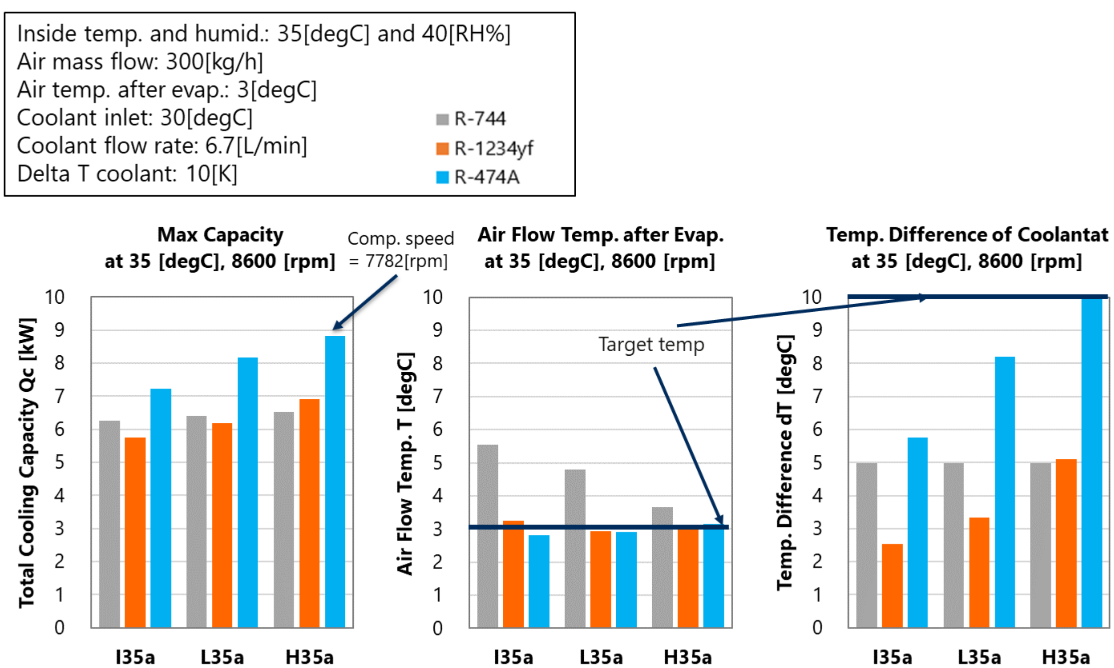

Figure 4. Bench evaluation of different thermal systems at maximum load cooling condition

R-744 is also showing demerits from the perspective of the efficiency already at mild temperature conditions (see Figure 5). Due to the relatively high share of operating hours at these conditions, this efficiency disadvantage will have a significant impact on the life cycle emissions of the vehicle.

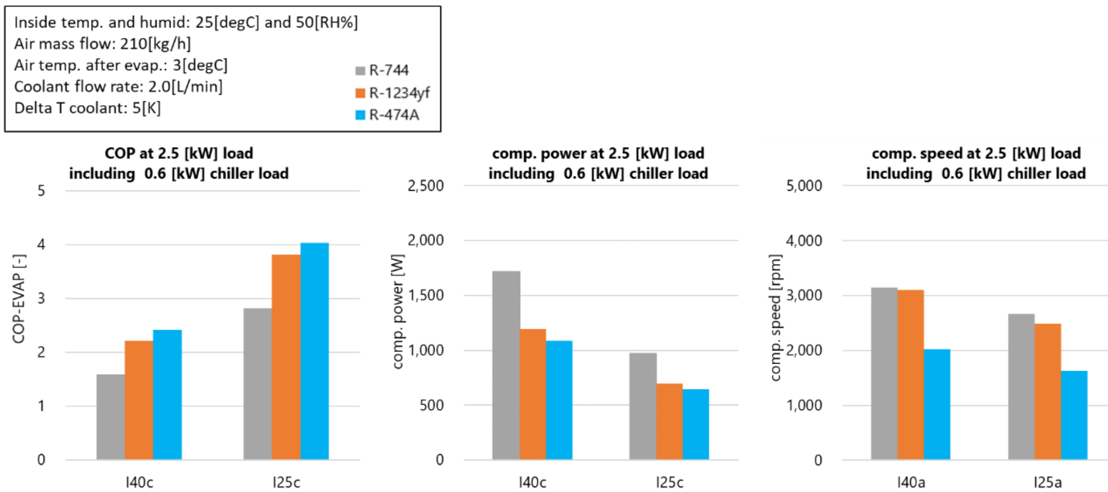

Figure 5. Bench evaluation of different thermal systems regarding COP comparison

Additionally, R-744 is a toxic gas at high concentration and being odorless and heavier than air it is dangerous for the vehicle passengers in case of leakage. This requires related measures like a CO_2 sensor for the cabin including a warning system accordingly.

The thermal system operates at significantly higher pressures compared to conventional systems with R-1234yf as refrigerant[7]. This occurs especially at high ambient temperatures because the system needs to operate above the critical point of +31°C. The system pressure relief valves operate in a range of 120-140bar. The high pressure level of R-744 reaching pressures up to 130bar on high-pressure side (as reference, system pressure relief valves operate in a range of 120-140bar) is five times higher than the pressure level at R-1234yf systems. In addition, the pressure up to 50bar on low pressure side is 10 times higher than with R-1234yf. Hence, the system components require a much higher safety factors towards the higher burst pressure leading to higher wall thicknesses at all components and the connector technology. Therefore, R-1234yf systems are lighter than R-744 systems with the consequence that

[7] Sun, D.; Zhang, X.; Liu, Z.;Zhang, H. Comparative Study onBoiling Heat TransferCharacteristics and Performance ofLow-Temperature Heating Systemof R744 and Its AzeotropicRefrigerant. Energies 2023, 16, 1313.https://doi.org/10.3390/en16031313

R-744 is already negatively influencing the overall vehicle efficiency due to the higher weight. Finally, the resting pressure of about 50bar is also a danger for workers in the workshop while the hood is open.

Another important issue will be the availability of R-744 components in case the complete European market will introduce this technology following the restriction schedule shown in the PFAS dossier. The supply chain of a thermal system is based on a global production of the affected components and subcomponents that partly will require new manufacturing facilities and production lines.

5.3 R-290 as alternative

R-290 (Propane) is not yet in use for air conditioning systems in the automotive sector due to its high flammability (level A3) requiring a dedicated risk assessment. It also creates explosive vapor-air mixtures. For safety reasons and if ever allowed, the use of R-290 in MAC would require a secondary loop system, with lower efficiency due to the energy loss at the interface between secondary loop and cabin loop. This additional layer of thermal resistance, the cycle's transient behavior and cabin thermal comfort during pull-down and various driving cycles may be different from traditional direct expansion (DX) systems Besides the secondary loop, additional safety measures to protect the passengers in case of a crash or fire would be necessary.

The performance and efficiency of R-290 for the use in a vehicle still needs to be evaluated as there is no system existing in the market yet, but the first test results available at the SAE CRP point towards efficiencies of COP~1 due to the mentioned efficiency loss in the two-step heat exchange process.

The implementation of a R-290 based system for the use in the automotive market would require several years more than for other refrigerant alternatives and would essentially depend on the results of the required risk assessments. As a result, this would lead to a limited availability of validated and homologated thermal systems for many years after the entry into force of the PFAS restriction.

Further risks of R-290 based systems need to be considered for cargo ships, garages, workshops, warehouses and car dealerships at the moment of servicing and for the aftermarket when handling the highly flammable propane.

5.4 R-152a as alternative

The last proposed alternative R-152a is a non-PFAS HFC with a GWP of 124 (under AR4) which is close to the current MACS limit of GWP<150 in the European automotive market. Compared to R-1234yf having a GWP of 4[8] this results in a GWP that is 31 times higher. This means that the global warming potential of a R-152a system is worse compared to today's thermal systems by a factor of 31.

It is a refrigerant with the flammability level A2 that, based on a required risk assessment, can be likely used only in secondary loops leading to efficiency loss as described for R-290[9].

The required development time can be estimated on a similar level as for the alternative R-290 as R-152a is neither existing in any series thermal system in the market. Moreover, the expected amendments to the EU F-Gas regulation might limit the quota for R-152a in the future making it impossible to use it in mobile air conditioning systems as the availability will then be limited.

Furthermore, from the thermo-physical properties point of view, R-152a offers less capacity over the complete temperature range compared to R-474A which limits the capability to manage heat flows at low temperatures for the cabin heating or during fast charging at hot ambient temperatures.

6. Socio-economic assessment of proposed alternatives

6.1 EU automotive market overview

Passenger Cars market unit sales are expected to reach 11.25m vehicles in 2027 in the EU-27 region[10]. The intended roll-out of BEVs (following EU decision that from 2035 on, all cars and vans sold in the EU will have zero CO_2-emissions) requires the

8 Annex II of Regulation (EU) No 517/2014

9 Yun Zhang, Cichong Liu, Daxiong Lu, Zhenjun Guo, Dajian Wang, Junye Shi, Jiangping Chen, Heat recovery design and test for the secondary loop heat pump MAC system, International Journal of Refrigeration, Volume 123, 2021, Pages 45-51, ISSN 0140-7007, https://doi.org/10.1016/j.ijrefrig.2020.10.038.

10 Source: https://www.statista.com/outlook/mmo/passenger-cars/eu-27) with an expected share of electric vehicles of estimated to get to 5.3M units by 2026 (source: https://inkwoodresearch.com/reports/europe-electric-vehicle-market-forecast-2022-2026/#:~:text=Report%20Summary,assessment%20years%202022%20to%202026.

acceptance by the market. In addition, future BEVs need to fulfill regulatory and product related standards and specifications in regards to passenger comfort and safety provided by a certain level of heating and cooling.

Besides that, BEVs are locally emitting zero CO_2, but considering the well-to-wheel approach, the driving range and therefore the use of energy, raw materials used to generate battery capacity, etc. need to be considered as well. An increase of efficiency of the thermal system reduces the required energy for the thermal system achieving higher driving ranges with a given battery capacity. High efficient thermal systems also allow to reduce the battery size compared to current state-of-the-art systems without reducing the driving range.

As shown above, R-744 is significantly less energy efficient and has limited operational capabilities at high and cold temperatures.

We are currently performing a life-cycle (LCCP) analysis of R-474A compared to R-744, to estimate the effects of factors such as system efficiency and weight in the overall cost of energy generation and CO_2-equivalent emissions of the European vehicle fleet. We expect to provide the results in our second submission.

6.2 Impact on EU automotive value chain

A restriction in BEVs of the commonly used refrigerant R-1234yf and its blend R-474A, will lead to limited availability of vehicles as only Volkswagen is offering R-744 systems as an option commercially, and the development lead time until entry into force of the PFAS restriction (worst case scenario) is not matching with the standard automotive development requirements regarding the evaluation, validation and homologation of new technologies. That circumstance creates the risk of a monopoly due to the very long development lead time of a R-744 thermal system.

As especially the use of the suggested alternatives R-744, R-290 and R-152a are also negatively affecting passenger safety, additional risk assessments are necessary to evaluate the toxicity and flammability of those alternatives, and new systems need to be designed.

Finally, there is a high risk that European car makers will lose technological competitiveness and therefore market share on a global level as considerable resources need to be mobilized with the EU losing track of the rest of the world market (ROW).

The automotive industry is an essential source of Europe's prosperity. The jobs provided by the automotive sector reaches 13.8 million people, representing about 6.1% of the total employment number in the EU[11]. Today, the EU is among the world's biggest producers of motor vehicles while the sector invests the most in research and development (R&D). To strengthen the competitiveness of the EU automotive industry and preserve its global technological leadership must be the highest priority goal of the European Union.

In major automotive markets like in the US or Asia, R-1234yf currently is not subject to any restriction and based on our knowledge and in the light of the latest United Nations Environment Programme (UNEP) Environmental Effects Assessment Panel (EEAP) report, it is not going to be the case in near future. This is putting the European manufacturers into a very challenging situation for those markets in regards of technical and commercial competition.

6.3 Impact on environment

The environmental impact of the refrigerant in the cooling cycle is dependent on several factors regarding the refrigerant itself and its degradation products as well as the carbon footprint of the cycle based on the refrigerant efficiency.

Considering the possible risk of a refrigerant in the environment, the main criterion is the system leakage. The less refrigerant is leaking from the cycle, the less the refrigerant is reacting in the world's atmosphere. The leakage rate of a state-of the-art cooling and heating cycle of modern thermal management systems is usually specified and reported at very low amounts of less than 10g per year (e.g. less than 2% p.a. in the worst case) by the manufacturers but also by various global associations and authorities such as the state of Minnesota[12]. Considering the Directive of end-of-life vehicles (ELV

[11] Source: https://single-market-economy.ec.europa.eu/sectors/automotive-industry_en
[12] https://www.pca.state.mn.us/sites/default/files/aq-mvp2-29n.pdf

Directive[13]) that contains the legal obligation to collect refrigerants at the end of life of a vehicle, the direct impact of refrigerants on the atmosphere is very low. A further enhancement of the ELV Directive as well as offered recycling measures can further reduce the refrigerant emissions.

As an example, Daikin has successfully implemented a recovery & reclaim program for refrigerants used in stationary applications in Europe[14], where the reclaimed refrigerant is used for both the first system charge and aftermarket refills. We think that with the right regulatory and monetary incentives, a similar scheme can be adopted in MACS refrigerants.

Another important aspect regarding the impact on the environment is the link between PFAS and the degradation product trifluoroacetic acid (TFA). The recently published UNEP 2022 Assessment Report of the EEAP on Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change[15] states that the UNEP is “of the opinion that the properties of TFA indicate that it should not be included in this class for the purposes of generic regulatory risk assessment.” as “TFA does not bioaccumulate nor is it toxic at the low to moderate exposures currently measured in the environment or those predicted in the distant future.”

It is therefore understood that the only reason for the inclusion of R-1234yf / TFA in the current restriction dossier is persistence. In this case, we strongly encourage the consideration of leak mitigation and prevention strategies as the right countermeasure to this concern.

As a counterpoint, we will perform an evaluation of the environmental impact of the different refrigerant alternatives, and R-744 in particular, on the vehicle level based on a Life Cycle Climate Performance (LCCP) model for different regions in a bottom-up approach from system to fleet. This allows to evaluate the total environmental footprint regarding the EU vehicle fleet energy efficiency and resulting emissions.

[13] DIRECTIVE 2000/53/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 September2000 on end-of life vehicles
[14] https://www.daikin-ce.com/en_us/about/environmental-responsibility/loop-by-daikin.html
[15] https://ozone.unep.org/system/files/documents/EEAP-2022-Assessment-Report-May2023.pdf

6.4 Impact on consumers

For the end user of a vehicle, the use of refrigerants with the flammability level of A2 and A3 can lead to an increased risk of fire accidents in vehicles. The exact risk value for R-290 (being A3) is currently under study by the SAE.

A negative health impact in case of less performing AC systems in hot weather countries and HP systems in cold weather seasons needs to be evaluated.

The roll-out of BEVs in Europe is not achieving its original policy targets mainly due to vehicle purchase price increases compared to ICE vehicles, and usability considerations such as driving range and high-speed charging. These factors will significant worsen in a scenario where only non-PFAS refrigerant alternatives are available.

7. Conclusion

The ban of technologies such as R-474A offering high efficiency thermal systems for BEVs will lead to higher energy consumption of electric vehicles over lifetime, higher CO_2-equivalent emissions and higher costs to the consumer.

Additionally, a ban of R-474A would prevent EU manufacturers from a global solution for their global production platforms. The alternatives R-744, R-152a and R-290 are either not released or technically unfeasible for a global implementation considering the global regulations and temperature distributions, from very hot to very cold weather, not to mention safety risks.

Therefore, we argue that a ban of R-474A due to a ban of R-1234yf as refrigerant in BEVs would have negative effects on the European automotive industry and the society as a whole. A time unlimited derogation for R-474A combined with leak mitigation strategies seems to be the most reasonable and cost-effective approach, in the light of the purported benefits and risks.