

PFAS REACH Annex XV Restriction Report

1ST Public Consultation (22 March – 25 September 2023)

Exclusion or Derogation of HFO-1234yf in MAC/TMS Applications from the PFAS Proposal for a Restriction

1. Introduction

Honeywell International Inc. (hereinafter - **Honeywell**)¹ is a global manufacturer and importer of various fluorinated gases to the European Union (EU), including [hydrofluorocarbons \(HFC\)](#) and [hydrofluoroolefins \(HFO\)](#) refrigerants and their mixtures (**blends**), primarily used in refrigeration, heating, ventilation and air conditioning (**RHVAC**), mobile air conditioning (**MAC**), thermal management systems (**TMS**) in electric vehicles (**EV**), propellants in medical dose inhalers (**MDI**) and insulation foams blowing agent applications.

On 13 January 2023, the competent authorities of five EU Members States (**Dossier Submitters**) submitted to the European Chemical Agency (**ECHA**) the [PFAS REACH Annex XV Restriction Report \(Proposal\)](#).² Honeywell submits the following information and comments to the ECHA 1st public consultation on the Proposal.

Honeywell supplies EU based customers *inter alia* with fluorinated gas [HFO-1234yf](#)³ (or refrigerant **R-1234yf**, trademark Solstice® yf) widely used as a refrigerant in MAC, vehicle heating, ventilation and air conditioning (**HVAC**) and TMS in EV systems applications. This substance formally falls within the definition of PFAS in the Proposal.

Contrary to REACH rules and wide scientific consensus⁴, the Proposal considers “all PFAS” as a group for the risk assessment purposes and concludes that all PFAS should be treated as non-threshold substances “in a similar manner to PBT/vPvB substances”. It also states that alternative refrigerants and refrigerant systems are readily available for HFO-1234yf in MAC and EV TMS applications. We challenge this conclusion as the Dossier Submitters failed to assess “*carefully and impartially*” all available information on safety, efficiency, health and environmental properties of alternatives as demonstrated below.

2. Executive summary

Comments on persistency of HFO-1234yf and TFA

[HFO-1234yf](#) is a low toxic, non-bioaccumulative, very low persistent (atmospheric lifetime 5-15 days), mildly flammable gas with very low-GWP, no-ODP and with well-established DNEL/PNEC levels as well

¹ See the list of acronyms and abbreviations (aligned with the Proposal) in **Annex I** below.

² On 22 March 2023, ECHA published the *PFAS REACH Annex XV Restriction Report* in the [Registry of restriction intentions until outcome](#) and started the 1st Annex XV report consultation with a final deadline for comments on 25 September 2023.

³ [Polyhaloalkene, EC no: 468-710-7, CAS no.: 754-12-1, Mol. formula: C3H2F4](#)

⁴ See e.g. at page 278 of the [Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change](#), 2022 Assessment Report, Environmental Effects Assessment Panel (EEAP); also in [Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts](#), J.K. Anderson, et al., 2022.

as no noticeable health or environmental hazards or PBT/vPvB equivalent concerns. Its only PFAS breakdown product is [trifluoroacetic acid \(TFA\)](#).⁵

According to the [TFA REACH registration dossier](#) and Chemical Safety Report (CSR), this substance fulfils the criteria for persistency, but it is not classified as a PBT or vPvB substance under Annex XIII REACH and does not raise equivalent levels of concern under Article 57(f) REACH.⁶ ECHA already reviewed/evaluated the TFA dossier without concluding that further regulatory actions were needed.⁷ Detailed assessments of TFA are provided to ECHA in the separate Honeywell submission reference no 76bb3d12-2101-4390-82cf-3498b47e8015.

A substantial body of scientific data on health and environmental effects demonstrates limited (*de minimis*) effects of HFO-1234yf emissions and resulting TFA on humans and the environment. Comprehensive independent assessments of UNEP panels repeatedly concluded that *“The current low concentration of trifluoroacetic acid (TFA) produced by the degradation of several hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs), is currently judged not to pose a risk to human health or to the environment.”*⁸ and that *“available evidence indicates that this breakdown product [TFA] is of minimal risk to human health”*.⁹ Moreover, the most recent EEAP 2022 Assessment Report also concluded that *“based on projected future use of these precursors of TFA [incl. HFC/HFO], no harm is anticipated”* and that TFA *“is unlikely to cause adverse effects out to 2100”*.¹⁰

The [Q&A 10 of Addendum to the EEAP Assessment Report](#) also confirmed that *“Now and in the distant future, predicted TFA concentrations in surface waters and terminal basins are thousands of times less than thresholds of concern for human or environmental health.”*¹¹

Detailed analysis on degradation of HFC/HFO and relevant hazard, exposure and risks assessments of TFA is provided in the Honeywell submission reference no: 76bb3d12-2101-4390-82cf-3498b47e8015.

In addition, HFO-1234yf used in MAC systems is thoroughly controlled via containment requirements (leaks controls, end-of-life collection, and disposal, etc.) in [MAC Directive](#)¹² and [ELV Directive](#)¹³. Therefore, conclusions in the Proposal suggesting existence of unacceptable risks from any HFO-1234yf emissions are erroneous, not supported by science and based on “hypothetical” or “zero risk” assumptions.¹⁴

Concerns with assessments in [Annex E of the Proposal](#)¹⁵

The industry changes anticipated in Annex E of the Proposal are massive, complex, and misrepresented in terms of practicality, efficiency, timing, and cost to the society. [Carbon dioxide \(CO₂ or R-744\)](#) based MAC and/or TMS in EVs systems represent only a tiny portion of the overall MAC/TMS systems used in serial vehicles production due to control, safety, reliability and cost related issues.

⁵ [Trifluoroacetic acid, EC no: 200-929-3, CAS no: 76-05-1, Molecular formula: C₂HF₃O₂](#)

⁶ See e.g., [Mammalian toxicity of trifluoroacetate and assessment of human health risks due to environmental exposure](#), Dekant et al, 17 February 2023.

⁷ E.g., in 2017-2021, [ECHA concluded comprehensive dossier evaluation of Trifluoroacetic acid](#), without indications of the need for further actions.

⁸ Page 9, [Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change: UNEP Environmental Effects Assessment Panel, Update 2020](#)

⁹ Pages 8-9, [Summary Update 2021 for Policymakers, UNEP Environmental Effects Assessment Panel](#)

¹⁰ See pages 25 and 259 of the [EEAP 2022 Assessment Report](#).

¹¹ Q&A 10, [Questions and Answers about the Effects of Ozone Depletion, UV Radiation, and Climate on Humans and the Environment](#), EEAP 2022 Assessment Report.

¹² 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 (as amended).

¹³ Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles (as amended)

¹⁴ “However, a preventive measure cannot properly be based on a purely hypothetical approach to the risk, founded on mere conjecture which has not been scientifically verified”, “Moreover, those institutions may not take a purely hypothetical approach to risk and may not base their decisions on a ‘zero risk’”, see e.g. [BASF Agro BV and Others v European Commission](#), Case T-584/13, para. 65 and 72.

¹⁵ See Section E.2.10, pages 346 – 360 of [Annex E of the Proposal](#).

Annex E also stipulates that highly flammable refrigerants like [R-152a](#) (1,1-difluoroethane, [HFC -152a](#)) (or [R-290, propane](#)) “have been shown to be efficient and safe with secondary loop refrigerant systems”. There is no evidence that hydrocarbon based secondary loop systems are efficient or appropriate in any automotive application, particularly due to very strong safety concerns (flammability, explosivity). In the meantime, there are a substantial number of examples of grave incidents involving uses of hydrocarbons in heat pumps and other RHVAC equipment worldwide (please refer to **Annex II** below). The absence of publicly available information on similar cases in the automotive industry is because those kinds of systems are simply not in use.

Moreover, the [Kigali Amendment to the Montreal Protocol](#) obliges developed countries to reduce HFC consumption (including HFC-152a) by 85% vs their baseline by 2036. Accordingly, [MAC Directive](#) already prohibits uses of F-gases with GWP 100 more than 150 in automotive MAC/HVAC applications. However, according to the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC AR6 of 2021), HFC-152a has atmospheric lifetime of 1.6 years (vs HFO-1234yf atmospheric lifetime of 5-15 days) and GWP 100 figure of 164, exceeding the MAC Directive 150 limit.¹⁶ This questions the rationality for further development of this refrigerant in all RHVAC systems.

Energy efficiency of CO₂ and secondary loop automotive systems

According to numerous research papers, CO₂ refrigerant systems are significantly less efficient than existing fluorinated refrigerants in warm to hotter weather. According to a recent 2023 study published in the International Journal of Refrigeration: “The main feature of using CO₂ as the refrigerant is that the refrigeration system works as a transcritical cycle at high ambient temperature due to the low critical temperature. Additionally, the high operating pressure of the CO₂ system and large pressure drop in the isenthalpic throttling process leads to significant irreversibility loss and low performance.”¹⁷ These efficiency losses lead to increasing energy needs and thus to higher fuel and/or electricity consumption of a vehicle, i.e., higher GHG emissions and consumer costs in comparison to HFO-1234yf systems.

It is stated on pages 356 and 369 of Annex E of the Proposal that “A barrier to introduction of CO₂ is its lower efficiency at medium to high temperatures”. This evidence is mentioned as relevant for the shipping of refrigerated containers (Reefer Containers) but is not acknowledged in the Proposal for MAC applications. The MAC related section of the Proposal simply suggests that CO₂ is more efficient than existing refrigerants. This approach also drastically contradicts the study from Technical Institute of Physics & Chemistry of Chinese Academy of Sciences (CAS)¹⁸ that compared several refrigerants in automotive applications. The study reviewed refrigerant performance under a variety of ambient conditions including heat pump (heating) and AC (cooling) points. Applying typical weather distribution patterns, it is evident that due to the inefficiency of CO₂ and hydrocarbon based secondary loop systems in warmer weather there is approximately an additional 18 to 22 percent yearly power increase required for these systems over HFO-1234yf.

Due to the additional power needed to run CO₂ systems in EVs (more electricity generation) and additional fuel burned to run secondary loop - hydrocarbon systems in internal combustion engines (ICE), the above losses in efficiency, would result in additional **annual** GHG emissions of **up to ten million tons** of CO₂ in Europe. Therefore, HFO-1234yf substitution by other refrigerants in MAC/TMS systems contradicts wider EU decarbonization goals (including under [European Green Deal](#), [Fit for 55](#), [REPowerEU](#)) and is disproportionate to alleged risks from HFO-1234yf and persistency of TFA.

Conversion timing

¹⁶ See Table 7.SM.6 at pages 17-18 of [The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity Supplementary Material](#), IPCC AR6 Report, 2021.

¹⁷ [Thermodynamic performance evaluation of an ejector-enhanced transcritical CO₂ parallel compression refrigeration cycle](#), Tao Bai et al, International Journal of Refrigeration, Volume 149, May 2023, Pages 49-61.

¹⁸ Technical Institute of Physics & Chemistry, Chinese Academy of Sciences (CAS), 2023. The full study is available in Chinese upon request. Relevant robust extracts/summaries in English are provided in **Annex III** below.

According to Annex E and Table 8 of the Proposal, CO₂ based HVAC and TMS systems are readily available for use in EVs. This conclusion incorrectly assumes that CO₂ hardware can be quickly scaled and that millions of systems could be supplied quickly based on a limited number of CO₂ systems in the field. World scale CO₂ component production will take many more years than Annex E contemplates.

The conversion from HFC-134a to HFO-1234yf refrigerant took more than 10 years. Automotive manufacturers are in the beginning of the transition to EVs and the refrigerant transition periods proposed are very short. Rushing to market with questionable, complicated, less efficient, and difficult to control HVAC/TMS systems, will certainly bring safety and use problems. Refrigerant systems are also EV battery cooling systems. Failures or malfunctions may mean forcing a vehicle to the side of the road to avoid fires caused by battery thermal runaway.¹⁹ Decreases in safety or reduced customer satisfaction will slow EV acceptance.

Similar to CO₂, secondary loop systems using extremely flammable gases like R-152a (or propane) have been studied in the automotive field. No light duty commercial vehicles have ever been mass produced globally in this configuration. R-152a or propane will increase fire risk for consumers (over current refrigerants) based on ignition energy, increased combustion energy, flame propagation and wider flammable concentrations. Suggesting such short implementation timing for an unproven, undeveloped, and untried system seems reckless and disproportionate. It will also likely increase the safety risk for millions of drivers across Europe.

Alternative approaches to the proposed regulation

According to the Proposal “*setting tighter leakage limits for systems based on fluorinated gases*” is possible and helpful. Reduced leaks improve reliability for customers, reduce warranty costs for manufacturers and help with the goals of the Proposal.

Finally, robust end-of-life reclamation of refrigerants and documentation could help with tracking refrigerant supplies and return more refrigerant to the field reducing the need for new refrigerant entering the service market. All the above are responsible means to reduce emissions. Respective Risk Management Measures (RMMs) are already provided in the [MAC Directive](#) and [ELV Directive](#) (including, on containment, recovery, reclamation and reuse of refrigerants) and could be enhanced at any time. This will be a less controversial, less costly and less disruptive approach to the regulation of MAC and TMS refrigerants for an industry in transition.

Conclusions

The introduction of a REACH restriction on HFO-1234yf as suggested in the Proposal, will violate requirements of the REACH Regulation, EU general legal principles and wider EU policies, resulting in very high, unjustified costs on society.²⁰

Honeywell submits that fluorinated gas HFO-1234yf used as a refrigerant in MAC systems of all types as well as in all EV applications should be excluded from the scope of the PFAS REACH restriction in question because its inclusion is based on incorrect and unsubstantiated concerns around persistence and decomposition products.

Alternatively, considering that the EU plans to ban sales of new vehicles with combustion engines from 2035 and that the estimated service life of a vehicle is around 20 years, a transition period for the full application of the restriction for all vehicles should be at least extended to 2055. In line with previous practices, this time-limited derogation should also cover maintenance/repair, refitting and reselling activities involving used/second-hand vehicles placed on the market before this date. This derogation could be also

¹⁹ See e.g., [Ignition: Spontaneous electric vehicle fires prompt recalls, but some owners stalled waiting on repairs](#); or on “thermal runaway” incidents in [Should You Be Worried About Electric Vehicle Battery Fires?](#)

²⁰ Please also refer to the detailed analysis of the legality, regulatory and scientific consistency of the Proposal in the previous [Honeywell submission reference no: bb6e00b6-571b-467a-ae79-7b046c6c9ab4](#).

conditional (progress-limited) to allow the industry to work towards development of alternatives with a transitional review by ECHA and the European Commission by the end of 2035.²¹

Comments from the European Automobile Manufacturers Association (ACEA) on the Proposal regarding the use of refrigerants do not reflect the diversity of HFC/HFO uses amongst car manufacturers globally. There are other major automotive producers that are not ACEA members who depend on the continued use of HFO-12324yf refrigerants in MAC and TMS EV systems. The Proposal manifestly ignores the inefficiencies and challenges of the suggested alternatives and their increased costs, risks and climate implications.

3. Detailed comments and information

3.1. MAC refrigerants background

When it became clear in the early 2000's that HFC-134a was a major contributor to climate change, governments in Europe and North America began to develop regulations that restricted or discouraged the use of it and many other high Global Warming Potential (GWP) refrigerants. Initial discussions with the auto industry in the EU began in the early 2000's culminating with the *EU MAC Directive* in 2006 requiring that light duty vehicle production move to refrigerants with a GWP of less than 150. The automotive industry formed a workgroup (Cooperative Research Project - CRP) and launched a major multi-year study to identify an **ideal** low-GWP refrigerant that could replace HFC-134a.

As many alternatives were considered and evaluated it soon became apparent that it would be difficult to find a refrigerant with similar properties compared to HFC-134a that would also offer similar performance in vehicle MAC systems. Refrigerants in the auto industry need high performance to quickly cool down a warm vehicle after sitting in direct sunlight (and now for EVs to cool down batteries, motors, and electronics). MAC systems also need the ability to dehumidify air for comfort and limit fogging on the glass for visibility and safety. Refrigerants need to be cost effective, reliable, safe in servicing and compatible with a wide variety of compounds required for automotive HVAC systems (hoses, lines, seals, oils, compressors, heat exchangers, etc.). They need to be safe and acceptable with regard to toxicity, flammability, leak exposure to vehicle passengers as well as thermal and environmental breakdown. The refrigerant type plays a vital role in overall vehicle safety. Last, a good MAC refrigerant minimizes energy consumption helping the HVAC system reduce power required for operation. In EVs, total HVAC and TMS systems energy consumption reduces vehicle range which is major concern for widespread EV adoption. The recently released [*The 2022 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee from the United Nations Environment Programme*](#) states at page XVI: "There is no single "ideal" refrigerant. Refrigerant selection is a balanced result of weighing several factors which include, environmental issues, suitability for the targeted use, availability, cost of the refrigerant and associated equipment and service, energy efficiency rating, safety, and ease of use."

All the above requirements were considered in the multi-year study conducted through a four phase [*Cooperative Research Project \(CRP\)*](#) sponsored by SAE International (the former Society of Automotive Engineers). The study included a global consortium of automotive engineers, Tier 1 MAC components suppliers, academics and government regulatory participants. In the end, there was a broad consensus that refrigerant HFO-1234yf (R-1234yf) had the best performance and fewest drawbacks in comparison to other refrigerants including CO₂ (R-744) and R-152a ([1,1-Difluoroethane](#)). Safety questions were raised during the study based on the mild flammability of HFO-1234yf, but significant research, testing and analysis showed that the risks to passengers were so low as to be insignificant (accepted by EU and US authorities as well as independent internationally recognized fire authorities).²² With over 200 million vehicles on the road globally today, HFO-1234yf has proven to be as safe and reliable as HFC-134a.

²¹ See Example 5, Examples of conditional derogations, pages 58-62, [Guidance for the preparation of an Annex XV dossier for Restrictions](#); see also para. 7 of [entry 72](#), [para. 8 of entry 50](#) or [paras. 3 and 10 entry 68 of Annex XVII REACH](#).

²² See the detailed presentation [Industry Evaluation of low global warming potential refrigerant HFO-1234yf](#).

Refrigerant HFO-1234yf was specifically designed to minimize persistence and overall environmental impact. As of today, every manufacturer producing light duty vehicles for sale in the EU, Turkey, UK, South Korea, Canada and the United States is using HFO-1234yf successfully. HFO-1234yf is the low-GWP refrigerant of choice for carmakers, consumers and for the environment.

3.2. HFO-1234yf and TFA misconceptions

According to the respective REACH registration dossier and CSR, [HFO-1234yf](#)²³ is a mildly flammable gas (ASHRE A2L) with very low-GWP (0,501, i.e., below CO₂)²⁴, no-ODP (0) and with no noticeable health or environmental hazards or PBT/vPvB equivalent concern. In 5-15 days upon release into the atmosphere the gas degrades to CO₂, hydrogen fluoride (HF) and trifluoroacetyl fluoride (CF₃C(O)F, CAS 359-08-2). The latter ultimately degrades to the naturally occurring²⁵ PFAS substance [trifluoroacetic acid \(TFA\)](#) which is removed from the atmosphere by dry and wet deposition. The conversion rate of HFO-1234yf to TFA is almost 1:1 on a molar and w/w basis, with ~100% molar yield. The volumes of other degradation products hydrogen fluoride (HF) and CO₂ are negligible. Detailed assessment of TFA is provided in the separate Honeywell submission to ECHA reference no 76bb3d12-2101-4390-82cf-3498b47e8015. REACH registration data and CSR of TFA²⁶ (including, DNEL/PNEC assessments, several times reviewed by ECHA) unequivocally demonstrate that it is not a non-threshold substance and does not have any similar risks to PBT/vPvB substances.²⁷

TFA is also formed during processes of atmospheric degradation of certain other fluorinated gases as well as from uses in plant protection, pharmaceutical and other perfluorinated compounds.²⁸ A substantial body of scientific data on health and environmental effects of HFO-1234yf and its main atmospheric decomposition product TFA is available worldwide (e.g., various studies of UN, OECD, EPA, individual scholars). All independent analysis demonstrates limited (*de minimis*) effects of HFO-1234yf emissions and resulting TFA on humans and the environment (e.g., UNEP).²⁹

For instance, comprehensive independent assessments of UNEP panels repeatedly concluded that “*The current low concentration of trifluoroacetic acid (TFA) produced by the degradation of several hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs), is currently judged not to pose a risk to human health or to the environment*.”³⁰ and that “*available evidence indicates that this breakdown product [TFA] is of minimal risk to human health*.”³¹

According to the most recent 2022 UNEP/WMO report: *TFA abundance and its environmental impacts have been assessed in many previous Assessments (e.g., Montzka, Reimann et al., 2011; Montzka, Velders et al., 2018; Carpenter, Daniel et al., 2018). Previous Assessments concluded that the environmental effects of TFA due to the breakdown of HCFCs and HFCs are too small to be a risk to the environment over the next few decades based on the projected future use of hydrocarbons, HCFCs, and HFOs.*³²

²³ Polyhaloalkene, EC no: 468-710-7, CAS no.: 754-12-1, Mol. formula: C₃H₂F₄

²⁴ See Table 7.SM.6 at pages 17-18 of [The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity Supplementary Material](#), IPCC AR6 Report, 2021.

²⁵ See e.g., EFCTC summary publication [Naturally Occurring TFA](#).

²⁶ CLP related information on [classification and labelling of TFA](#) is available at ECHA website.

²⁷ See the most recent comprehensive [Mammalian toxicity of trifluoroacetate and assessment of human health risks due to environmental exposure](#), Wolfgang Dekant, Raphael Dekant, 17 February 2023 and [Scientific Assessment of Ozone Depletion: 2022](#), GAW Report No. 278, 509 pp.; World Meteorological Organization (WMO): Geneva, 2022.

²⁸ See also in section B.4.1.3.2, Annex B of the Proposal.

²⁹ [Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change: UNEP Environmental Effects Assessment Panel, Update 2020](#), see also [EFCTC summaries on TFA](#).

³⁰ Page 9, [Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change: UNEP Environmental Effects Assessment Panel, Update 2020](#)

³¹ Pages 8-9, [Summary Update 2021 for Policymakers, UNEP Environmental Effects Assessment Panel](#)

³² Page 137, [Scientific Assessment of Ozone Depletion: 2022](#), GAW Report No. 278, 509 pp.; WMO: Geneva, 2022

Moreover, the EEAP 2022 Assessment Report also concludes that “based on projected future use of these precursors of TFA [incl. HFC/HFO], no harm is anticipated” and that TFA “is unlikely to cause adverse effects out to 2100”.³³

The Q&A 10 of Addendum to the [EEAP 2022 Assessment Report](#) also confirms that “However, for lakes and oceans, the effects of increased concentrations of naturally occurring mineral salts, such as sodium chloride, and other water-soluble minerals are greater and more biologically significant than those caused by TFA salts. Salts of TFA in soil are taken up by plant roots and concentrate in the leaves, where they appear to have no effects. If animals eat the leaves, TFA is rapidly excreted and does not accumulate in their bodies or in the food chain.”³⁴

Finally, EEAP concluded that “Based on current knowledge, [HFC/HFO] breakdown products do not pose environmental concerns. Based on estimates of current and future use of HFCs and other replacements for CFCs, additional inputs of TFA to the ocean will only slightly (less than 0.5% per year) increase the amounts that have been present historically. Now and in the distant future, predicted TFA concentrations in surface waters and terminal basins are thousands of times less than thresholds of concern for human or environmental health.”³⁵

In April 2023 the US EPA wrote, “EPA studied the potential generation of TFA when first listing neat (i.e., 100%, not in blends) HFO-1234yf as acceptable, subject to use conditions, in motor vehicle air conditioning. The myriad studies EPA referenced all concluded that the additional TFA from HFO-1234yf did not pose a significant additional risk, even if it were assumed to be used as the only refrigerant in all refrigeration and air conditioning equipment.”³⁶

HFO-1234yf use in MAC systems³⁷ is thoroughly controlled via containment requirements (leaks controls, end-of-life collection, and disposal, etc.) in the [MAC Directive](#)³⁸ and [ELV Directive](#)³⁹. HFO-1234yf is also subject to various containment, monitoring, certification and reporting obligations under the [EU F-Gas Regulation](#)⁴⁰ (as Annex II substances). The above EU legislation specifically aims to considerably decrease all HFC/HFO emissions in a medium term.

Furthermore, the Proposal erroneously considers “all PFAS” as a group for the risk assessment purposes and concludes that all PFAS, including HFO-1234yf and TFA, should be treated as non-threshold substances “in a similar manner to PBT/vPvB substances”. This approach is not scientifically justified. In this regard, the most recent [EEAP 2022 Assessment Report](#)⁴¹, unequivocally cited a common agreement among the majority of experts that “all PFAS should not be grouped together, persistence alone is not sufficient for grouping PFAS for the purposes of assessing human health risk, and that the definition of appropriate subgroups can only be defined on a case-by-case manner” and that “it is inappropriate to

³³ See pages 25 and 259 of the [EEAP 2022 Assessment Report](#).

³⁴ Please also see, Q&A 10, [Questions and Answers about the Effects of Ozone Depletion, UV Radiation, and Climate on Humans and the Environment](#), EEAP 2022 Assessment Report.

³⁵ *Ibid.*

³⁶ Page 26414, [Federal Register / Vol. 88, No. 82 / Friday, April 28, 2023 / Rules and Regulations, 2023-08663.pdf \(govinfo.gov\)](#)

³⁷ Relevant [SAE](#) and ISO standards also apply.

³⁸ 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 (as amended).

³⁹ Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles (as amended)

⁴⁰ Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 (as amended and currently under review, available [here](#)).

⁴¹ [Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change](#), 2022 Assessment Report, Environmental Effects Assessment Panel (EEAP), available at - <http://ozone.unep.org/science/eeap>

assume equal toxicity/potency across the diverse class of PFAS".⁴² At page 25 the Report concludes that *"Trifluoroacetic acid has biological properties that differ significantly from the longer chain polyfluoroalkyl substances (PFAS) and inclusion of TFA in this larger group of chemicals for regulation would be inconsistent with the risk assessment of TFA"*.

In the above referenced publication by the US EPA, it also states that *"in evaluating alternatives using its comparative risk framework, SNAP already considers potential risks to human health and the environment. Regardless of what definition of PFAS is used, not all PFAS are the same in terms of toxicity or any other risk. Some PFAS have been shown to have extremely low toxicity, for example. If a chemical has been found to present lower overall risk to human health or the environment, it might be found acceptable under SNAP regardless of whether or not it falls under a particular definition of PFAS."*⁴³

Considering the above, conclusions in section 1.1.6 of the Proposal suggesting the existence of unacceptable risks from HFO-1234yf emissions that are not adequately controlled and that any such emissions should be used as a proxy for risks are erroneous, not proved by science and based on "hypothetical" or "zero risk" assumptions.⁴⁴ These conclusions are in contradiction with available solid scientific data, REACH registration information and ECHA practices. Honeywell submits that HFO-1234yf should be excluded from the scope of the PFAS restriction in question.

3.3. Other concerns with the assessments in [Annex E of the Proposal](#)⁴⁵ and proposed restrictions

The industry changes being suggested in the Proposal are massive, complex, and misrepresented in terms of practically, efficiency, timing, and overall cost to the society. On page 250 the Annex E states that *"CO₂ can be used in place of fluorinated gases in electric vehicles and combustion engine vehicles with electric compressors (hybrid and plug-in hybrid cars)"*. The assumption is that CO₂ systems are readily available, fully understood, effective and that the necessary components can simply be purchased by vehicle manufacturers and used in the future is incorrect. Every single CO₂ component of a vehicle refrigeration system needs to be developed, redesigned and tooled up for significant production volumes. CO₂ system components are not readily available and would need considerable time, investment and R&D activities to achieve significant volume capacity. Most vehicle manufacturers have never used CO₂ HVAC or TMS systems in a single model. We are aware of only two light duty automotive manufacturers that have ever produced these systems, Daimler and the VW Group⁴⁶.

CO₂ based HVAC systems currently in production (for ICE or EV cars) represent a tiny portion of the total number of vehicles in the market and the reliability and performance of these systems are highly questionable. Several of the models that were launched with standard or optional CO₂ MAC systems in Europe are now using HFO-1234yf technology. For instance, Mercedes has offered optional CO₂ AC systems on some versions of its E and S class vehicles since 2017 but it has since dropped CO₂ on those models.⁴⁷ The more recent Mercedes EQ series of electric vehicles was launched with and continues to use HFO-1234yf - not CO₂.⁴⁸ The Audi A8 in Europe was released with CO₂ on some models but not in the US.⁴⁹ CO₂ refrigerant systems for vehicles have several drawbacks and most, if not all CO₂ models are

⁴² [Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts](#), J.K. Anderson, et al., 2022

⁴³ Page 26414, [Federal Register / Vol. 88, No. 82 / Friday, April 28, 2023 / Rules and Regulations, 2023-08663.pdf \(govinfo.gov\)](#).

⁴⁴ "However, a preventive measure cannot properly be based on a purely hypothetical approach to the risk, founded on mere conjecture which has not been scientifically verified", "Moreover, those institutions may not take a purely hypothetical approach to risk and may not base their decisions on a 'zero risk'", see e.g. [BASF Agro BV and Others v European Commission](#), Case T-584/13, para. 65 and 72.

⁴⁵ See Section E.2.10, pages 346 – 360 of [Annex E of the Proposal](#).

⁴⁶ See e.g., [Mercedes-Benz dumps R744](#), [Audi Electric SUVs Offer CO2 Heat Pump to Boost Driving Range](#), [Volkswagen Cites Efficiency Gains from CO2 Heat Pump in First Electric SUV Coupe](#).

⁴⁷ [Mercedes-Benz dumps R744 – VASA](#)

⁴⁸ [Mercedes-Benz EQS, EQE, And EQS SUV To Get Standard Heat Pump, More Range](#)

⁴⁹ [R744 | future:gas automotive air-conditioning refrigerant seminar roadshow \(futuregas.ac\)](#)

either cancelled or on hold today due to a supply shortage of microchips required to control the system.⁵⁰ One manufacturer decided to voluntarily refund part of the cost for the optional CO₂ heat pump system to customers because the system couldn't meet the promised performance specifications as a heat pump (Perry 2022).⁵¹

None of these applications would represent a success story for CO₂ systems. If CO₂ systems are as efficient, cost effective and available as described in the Annex E with significant benefits for vehicle operation and car owners; why haven't they achieved widespread OEM and consumer adoption? CO₂ is not an ideal refrigerant. It has significant drawbacks for cost, performance, efficiency and reliability.

The largest manufacturer of EVs in the world, Tesla, currently uses HFO-1234yf for AC and heat pump operation⁵². Stellantis currently uses HFO-1234yf in EV heat pumps.⁵³ JLR uses HFO-1234yf for their EV heat pump⁵⁴ Hyundai, and Kia EVs have HFO-1234yf heat pumps. General Motors EVs also use HFO-1234yf based heat pumps.⁵⁵ Toyota and Subaru EVs also use HFO-1234yf and have a heat pump.⁵⁶

The Annex E goes further at page 250 to state that CO₂ as a refrigerant "*is unsuitable for combustion engine vehicles with mechanical compressors*" due to the difficulty in retaining refrigerant at the AC compressor shaft lip seal necessary to drive the compressor. While this may be true, refrigerant leaks can occur at any refrigerant connection which brings into question the overall durability expected with CO₂ systems in general. Refrigerant systems in EVs are responsible not only for occupant comfort but are also crucial for thermal management of the battery, electric motors and other electronic components. There is very little experience in the field with CO₂ systems that would support a widespread expansion of this technology in the EV market. A shift now to less efficient CO₂ MAC systems would increase the impact of motor vehicles on the environment. Any CO₂ refrigerant mandate would be viewed as a distraction to vehicle manufacturers who currently are preoccupied with designing and building EVs and making them more cost efficient, safer and more appealing to consumers.

Although CO₂ is not flammable and is also considered low toxicity (A rated by ASHRAE), this refrigerant does have unique challenges with regard to health and safety. CO₂ refrigerant releases into the passenger compartment were concerning enough for the US EPA to put usage restrictions on CO₂ systems due to the *anaesthetic and health effects* of higher CO₂ concentrations in the vehicle cabin. Moreover, due to significantly higher pressures, CO₂ systems pose additional risks in the case of automotive collisions and vehicle service.⁵⁷ While automotive manufacturers do an excellent job of managing risks, CO₂ systems have not reached broad market volumes to prove safety in the field. In 2008, the major SAE International study on alternate refrigerants found that R-744 (CO₂) MAC systems posed greater risks for consumers than HFO-1234yf and that it also had a greater environmental impact for climate change based on Life Cycle Climate Performance (LCCP) models⁵⁸.

The Annex E also proposes at page 250 that highly flammable refrigerants like R-152a (or R-290, propane) "*have been shown to be efficient and safe*" with secondary loop refrigerant systems. Since there has never been a hydrocarbon based secondary loop system installed on a serial production vehicle anywhere; we can only offer honest scepticism of these claims. Using highly flammable gases in automotive applications requires significant study, development, investment, testing, risk mitigation and cost analysis. It is likely that there will be increased risks for consumers if they are used in vehicles of any kind based on significantly

⁵⁰ [Audi No Longer Putting Heat Pumps In Q4 e-tron \(insideevs.com\)](#) [VW ID.4 Is Being Shipped Without A Heat Pump Due To Semiconductor Shortage \(insideevs.com\)](#)

⁵¹ [The VW ID.4's Heat Pump Confusion \(Does it Have One?!\) - Green Car Future](#)

⁵² [Tesla's Innovative And Efficient Heat Pump Explained In New Video \(insideevs.com\)](#)

⁵³ [Stellantis extends range of Peugeot, Opel, DS small EVs | Automotive News Europe \(autonews.com\)](#)

⁵⁴ [Jaguar I-PACE | Thermal Management Systems | Jaguar USA](#)

⁵⁵ [GM Adds a Heat Pump to Its Ultium-Powered EVs for More Range \(cnet.com\)](#)

⁵⁶ [DENSO Products Electrify Toyota and Subaru's New All-Electric bZ4X and SOLTERRA](#)

⁵⁷ See chapter "CO₂ effect on car crashes" in [CO₂ buildup in vehicle cabins becoming a safety issue, 2017-04-17](#).

⁵⁸ Slides 17-19 in [Industry Evaluation of low global warming potential refrigerant HFO1234yf](#), SAE International, 2008

lower ignition energy; much higher combustion energy; much higher burning velocity and wider flammable concentration limits.⁵⁹ These safety risks augment considerably in possible situations of batteries overheating and ignition in EVs. The truth is that there is no evidence (and even evidence to the contrary based on its absence in the market) that hydrocarbon based secondary loop systems are efficient or appropriate in any automotive application. In the meantime, there is substantial number of examples of grave incidents involving uses of hydrocarbons in heat pumps and other RHVAC equipment worldwide (please refer to **Annex II** below). The absence of publicly available information on similar cases in the automotive industry is because those systems are simply not in use.

Annex E frequently quotes (see e.g. at pages 250, 358, 367-369) the additional cost to implement CO₂ to be €300 per vehicle. This cost seems to be misleading given that the main automotive manufacturer of CO₂ systems has been charging €1,250 for the optional CO₂ heat pump system over the existing R-1234yf AC system.⁶⁰ The Annex E (see Table E.120) further states that it is assumed that all R&D and re-certification costs and additional cost for components are assumed to be included in the underestimated €300 per vehicle. Somehow the investment of many millions of euros of capital required to create the new components and manufacturing processes were also ignored.

The report goes further in the same section (Table E.120) to state: *“In the event of increased energy losses through the use of technologies [presumably the proposed alternative MAC technologies] that are less energy efficient, additional costs of abatement for greenhouse gas emissions elsewhere in the economy to ensure that climate goals and targets are met.”* The report finds that this is an important enough topic to mention, but states that there is no data on this. On page 369 of the Annex E it is noted while referring to CO₂ refrigerant systems with shipping containers that: *“A barrier to introduction of CO₂ [refrigerant] is its lower efficiency at medium to high temperatures...”* While this is a widely recognized engineering concern, somehow this information was ignored when discussing MAC systems. Problems with CO₂ (and secondary loop) refrigeration efficiency will be discussed in detail below. Are auto manufacturers expected and prepared to find emissions offsets for the inefficient systems being proposed here? As no data has been provided on this, the assumption is that it would add no cost to somehow reduce emissions to offset these inefficiencies.

On page 369 of Annex E of the Proposal a price for HFO-1234yf is quoted as \$100/g (ca. €91,000/Kg). This information is completely inaccurate, and the Dossier Submitters bluntly ignored real world HFO-1234yf prices. A quick search for aftermarket HFO-1234yf retail prices in Europe reveals approximately €71/Kg not €91,000/Kg, an overstatement of >1000 times.⁶¹ Bulk HFO-1234yf prices to automakers are even lower.

This mistake explains why the Dossier Submitters grossly underestimated the added cost to the industry to switch to a CO₂ or HFC-152A system. In their calculations, they used a cost of HFO-1234yf per vehicle of € 54,600 when the real world estimate of the cost per vehicle of HFO-1234yf is just € 42.60 (600 g charge). In other words, the Dossier Submitters calculated substitution costs on the basis of a wrong estimate of the cost of the current HFO-1234yf system cost. They inflated the HFO-1234yf fluid cost making the switching cost to CO₂ look much more favourable than it really is. Corresponding errors renders the overall substitution costs analysis and conclusions at pages 367-369 of Annex E of the Proposal flawed and unreliable. The real cost differential (increase) would be substantially higher than reported because the higher cost of the CO₂ MAC equipment would not be offset by the overstated cost savings from replacing the HFO-1234yf fluid with a lower cost CO₂ refrigerant fluid.

Finally, Table E.129 on page 379 of Annex E of the Proposal concludes that it is unlikely that countries outside the EU will follow this proposed regulatory direction, stating only that *“There is no reason to expect*

⁵⁹ [HFO-1234yf - A Low GWP Refrigerant for MAC - Honeywell/DuPont Joint Collaboration \(lexissecuritiesmosaic.com\)](https://www.lexissecuritiesmosaic.com/HFO-1234yf-A-Low-GWP-Refrigerant-for-MAC-Honeywell-DuPont-Joint-Collaboration)

⁶⁰ [VW Lowers ID.3, ID.4 Heat Pump Price Over Poor Cold-Weather Efficiencyhttps://www.autoevolution.com/news/vw-lowers-id3-id4-heat-pump-prices-over-substandard-efficiency-162496.html](https://www.autoevolution.com/news/vw-lowers-id3-id4-heat-pump-prices-over-substandard-efficiency-162496.html)

⁶¹ [R1234yf - Buy refrigerant for 399 euros per 5 kg cylinder of gas - alvadi.de](https://www.alvadi.de/en/1234yf-Buy-refrigerant-for-399-euros-per-5-kg-cylinder-of-gas)

exports of vehicles from the EU to be affected as systems could be filled with [working] fluorinated gases after export.” This recognition does question the effectiveness and reasonableness of this action based on not expecting other countries to follow this extreme regulation. Because secondary loop and CO₂ based refrigerant systems cannot just be filled with traditional refrigerants and would need a complete redesign with new components, one would also assume that the cost to develop and tool both traditional refrigerant systems and the significantly higher cost CO₂ and/or SL-MAC systems in the same models would reduce EU industry export competitiveness and significantly add to the cost burden for manufacturers wanting to please their export customers.

3.4. Recent studies on the efficiency of CO₂ as an automotive refrigerant

The latest research on CO₂ as an automotive refrigerant reveals issues with cooling and efficiency – Coefficient of Performance (COP). “The main feature of using CO₂ as the refrigerant is that the refrigeration system works as a transcritical cycle at high ambient temperature due to the low critical temperature (31.1 °C). Additionally, the high operating pressure of the CO₂ system and large pressure drop in the isenthalpic throttling process leads to significant irreversibility loss and low performance.”⁶²

[The 2022 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee from the United Nations Environment Programme](#) states that: “In the air conditioning mode, the cooling COP decreases with increasing ambient temperatures; however, the COPs of the different refrigerants are very similar up to an ambient temperature of about 30 °C. Above this temperature the energy efficiencies of HFC134a and HFO-1234yf refrigerant are better than that of R-744 (Junqi, 2021)” (see page 194) and then goes further to state: “... R-744 is less suitable in hot and humid climates where energy efficiency is somewhat lower than that of HFC-134a and HFO-1234yf systems” (page 197).

In a recent study (August 2022) Xia Song et. al comparing CO₂ to R-134a (HFO-1234yf being similar to R-134a) states that “According to performance evaluation results by Brown et al. (Brown et al., 2002), the Coefficient of Performance (COP) of the CO₂ system was 21% lower at 32.2°C and 34% lower at 48.9°C than the HFC-134a system. At higher compressor speeds and ambient temperatures, the COP disparity of CO₂ system was even more significant (Song et al., 2021b). From the viewpoint of the second law of thermodynamics, the overall energetic performances of the vapour compression plant working with HFC-134a were consistently better than those obtained using CO₂ as refrigerant (from a minimum of 20% to a maximum of 44%) (Aprea et al., 2013)”.⁶³

Another recent publication (October 2021, Onan and Erdem) states: “The performance of the cooling processes of R1234yf and R744 refrigerant gases was compared with that of R134a. A simulation model was first developed. This simulation model was validated with experimental results. Analysis was conducted for both cooling and heating modes. In the case of cooling, evaporation temperature was 5 °C–7.5 °C, condenser, or gas cooler outlet temperature was 35 °C–50 °C and the cooling load was 10 kW. In heating mode, evaporation temperature was –4 °C–12 °C, condenser, or gas cooler outlet temperature was 45 °C–50 °C and the heating load was 13.5 kW. The results were analyzed in terms of the coefficient of performance (COP), compressor power consumption, and compressor discharge temperature. In terms of COP and compressor power consumption, R134a gave the best results in all cases. R1234yf gave the closest results to R134a. In terms of compressor discharge temperature, which affects the lifetime and lubrication quality of the compressor, R1234yf gave the lowest temperatures in all cases.”⁶⁴

According to another study which reviewed information related to several proposed improvements in CO₂ transcritical operation “...(the) COP improvement percentages of these modifications were reported to vary

⁶² [Thermodynamic performance evaluation of an ejector-enhanced transcritical CO₂ parallel compression refrigeration cycle - ScienceDirect](#)

⁶³ [Experimental study on improved performance of an automotive CO₂ air conditioning system with an evaporative gas cooler](#), Xia Song et al, International Journal of Refrigeration, August 2022.

⁶⁴ [R1234yf and R744 as alternatives to R134a at mobile air conditioners](#), C. Onan, Serkan Erdem, 25 October 2021

from a minimum of 7% to a maximum of 47.3%. Nevertheless, the above modifications have more or less drawbacks or challenges, such as high cost and great system complexity (Yu et al., 2019a)".⁶⁵

CO₂ becomes transcritical at a gas cooler exit temperature of 31 °C ... "An efficiency drop also occurs with HFC systems when the ambient temperature increases, but the change is not as great as it is with R744 when the change is from sub- to transcritical".⁶⁶ If the gas cooler and airflow system of a CO₂ vehicle were 100% effective for a given point then at or above an ambient of 31°C the system would operate in the less efficient transcritical zone. Making a gas cooler 100% effective would require extremely large heat exchangers that are not practical for light duty vehicles, hence CO₂ frequently operates transcritically at lower ambient temperatures than 31°C. The air inlet temperature to the gas cooler (in front of a vehicle) is also frequently higher than actual ambient conditions based on radiation off asphalt at low speeds or behind other vehicles. Also at low speeds, recirculation of warm air around the heat exchanger from behind to the front will also raise the inlet air temperature.⁶⁷ Given these two automotive conditions, inefficient transcritical operation for CO₂ refrigerants systems can happen quite frequently even in mild weather conditions.

The efficiency, capacity and power consumption level of automotive air conditioning systems has become even more important as more and more people in Europe want AC systems in their new vehicles. The effects of global warming have driven up summer temperatures across all of Europe. For instance, parts of Spain and France reached over 30°C starting in March.⁶⁸ Previously it was uncommon for temperatures above 30°C in most of the UK, however last year temperatures in many areas exceeded 40°C⁶⁹. In Germany, temperature above 38°C were recorded in 2022.⁷⁰ In 2020 temperatures all across France reached above 30°C for as much as a week straight.⁷¹

The recent study (March 2023) by the Technical Institute of Physics & Chemistry of the Chinese Academy of Sciences (CAS) looked at both heat pump and traditional air conditioning test points to compare R-134a, R-1234yf, CO₂ and Propane (with a secondary loop).⁷² All of the systems were equipped with an inner heat exchanger (IHx). The results are discussed in section 3.5. below.

3.5. Study of the Technical Institute of Physics & Chemistry, Chinese Academy of Sciences (CAS)

3.5.1. Introduction

It is widely recognized that R-744 systems and secondary loop systems can lose efficiency under certain operating conditions. The [Technical Institute of Physics & Chemistry \(CAS\)](#) studied the performance differences between systems using CO₂ and those using R-290 (propane) with secondary loop vs. traditional refrigerants. They compared the efficiency of refrigerants that might be used in various MAC eV systems. The study was performed at different ambient temperatures: -20°C, -10°C, 0°C, 25°C, 35°C, and 45°C. The study was performed with scroll compressors including a 34cc compressor for the HFC and HFO refrigerants, and a 6.8cc compressor for the R744 refrigerant. The evaporating temperatures were held constant for each of the alternatives, except for R-290, which uses a secondary loop. In the case of secondary loop, the evaporating temperature was set -3°C below non-secondary loop systems. The compressor speed was adjusted to achieve the same capacity. The resultant compressor powers were

⁶⁵ [An updated review of recent advances on modified technologies in transcritical CO2 refrigeration cycle](#), Binbin Yu, December 2019.

⁶⁶ [CO2 as a Refrigerant — Introduction to Transcritical Operation \(emerson.com\)](#)

⁶⁷ See detailed explanations at - [2924.fm \(nhtsa.gov\)](#)

⁶⁸ See e.g., [From freezing to frazzling in just days: Spain to get 30C in March - The Local](#)

⁶⁹ [Guest post: A Met Office review of the UK's record-breaking summer in 2022 - Carbon Brief](#)

⁷⁰ [Heatwave: Germany sees record high temperatures - The Local](#)

⁷¹ [Temperatures of 30C plus for all of France this week \(connexionfrance.com\)](#)

⁷² Technical Institute of Physics & Chemistry, Chinese Academy of Sciences (CAS), March 2023. The full study is available in Chinese upon request. Relevant robust study extracts/summary in English are provided in **Annex III** below.

then used to calculate the efficiency differences among the alternatives. The results are shown in tables below.

Heating @ -20°C(50%fresh air, Capacity demand:3.79kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	-25	-25	-25	-28
Tc(condensing temperature)[°C]	50	50	/	52
Pe(evaporating pressure)[MPa]	0.11	0.12	1.68	0.18
Tc(condensing pressure)[MPa]	1.16	1.15	8	1.6
Condenser outlet temperature[°C]	35	35	10	37
Evaporator outlet temperature[°C]	-22	-22	-22	-22
Compressor inlet temperature[°C]	-2	-2	-5	7.92
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	118	116	51	88
Theoretical COP	3.6	3.53	3.93	3.32
Theoretical capacity[kW]	4.22	4.22	4.25	4.5
Theoretical compressor power[kW]	1.17	1.19	1.08	1.36
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	3.8	3.79	3.82	3.82
Predicted compressor power[kW]	1.56	1.59	1.44	1.81
Air flow rate[m ³ /h]	300	300	300	300
Fan Power[kW]	0.5	0.5	0.5	0.53
Predicted system energy consumption[kW]	2.06	2.09	1.94	2.34
Predicted system COP	1.84	1.81	1.97	1.63
Predicted system COP (%yf)	101.66%	100.00%	108.84%	90.06%

Heating @ -10°C(Full fresh air, Capacity demand:3.79kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	-15	-15	-15	-18
Tc(condensing temperature)[°C]	50	50	/	52
Pe(evaporating pressure)[MPa]	0.16	0.18	2.29	0.26
Tc(condensing pressure)[MPa]	1.32	1.30	8.00	1.79
Condenser outlet temperature[°C]	35	35	9	37
Evaporator outlet temperature[°C]	-12	-12	-12	-15
Compressor inlet temperature[°C]	8	8	-2	5
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	79	79	39	63
Theoretical COP	4.28	4.22	4.88	3.9
Theoretical capacity[kW]	4.19	4.19	4.25	4.48
Theoretical compressor power[kW]	0.98	0.99	0.87	1.15
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	3.77	3.77	3.82	3.81
Predicted compressor power[kW]	1.3	1.32	1.16	1.53
Air flow rate[m ³ /h]	300	300	300	300
Fan Power[kW]	0.5	0.5	0.5	0.53
Predicted system energy consumption[kW]	1.8	1.82	1.66	2.07
Predicted system COP	2.09	2.07	2.3	1.84
Predicted system COP (%yf)	100.97%	100.00%	111.11%	88.89%

Heating @ 0°C(Full fresh air, Capacity demand:3.79kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	-5	-5	-5	-8
Tc(condensing temperature)[°C]	50	50	/	52
Pe(evaporating pressure)[MPa]	0.24	0.27	3.05	0.37
Tc(condensing pressure)[MPa]	1.32	1.30	8.00	1.79
Condenser outlet temperature[°C]	5	5	5	8
Evaporator outlet temperature[°C]	-2	-2	-2	-5
Compressor inlet temperature[°C]	3	3	3	1
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	46	46	29	39
Theoretical COP	6.32	6.45	6.59	5.63
Theoretical capacity[kW]	4.22	4.26	4.25	4.51
Theoretical compressor power[kW]	0.67	0.66	0.64	0.8
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	3.8	3.84	3.82	3.84
Predicted compressor power[kW]	0.89	0.88	0.86	1.07
Air flow rate[m ³ /h]	300	300	300	300
Fan Power[kW]	0.5	0.5	0.5	0.53
Predicted system energy consumption[kW]	1.39	1.38	1.36	1.62
Predicted system COP	2.73	2.78	2.81	2.37
Predicted system COP (%yf)	98.20%	100.00%	101.08%	85.25%

Cooling @ 25°C(Capacity demand:3.45kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	0	0	0	-3
Tc(condensing temperature)[°C]	45	45	/	47
Pe(evaporating pressure)[MPa]	0.29	0.32	3.49	0.43
Tc(condensing pressure)[MPa]	1.16	1.15	8	1.6
Condenser outlet temperature[°C]	30	30	30	30
Evaporator outlet temperature[°C]	5	5	5	5
Compressor inlet temperature[°C]	25	25	25	25
IHX outlet temperature(high pressure side)[°C]	17.43	16.41	22.85	17.04
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	50	50	40	48
Theoretical COP	5.52	5.55	4.49	4.82
Theoretical capacity[kW]	3.91	3.89	3.88	4.15
Theoretical compressor power[kW]	0.71	0.7	0.86	0.86
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	3.52	3.5	3.49	3.53
Predicted compressor power[kW]	0.95	0.93	1.15	1.15
Air flow rate[m ³ /h]	450	450	450	450
Fan Power[kW]	0.5	0.5	0.5	0.56
Predicted system energy consumption[kW]	1.45	1.43	1.65	1.7
Predicted system COP	2.44	2.44	2.11	2.08
Predicted system COP (%yf)	100.00%	100.00%	86.48%	85.25%

Cooling @ 35°C(Capacity demand:4.23kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	0	0	0	-3
Tc(condensing temperature)[°C]	55	55	/	57
Pe(evaporating pressure)[MPa]	0.29	0.32	3.49	0.43
Tc(condensing pressure)[MPa]	1.49	1.46	10	1.99
Condenser outlet temperature[°C]	40	40	40	40
Evaporator outlet temperature[°C]	5	5	5	5
Compressor inlet temperature[°C]	25	25	25	25
IHX outlet temperature(high pressure side)[°C]	27.79	26.85	33.77	27.54
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	66	67	58	63
Theoretical COP	4.27	4.24	2.9	3.79
Theoretical capacity[kW]	4.74	4.69	4.73	4.99
Theoretical compressor power[kW]	1.11	1.11	1.63	1.32
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	4.27	4.23	4.26	4.24
Predicted compressor power[kW]	1.48	1.48	2.17	1.76
Air flow rate[m ³ /h]	450	450	450	450
Fan Power[kW]	0.5	0.5	0.5	0.56
Predicted system energy consumption[kW]	1.98	1.88	2.67	2.32
Predicted system COP	2.16	2.14	1.59	1.83
Predicted system COP (%yf)	100.93%	100.00%	74.30%	85.51%

Cooling @ 45°C(Capacity demand:5.75kW)				
	R134a (With IHX)	R1234yf (With IHX)	R744 (With IHX)	R290 (Secondary loop with IHX)
Te(evaporating temperature)[°C]	0	0	0	-3
Tc(condensing temperature)[°C]	63	63	/	65
Pe(evaporating pressure)[MPa]	0.29	0.32	3.49	0.43
Tc(condensing pressure)[MPa]	1.8	1.76	11	2.34
Condenser outlet temperature[°C]	50	50	50	50
Evaporator outlet temperature[°C]	5	5	5	5
Compressor inlet temperature[°C]	25	25	25	22
IHX outlet temperature(high pressure side)[°C]	38.23	37.35	45.12	38.11
Compressor displacement[cc]	34	34	6.8	34
Compressor speed[Hz]	98	103	107	95
Theoretical COP	3.47	3.38	1.93	3.09
Theoretical capacity[kW]	6.39	6.42	6.40	6.81
Theoretical compressor power[kW]	1.84	1.9	3.32	2.2
Compression efficiency	0.75	0.75	0.75	0.75
Heat transfer attenuation	10%	10%	10%	15%
Predicted airside capacity[kW]	5.75	5.78	5.76	5.79
Predicted compressor power[kW]	2.46	2.53	4.42	2.97
Air flow rate[m ³ /h]	450	450	450	450
Fan Power[kW]	0.5	0.5	0.5	0.58
Predicted system energy consumption[kW]	2.96	3.03	4.92	3.55
Predicted system COP	1.95	1.91	1.17	1.65
Predicted system COP (%yf)	102.09%	100.00%	61.26%	86.39%

These results are not surprising. Early modeling of HFO-1234yf in the early 2000's showed a better Life Cycle Climate Performance (LCCP) than CO₂. This includes the refrigerant manufacturing, direct emissions from vehicle refrigerant leaks and the total effect of HVAC system weight and AC compressor power on vehicle emissions. The referenced SAE International study (using the LCCP model) demonstrated that CO₂ HVAC systems resulted in a 10-15% increase in climate warming emissions when evaluated across population biased weather patterns for Europe and North America.⁷³

The SAE International study was done using vehicles with internal combustion engines and considered MAC cooling only. For EVs, the TMS may also include a heat pump to improve energy efficiency for heating the vehicle. CO₂ does show some potential efficiency gains for heat pump operation at very low ambient temperatures but given increasing worldwide air temperatures and recognizing that most people in the EU are already exposed to hot conditions much more frequently than very cold ones (below -10°C or -20°C) this gain is not significantly beneficial. Moreover, enhanced HFO-1234yf heat pump systems using all sources of waste heat approach the same efficiency/effectiveness of CO₂ systems in cold conditions.

3.5.2. Further analysis of efficiency

Using data from the CAS study and adding information on R-152a refrigerant, Honeywell performed additional analysis described below comparing energy performance of R-290 and R-152a refrigerants in secondary loop systems vs traditional HFO-1234yf systems. This analysis considered various ambient temperature conditions and energy efficiencies for CO₂, R-152a and propane (R-290) and allowed to calculate additional GHG (CO₂) emissions due to extra energy needed for both ICE (by burning more fuel) and EV (by generating additional electric power) vehicles using the above systems *vis-à-vis* HFO-1234yf systems.

This analysis was performed to understand the magnitude of these increased emissions. Using the theoretical compressor power at each ambient temperature, a weighted average compressor power can be approximated using % time that the vehicle is operating at the different temperatures. The percent time the vehicle operates at different temperatures is available through the Society of Automotive Engineers (SAE) Interior Climate Control Committee (ICCC) Life Cycle Climate Performance (LCCP) model.⁷⁴ Using HFO-1234yf as the baseline, the weighted average difference in compressor power can be calculated. The compressor power difference is used to calculate increased energy required, thus increased emissions (see the table below). The R-134a data is not used as it is not a low global warming fluid under consideration.

		Technical Institute of Physics & Chemistry, CAS		
Ambient Operating Temperature (% operating time at temperature)		R1234yf	R744 (CO ₂)	R290 (Propane)
Compressor Power (kW)	-20C (1%)	1.59	1.44	1.81
	-10C (4%)	1.32	1.16	1.53
	0C (29%)	0.88	0.86	1.07
	25C (58%)	0.93	1.15	1.15
	35C (7%)	1.48	2.17	1.76
	45C (1%)	2.53	4.42	2.97
	Weighted Average	0.99	1.17	1.21
	Average increased power vs. R1234yf (kW)	-	0.18	0.22

⁷³ See slide 17 in [Industry Evaluation of low global warming potential refrigerant HFO1234yf](#), SAE International, 2008

⁷⁴ See slide 8 in See slide 17 in [Industry Evaluation of low global warming potential refrigerant HFO1234yf](#), SAE International, 2008; and [Development of a Tool for Estimating the Life Cycle Climate Performance of MAC Systems 2019-01-0611](#)

The average distance driven by EU vehicles is approximately 11,300 km per year and the average vehicle speed while operating is 30 kph. Therefore, the average # of vehicle operating hours is 377 hours/yr.⁷⁵ Given the average power difference shown in the table above and the # of vehicle operating hours/year, an average vehicle energy difference can be calculated. Using a typical internal combustion engine efficiency of 0.33, the required additional energy needed from a combustion fuel engine can be determined. Using 33.7 kWh of energy per gallon of gasoline, the increased gallons of gasoline needed per year to operate the heating and cooling system, using the alternative refrigerants, can be calculated. Each gallon of gasoline has 8.887 kg of CO₂ emissions. It should be noted that this value is for regular fuel. Diesel gasoline has 10.180 kg of CO₂ emissions per gallon.⁷⁶ For this study, only regular fuel will be considered, which is conservative. With this information, the total additional CO₂ emissions from using additional fuel per year can be calculated for a given # of vehicles. Two different scenarios were considered. The first scenario looks at the increased emissions after the first 5 years of vehicles are on the road with an alternate refrigerant. In this case, there are an average of 30 million vehicles on the road during this first 5-year period, given that 10 million new vehicles are produced each year in the EU. The second scenario considers all vehicles operating in the EU. There are currently 253 million vehicles operating in the EU⁷⁷. Table below demonstrates the increased emissions/year for these two scenarios.

			Technical Institute of Physics & Chemistry, CAS		
		Ambient Operating Temperature (% operating time at temperature)	R1234yf	R744 (CO ₂)	R290 (Propane)
		Average increased power vs. R1234yf (kW)	-	0.18	0.22
		Vehicle Yearly Hours	377		
		Energy Difference per year (kWh)	-	68.2747	81.9221
Additional CO2 emissions Gas equivalent		Engine Efficiency	0.33		
		Additional Equivalent Energy Used (kWh)	-	206.89	248.25
		Energy/gal gasoline (kWh)	33.7		
		Additional gas/year (gal)	-	6.14	7.37
		CO2 emissions per gallon gas (kg)	8.887		
		Additional CO2 per vehicle per year (kg)	-	54.56	65.47
	Yearly average emissions difference after the first 5 years of converting to alternatives	Average # of new EU vehicles/yr	10,000,000		
		Total # of new EU vehicles after 5 years	60,000,000		
		Total Average # of new vehicles on road after 5 years	30,000,000		
		Total Average Additional CO2 (metric tons)/yr			
		After 5 years of new vehicles	-	1,636,788	1,963,965
	Yearly emissions difference if all vehicles on road converted to alternatives				
		Total # of EU vehicles	253,000,000		
		Total Additional CO2 (metric tons)/yr	-	13,803,578	16,562,769

To contrast against the second scenario, an additional study was looked at assuming all 253 million vehicles on the road were electric vehicles. This would be several years/decades away, but it demonstrates that the additional electrical power needed still results in increased emissions from the electrical power grid. A value of 4.33 x 10⁻⁴ metric tons of CO₂ emissions per kWh of electrical energy is used.⁷⁸ And while it may be that the amount of CO₂ emissions per kWh of electrical energy may decrease over time as the electrical grid moves more to renewable energy sources, the energy used to power a vehicles heating/cooling system will still want to be minimized as the grid energy will need to be used as efficiently as possible to ensure enough energy is available to satisfy all needs. The table below summarizes the results.

⁷⁵ [CHANGE IN DISTANCE TRAVELLED BY CAR](#), Sectoral profile – transport, Odyssee-Mure.

⁷⁶ [Miles per gallon gasoline equivalent](#), Energy Education.

⁷⁷ [An almost 9 % increase in EU-registered passenger cars since 2016](#), Passenger cars in the EU, EUROSTAT.

⁷⁸ [Greenhouse Gases Equivalencies Calculator - Calculations and References](#).

			Technical Institute of Physics & Chemistry, CAS		
Ambient Operating Temperature (% operating time at temperature)			R1234yf	R744 (CO ₂)	R290 (Propane)
Average increased power vs. R1234yf (kW)			-	0.18	0.22
Vehicle Yearly Hours			377		
Energy Difference per year (kWh)			-	68,2747	81.9221
Additional CO ₂ emissions Electric equivalent	Yearly emissions difference if all vehicles on road converted to alternatives	# of EU vehicles	253,000,000		
		Total Additional kWh usage/yr	-	17,273,499,100	20,726,291,300
		Metric tons of CO ₂ /kWh	4.33E-04		
		Total Additional CO ₂ (metric tons)/yr	-	7,479,425	8,974,484

Honeywell has performed extensive testing of HFO-1234yf, using a typical vehicle's heating cooling system. The testing was done by a 3rd party, [Creative Thermal Solutions](#). Testing was done at the conditions outlined in [SAE J2765](#), updated for heating condition points. Once the testing was completed, Honeywell used the data to create a simulation model that would match the actual test results. This allows Honeywell to evaluate design alternatives and/or different refrigerant fluids without the need to build and test in a chamber. Using this simulation model, Honeywell evaluated HFO-1234yf against R-290 (propane) and R-152a. The same methodology was used to determine additional CO₂ emissions as was followed for the data provided by the Technical Institute of Physics & Chemistry, Chinese Academy of Sciences (CAS) (see above). The results are shown in the summary table below. Honeywell's results for R-290 are slightly different vs. the results provided by the Technical Institute of Physics & Chemistry, but they demonstrate that increased energy is, indeed, utilized for R-290. This also allows for a comparison of R-152a, a refrigerant that the Technical Institute of Physics & Chemistry did not consider.

			Honeywell Analysis		
Ambient Operating Temperature (% operating time at temperature)			R1234yf	R290 (SL)	R152a (SL)
Average increased power vs. R1234yf (kW)			-	0.28	0.20
Vehicle Yearly Hours			377		
Energy Difference per year (kWh)			-	104.5421	73.8543
Additional CO ₂ emissions Gas equivalent	Yearly average emissions difference after the first 5 years of converting to alternatives	Engine Efficiency	0.33		
		Additional Equivalent Energy Used (kWh)	-	316.79	223.80
		Energy/gal gasoline (kWh)	33.7		
		Additional gas/year (gal)	-	9.40	6.64
		CO ₂ emissions per gallon gas (kg)	8.887		
		Additional CO ₂ per vehicle per year (kg)	-	83.54	59.02
		Average # of new EU vehicles/yr	10,000,000		
		Total # of new EU vehicles after 5 years	60,000,000		
		Total Average # of new vehicles on road after 5 years	30,000,000		
		Total Average Additional CO ₂ (metric tons)/yr After 5 years of new vehicles	-	2,506,247	1,770,551
	Yearly emissions difference if all vehicles on road converted to alternatives	Total # of EU vehicles	253,000,000		
		Total Additional CO ₂ (metric tons)/yr	-	21,136,014	14,931,645
		# of EU vehicles	253,000,000		
		Total Additional kWh usage/yr	-	26,449,151,300	18,685,137,900
Additional CO ₂ emissions Electric equivalent	Yearly emissions difference if all vehicles on road converted to alternatives	Metric tons of CO ₂ /kWh	4.33E-04		
		Total Additional CO ₂ (metric tons)/yr	-	11,452,483	8,090,665

3.5.3. Conclusions on efficiency

HFO-1234yf has been demonstrated to be an effective refrigerant in automobiles and utilizes the least amount of energy vs. other low-GWP alternatives. HFO-1234yf is currently being used to cool and/or heat cars in approximately 200 million vehicles globally in both gas and electric vehicles. Utilizing R-744 (CO₂), R-290 (propane), or R-152a will result in significantly increased CO₂ emissions to the atmosphere from both gas-powered and EV vehicles (please find cumulated data in the final table below). Additionally, R-290 and R-152a refrigerants are significantly more flammable than HFO-1234yf and will pose an additional safety risk if adopted. HFO-1234yf has been extensively studied by multiple EU and US agencies and has been determined to be a safe and effective refrigerant for use in automotive cooling and heating systems.

Additional CO ₂ Emissions vs. R1234yf for EU Vehicles			
Average yearly additional CO ₂ Emissions from alternative refrigerants			
(metric tons/yr)			
	R744 (CO ₂)	R290 (Propane)	R152a
From internal combustion engine Vehicles After 1st 5 years of using alternative	1,636,788	1,963,965	1,770,551
From internal combustion engine Vehicles All vehicles converted to alternative	13,803,578	16,562,769	14,931,645
From Electric Vehicles All vehicles converted to alternative	7,479,425	8,974,484	8,090,665

3.6. Conversion timing

According to [Annex E](#) and Table 8 of the Proposal, CO₂ based systems are ready now for EV and hybrid vehicles with an electric compressor. This information is based on a very small sampling of in-service vehicles; most offering CO₂ only as optional equipment. The required capacity to design, launch and produce electric CO₂ MAC compressors, connectors, piping and tubing, evaporators and condensers simply does not exist due to the extremely limited use of CO₂ today. CO₂ systems also need more than just a new compressor (as is implied); every single component in the CO₂ MAC system needs to be redesigned and retooled and additional new components (not used in current MAC systems) need to be developed to work with the higher pressures of CO₂ systems. Many auto manufacturers dropped their development of CO₂ MAC systems 12 to 15 years ago due to the added cost, complexity, inefficiency, and the potential for aftermarket service safety incidents as well as customer warranty claims due to the much higher pressures.

The conversion from R-134a to HFO-1234yf took more than 10 years (2006 - 2016) and with the exception of developing an Internal Heat exchanger (IHx), this change was relatively simple using existing components as well as manufacturing and testing facilities. Automotive manufacturers are in the middle of the biggest revolution in transportation history. Rushing to market with unproven technologies like CO₂ will likely create consumer dissatisfaction issues just when the auto industry is working to increase consumer demand. Perhaps the AC system will not work as expected. Perhaps it will lead to increased vehicle service. If not functioning, it may lead to vehicles unable to be driven due to an inability to cool the batteries. Having a new EV stuck on the side of the road will not add to EV adoption rates and overheating batteries can lead to significant environmental and safety hazards (fires). Is this justified in comparison to an “Environmental impact” (Table E.123 of Annex E of the Proposal) assessments that are based on “weak evidence (i.e., not based on referenced data or documented assessments)”? Delaying a transition to EVs and increasing fuel and electricity consumption in the transportation sector will have a disproportionate environmental impact vs the alleged TFA persistency risks. This will also be contrary to the wider-EU [European Green Deal](#), [Fit for 55](#), and [REPowerEU](#) objectives and decarbonization goals of the Paris Agreement (see on additional GHG emissions in section 3.5 above).

Similar to CO₂, secondary loop systems (SL-MAC) using extremely flammable gases like R-152a (or propane) have been studied in the automotive field for 20 years and yet there has not been a single light duty commercial vehicle produced globally with this refrigerant. The Proposal characterizes R-152a in secondary loop systems as “appropriate” and goes further to state that it can be used for vehicles with internal combustion engines. However, it is not stated how the Dossier Submitters came to this conclusion. Using highly flammable gases in automotive applications requires years of risk assessments, significant study, development, investment, testing and cost. This will also increase the fire risk for consumers/drivers over current refrigerants based on significantly lower ignition energy; much higher combustion energy; much higher burning velocity and wider flammable concentration limits.⁷⁹

⁷⁹ [HFO-1234yf - A Low GWP Refrigerant for MAC - Honeywell/DuPont Joint Collaboration \(lexissecuritiesmosaic.com\)](#)

The Annex E also states at page 380 that “A 5-year derogation seems most appropriate for PFAS use in typical transport MAC and refrigeration systems given the likely availability of alternatives at the present time...” In essence, there is no evidence (and even evidence to the contrary) that hydrocarbon secondary loop systems are appropriate in automotive applications. Suggesting a 5-year implementation timing for an unproven, undeveloped and untried system that will likely create higher safety risks for consumers seems reckless and inappropriate.

In this regard, please refer to **Annex II** below which outlines certain publicly reported grave/deadly incidents involving HVAC equipment using flammable hydrocarbons. Arguably similar incidents in the automotive sector could lead to even more dangerous consequences. The absence of similar reporting regarding hydrocarbons based MAC systems is because such systems simply are not in use.

3.7. Alternative regulations

According to page 358 of Annex E of the Proposal, “*The development work on CO₂ based systems may be useful for setting tighter leakage limits for systems based on fluorinated gases, noting the experience reported by UBA (UBA, 2009).*” CO₂ used as a refrigerant has proven difficult to contain even though there have been sealing improvements made. These same improvements could be applied to HFO-1234yf systems. Reduced leaks improve reliability for customers, reduce warranty costs for manufacturers and help with the goals of the Proposal (overall PFAS emissions reductions). There is no downside to improved sealing other than a modest increase in cost that could be partially offset by improved warranty costs. This type of improvement is reflected by the industry trend to seal washers (over o-rings) after initial restrictions or incentives were established in the EU and the US.⁸⁰

To the same extent, requiring component repair when a customer seeks service for a low charged vehicle (as opposed to just topping off with additional refrigerant) is an option that has been explored in US government and MAC service repair forums. This will come with added cost to the consumer, but that cost would again be expected to be partially offset by improved reliability and reduced repair and refrigerant costs. Setting regulations and establishing well thought out, coherent policies for improved refrigerant retention could lead to increased global action based on the mirroring of well written policies.

Vehicle accidents will continue to release refrigerants into the atmosphere; however, with many car OEMs including new anti-collision safety systems as standard equipment on their new vehicles we can expect to see reduced crash rates and lower refrigerant releases from collisions. Better reporting on refrigerant releases based on vehicle accidents could also be required to help account for refrigerant supplies. To the same extent, more rigorous reporting on service uses of refrigerant could help with documenting illegal importing of high-GWP refrigerants.

Finally, robust, end of life reclamation of refrigerants and documentation could help with tracking refrigerant supplies and return more refrigerant to the field reducing the need for new refrigerant entering the service market. All the above are responsible means to reducing the very emissions that are proposed in this ruling. They will also be less controversial, less costly and less disruptive to an industry in transition.

In this regard, HFO-1234yf is already subject to various containment, monitoring, certification and reporting obligations under the [EU F-Gas Regulation](#)⁸¹ (as Annex II substances). Its use in MAC systems⁸² is also thoroughly controlled via risks management measures and containment requirements (leaks controls, end-of-life collection, and disposal, etc.) under the [MAC Directive](#)⁸³ and [ELV Directive](#)⁸⁴. The above EU

⁸⁰ [Air Conditioning O-Rings vs Sealing Washers on R4 Kompressors - YouTube](#)

⁸¹ Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 (as amended and currently under review, available [here](#)).

⁸² Relevant [SAE](#) and ISO standards also apply.

⁸³ 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 (as amended).

⁸⁴ Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles (as amended)

legislation specifically aims to considerably decrease all refrigerant emissions in a medium term and could be enhanced at any time.

4. Conclusions

Efficient and safe transportation in the EU is critical/vital for reaching objectives of the EU Green Deal and wider EU policies (REPowerEU, etc.). Nowadays, EU road transport is responsible for ca. 20% of CO₂ emissions in EU (14% for cars & vans). Taking into account the higher efficiency of HFO-1234yf in warm to hot weather conditions (in comparison to CO₂ and hydrocarbon based secondary loop) combined with its proven reliability and low cost to service in over 200 million cars worldwide; it is clear that HFO-1234yf is the only MAC refrigerant choice that enables the EU to reach its climate goals as well as ensure ambitious decarbonization targets set for 2030 are met (55% reductions of CO₂ emissions) and that the EU reaches carbon neutrality by 2050.

Having a safe and efficient MAC refrigerant with low health, safety and environmental effects is essential for MAC/HVAC and EV TMS systems. There are no other MAC refrigerants available today which provide as comprehensive a range of advantages as HFO-1234yf including low-GWP, balanced energy efficiency, establishment in the market, negligible climate, health and environmental impacts, ease of service, safety in use and low total cost of ownership. HFO-1234yf was intentionally developed to satisfy these needs.

Moreover, according to Table E.123 of Annex E of the Proposal, assessments of the environmental impact of the proposed ban on HFO refrigerants in MAC sector are based on **weak** environmental evidence (i.e., not based on referenced data or documented assessments). However, the changes required from the EU automotive industry due to the proposed PFAS restriction would be massive with potentially billions of euros of investments required and uncertain effects on safety and the environment. This approach is unacceptable from the good administration and other general principles of ECHA and EU Law.

HFO-1234yf is an excellent refrigerant for MAC systems and is currently being used in almost every new heat pump system used in new EV cars today. Further, EV development by automotive manufacturers brings many challenges of its own. Redesigning, reinventing, validating and commercializing new refrigerant systems distracts and uses important resources that manufacturers need for their primary goals - the development of cost effective, longer driving range EVs in the EU and beyond. Encouraging EV development and wider acceptance by customers are two of the key elements needed to reach the objectives of the EU Green Deal.

HFO-1234yf should be excluded from the scope of the PFAS restriction Proposal because it is low hazard, not persistent and concentrations of TFA produced from its atmospheric degradation are negligible and at magnitudes below respective DNEL/PNEC thresholds. Extremely low current and predicted levels of TFA concentrations unequivocally confirm absence of unacceptable risks within the meaning of Title VIII REACH. Moreover, respective risks are already adequately controlled by the EU-wide risks management measures (i.e., under the EU F-Gas Regulation, MAC Directive, ELV Directive and comprehensive international industry standards) that could be adjusted at any time. In this respect, short atmospheric lifetimes of many HFO gases would allow effective and rapid interventions, if warranted.

Comments from the European Automobile Manufacturers Association (ACEA) on the Proposal regarding the use of refrigerants do not reflect the diversity of HFC/HFO uses amongst car manufacturers globally. There are other major automotive producers that are not ACEA members who depend on the continued use of HFO-1234yf refrigerants in MAC and TMS EV systems. The Proposal manifestly ignores the inefficiencies and challenges of the suggested alternatives and their increased costs, risks and climate implications.

Introduction of the proposed REACH restrictions in these circumstances will violate REACH Regulation, EU general legal principles and wider policies and result in very high costs on the society as well as increased indirect CO₂ emissions contributing to accelerated global warming.

Therefore, Honeywell submits that in line with Articles 68-69 REACH requirements fluorinated gas HFO-1234yf should be excluded from the PFAS restriction due to the absence of unacceptable risks, existence of measures for the adequate control of emissions under other EU regulations, absence of a safe, feasible and effective alternative and potentially very high switching costs for the society. Alternatively, HFO-1234yf use in MAC/HVAC and TMS systems of EV, hybrid and internal combustion engine vehicles with all types of compressors should be covered by the time-limited derogation until 2055. In line with previous practices, this derogation should also cover maintenance/repair, refitting and reselling activities involving used/second hand vehicles placed on the market before this date. This derogation could be also conditional (progress-limited) to allow the industry to work towards development of alternatives with a comprehensive transitional review (re-assessment) by ECHA and the European Commission by the end of 2035.⁸⁵

Annex I - List of acronyms and abbreviations

Annex II - Hydrocarbon Refrigerants Casualties (selected incidents)

Annex III - Technical Institute of Physics & Chemistry, Chinese Academy of Sciences (CAS), 2023 - relevant robust extracts/summaries in English.

⁸⁵ See Example 5, Examples of conditional derogations, pages 58-62, [Guidance for the preparation of an Annex XV dossier for Restrictions](#); see also para. 7 of [entry 72](#), [para. 8 of entry 50](#) or [paras. 3 and 10 entry 68 of Annex XVII REACH](#).