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# Carrar's position paper of PFAS ban

## The Importance of Hydrofluoroolefins in the EV Sector and the Impact of the Proposed Pfas Restrictions on the Sector

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# 1 Executive Summary

The European Union (EU) is resolute in its goal to achieve climate neutrality by 2050 through a transition to a clean energy economy, prominently featuring electric vehicles (EVs) as a cornerstone of this effort. Essential to this transition are zero emission technologies, such as EVs, which promise reduced emissions, improved air quality, and economic growth. This sentiment is echoed globally, as various nations, including China, the USA, and Canada, are embracing EVs to combat climate change and foster sustainable transportation.

The adoption of EVs offers a critical avenue for reducing emissions and diversifying energy sources, aligned with the EU's commitment to sustainable mobility. Numerous initiatives, such as RePowerEU and Fit for 55, focus on reducing reliance on fossil fuels and enhancing the EV ecosystem. However, challenges such as costs and charging infrastructure remain, highlighting the need for advanced battery technologies.

Carrar, a pioneering sustainable transportation solutions startup, is at the forefront of addressing these challenges through innovative battery modules. Their technology enhances battery performance, lifespan, and safety, aligning with global sustainability objectives and driving the transformation of the mobility landscape.

Amid this progress, concerns arise from the European Chemicals Agency's (ECHA) proposed ban on per- and polyfluorinated alkyl substances (PFAS), which includes hydrofluoroolefin (HFO) used in Carrar's thermal management systems (TMS). While the EU's Chemicals Strategy for Sustainability aims to restrict PFAS, an approach is needed that considers the complex nuances of these substances and their vital applications, especially in the context of EVs and decarbonization.

HFOs, like those used by Carrar, are crucial for efficient and safe EV battery thermal management. Their stability and unique properties make them indispensable for EV technology, bolstering durability, performance, and safety. The rapid adoption of EVs is essential for achieving emission reduction targets and mitigating climate change impacts. Therefore, hindering the use of HFOs could hinder the EU's progress toward these goals.

Carrar's technology not only addresses environmental concerns related to battery production and disposal but also contributes to economic growth by extending battery lifespans and reducing resource demand. Additionally, the use of HFOs aligns with the EU's emissions reduction strategies and supports the growth of the EV industry, which, in turn, leads to reduced air and noise pollution.

Balancing environmental concerns with societal needs is crucial. Instead of an outright ban on PFAS, a nuanced approach that considers the benefits of HFOs in achieving emission reduction goals, technological advancement, and environmental sustainability is recommended. Carrar's cooling solutions and other innovative technologies can guide policy decisions toward a more sustainable and efficient future.

In conclusion, Carrar's innovative battery technology, which relies on HFOs, is pivotal for advancing EV adoption, meeting emission reduction targets, and fostering economic growth. The ECHA should grant an exemption from the proposed ban on PFAS, recognizing the crucial role HFOs play in achieving the EU's climate neutrality goals and creating a cleaner, greener future.

# 2 Introduction

## 2.1 EU ambition in Fighting Climate Change

The European Union has set an ambitious goal of achieving climate neutrality by 2050. In order to achieve this goal, the EU is committed to phasing out the use of fossil fuels and transitioning to a clean energy economy. Many initiatives are being implemented to reach this ambition, including increasing energy efficiency and reducing industry related emissions, decarbonizing of the power sector, reforestation, investing in research and development and more. The transition to zero emission technologies will have a numerous benefits by reducing air pollution, improving public health, and creating new jobs. It will also help the EU to meet its climate neutrality goal and contribute to the global fight against climate change.

One of the key pillars of the EU's climate neutrality strategy is the promotion of zero emission technologies. These technologies include electric vehicles, hydrogen fuel cell vehicles, and renewable energy sources. The EU is committed to investing in research and development of zero emission technologies, providing financial incentives for their deployment, and creating a supportive regulatory environment for their adoption.

### 2.1.1 EU initiatives

To achieve climate neutrality by 2050, the EU has launched a number of initiatives, the most relevant for the mobility sector are RePowerEU[1], Fit for 55[2], and Clean Mobility[3]. All these initiatives focus on reducing reliance on fossil fuels through shifting the EU's transport system towards more sustainable solutions.

- RePowerEU is the EU's plan to reduce its reliance on Russian fossil fuels and accelerate the transition to a clean energy future.
- Fit for 55 is a package of legislative proposals that aims to put the EU on track to achieve its climate neutrality target by 2050 by reducing GHG emissions by 55% by 2030. The package includes a number of measures that would promote the adoption of EVs, such as stricter CO2 emissions standards for cars and vans, and increased investment in EV charging infrastructure.
- The Clean Mobility is a key part of the Green Deal, aiming to make the EU's transport system more sustainable by reducing emissions from road, rail, air, and maritime transport. The package includes a number of measures that would promote the use of EVs, such as the introduction of low-emission zones in cities and the provision of financial incentives for the purchase of EVs.

These initiatives are all essential if the EU is to play its part in tackling the global climate crisis. They are ambitious, but they are achievable if the EU works together to implement them.

### 2.1.2 Other policies

A report[4] published by The International Energy Agency (IEA) outlines the policies that are being used to promote the deployment of electric vehicles (EVs). The report identifies a number of key policy areas, including governmental regulation, financial incentives and subsidies, as well as investment in infrastructure and research. The report also states that much more needs to be done to accelerate the transition to electric mobility. To date, over twenty countries worldwide have announced a phase out in sales of Internal combustion engine (ICE) cars, with timelines ranging from 2025 in Norway, through many the UK, China and Japan in 2035, Canada in 2040 to Germany and Costa Rica in 2050.

[1] EUR-Lex - 52022DC0230 - EN - EUR-Lex (europa.eu)

[2] Fit for 55 - The EU's plan for a green transition - Consilium (europa.eu)

[3] Clean and sustainable mobility for a climate-neutral EU - Consilium (europa.eu)

[4] Policies to promote electric vehicle deployment – Global EV Outlook 2021 – Analysis - IEA

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### 2.1.3 Outside the EU

The EU is not alone in embracing the EV revolution

- China has introduced the New Electric Vehicle (NEV) subsidies[5] favoring longer range models. Along with investing in infrastructure, battery reuse and recycling, China is well on its way to achieve its goals.
- In the USA, the situation is more complex and effective initiatives are at a state level, with California leading the way with an ICE sales phase out by 2034[6] .
- India's key policy in this section is FAME II[7], a continuance from FAMEI that was unveiled in 2013. Urban policies are also in place, such as Switch Delhi[8] targeting 50% EV buses by 2024.
- Canada continues to support infrastructure adaptation and Zero-emission vehicles incentives[9].
- Japan, Chile and New Zealand are just a few more examples of the global efforts to adopt EVs as a mean to reduce emissions and battle climate change.

## 2.2 Why EVs

The EU and global commitments to EV's are a major step forward in the fight against climate change. By being zero emissions and pollution and through diversifying the energy mix, EVs have the potential to pave the way for a more sustainable future.

Several measures are used to promote adoption of EVs by incentivizing EV infrastructure and purchase as well as legislative steps. The EU Commission estimates that these measures could help to increase the number of EVs in the EU from a current level of about 10 million EVs to 60 million by 2030. Another advantage is reducing dependence on imported and in particular Russian fossil fuels, an issue that is material in light of the Ukraine war, as EVs can use renewable energy sources.

In addition to these initiatives, the EU has also invested heavily in research and development of EVs, to increase accessibility and affordability, and to improve the performance of EVs, making the EU a global leader in the development and production of EVs. On the social impact of EVs, R&D, production and sale of EVs creates jobs in a number of sectors, estimated by RePower EU at up to 1 million jobs in the EU by 2030.

## 2.3 EV market review

The transportation landscape has undergone a significant transformation in recent years in light of the rapid rise of EVs. The EV market is growing rapidly, with global sales expected to reach 14 million units in 2023[10] and over 40 million new car sales in 2030. This growth is being driven by a number of factors, including government regulations, increasing environmental awareness, and falling battery prices. Forecasts of the various automotive sectors state that by 2030, 50% of new private car sales will be of EVs and, 30% of new buses and trucks sales will be of EVs. With a CAGR of over 40% YoY, The EV market is poised for significant growth in the coming years. As it matures, we can expect to see even more innovation and excitement in this space.

### 2.3.1 EV market penetration challenges

EV market penetration is held back for two main reasons – cost, as EVs are still more expensive than the ICE alternatives, and range anxiety due to lack of sufficient charging infrastructure, time of charge, frequency of

[5] China announced 2020–2022 subsidies for new energy vehicles (theicct.org)

[6] Governor Newsom's Zero-Emission by 2035 Executive Order (N-79-20) | California Air Resources Board

[7] FAMEI: National Automotive Board (NAB) (heavyindustries.gov.in)

[8] Switch-hit: Mass campaign to popularise electric vehicles in Delhi | Delhi News - Times of India (indiatimes.com)

[9] Electric and Alternative Fuel Infrastructure (canada.ca)

[10] https://iea.blob.core.windows.net/assets/dacf14d2-eabc-498a-8263-9f97fd5dc327/GEVO2023.pdf

charging, and more. Despite these challenges, the adoption of EVs is growing. In 2021, global EV sales reached 6.6 million, up from 2.1 million in 2018. This growth is expected to continue in the coming years, as the cost of EVs comes down and the charging infrastructure improves.

#### 2.3.2 Facing the Anxiety challenge

Overall, the range of EVs is improving at a rapid pace. This is due to a number of factors, mostly due to improved battery technology. Battery technology is constantly improving, resulting in longer-range EVs, faster charging speeds, reduced costs, increased lifespan, and improved safety. It is important to note that the lifespan of EV batteries is improving as result of developments in improved battery chemistry, reducing depth of charge, and better thermal management. Another issue with battery lifespan is mineral supply constraints[11]. The key ingredients for EV batteries are facing significant hurdles in the shape of geopolitical upheavals, human rights violations, and environmental concerns, all resulting in a possible raw material shortage and price increase[12]. Therefore, increasing lifespan is crucial to the success of this industry.

#### 2.3.3 Battery Thermal Management

As EV batteries become more powerful and the user demand increases, batteries generate more heat, the role of thermal management increases significantly to improve performance, lifespan, and safety. The most common methods are cold plate, fluid cooling (e.g. water, ethylene glycol, and engine oil), and immersion cooling, which can be either one-phase or two-phase immersion cooling.

#### 2.3.4 The role of PFAS

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that have been used in a variety of applications. PFAS are known to be persistent in the environment and can bioaccumulate in the body, thus been linked to a number of health problems, including cancer, liver damage, and developmental defects.

The solution offered by Carrar is the use of hydrofluoroolefin (HFOs) as a cooling fluid. HFOs are considered to be less harmful to the environment than other PFAS, such as PFOA and PFOS. HFOs have lower GWP, low flammability and high dielectric strength, making them ideal for use in electronics.

### 2.4 Carrar's Technology

Carrar is a well-established startup that has ventured into the domain of sustainable transportation solutions. Our focus lies in the design and provision of battery modules that cater to diverse vehicle configurations and battery chemistries. At the core of our innovation is a state-of-the-art two-phase technology, which equips our battery modules with a unique advantage in effectively dissipating heat. This paper expounds upon the transformative potential of Carrar's solutions in the context of advancing the sustainable zero-emission transportation agenda on a global scale as part of the EU ambition as previously outlined.

Carrar's battery modules stand out for their exceptional quality and high-performance attributes. These modules not only uphold reliability but also offer cost-effectiveness to vehicle owners and original equipment manufacturers (OEMs), thereby fostering a sustainable ecosystem within the automotive industry.

#### 2.4.1 Carrar's TMS innovations

Carrar's immersion-based battery modules exemplify a notable application focus. Through thorough experimentation, we substantiate our capacity to uphold uniform temperature distributions, showcasing an average variance of less than 2 degrees Celsius. This resilience remains steadfast even in challenging scenarios characterized by high charge-discharge rates (C-rates) and heightened ambient temperatures, where our technology ensures unwavering temperature control. Carrar's innovative approach extends to tackling scenarios involving elevated heat flux, which encompasses essential components like insulated gate bipolar transistors (IGBTs) within inverters or

[11] Cobalt Crisis In The Growing EV Industry (electricbee.co)

[12] Global Electric Vehicle Outlook 2022 (windows.net)

converters, among other related elements. Stringent assessments conducted under extreme ambient conditions, encompassing temperatures reaching 85°c, validate our proficiency in maintaining optimal thermal thresholds for these critical constituents.

Carrar's offerings are distinguished by their integration of multifaceted benefits within a compact form factor. This integration is achieved through a proprietary thermal management system capable of dissipating approximately 25 kW of heat from a normal passenger vehicle and 50 kW from a commercial vehicle. Notably, our low-pressure system design enables lightweight product development, thereby showcasing superior energy densities compared to conventional alternatives.

### 2.4.2 Enhanced Performance and Safety

The pinnacle of Carrar's innovation lies in its battery modules, characterized by elevated performance metrics and enhanced safety profiles. This transformation is realized through the integration of cutting-edge technologies, resulting in accelerated charging rates, prolonged battery lifespans (up to quadruple existing benchmarks), and fortified safety mechanisms that curtail body harm and environmental risks of thermal runaway incidents. Such advancements significantly contribute to the sustainable transformation of vehicular propulsion systems.

### 2.4.3 Conclusion

Carrar's visionary strides in sustainable transportation through innovative battery module solutions hold immense promise for reshaping the mobility landscape. By championing the integration of advanced technologies, rigorous experimentation, and a commitment to global sustainability objectives, Carrar presents a compelling blueprint for a greener and more sustainable future in transportation. As we collectively pursue the UN's sustainable development goals, Carrar's contributions serve as a beacon of hope for a cleaner and more efficient mode of global mobility.

# 3 Regulatory Framework

## 3.1 Current status

The European Union's Chemicals Strategy for Sustainability[13] has laid out plans to ban and phase out per- and polyfluorinated alkyl substances (PFAS) while allowing their use only in essential cases. In this case, PFAS are specialty chemicals used for EV battery thermal regulation. **With no substitute currently available, a general PFAS ban would thereby impact both directly and heavily impede achieving the EU's decarbonization objectives.** Therefore, there is a need to reconcile the ban on PFAS with the EU's ambitious decarbonization objectives. The policy measures put forth in the strategy plan for a change in the policy and regulatory approach of PFAS. The Strategy concludes that all PFAS should be considered as a single chemical class and should be restricted except when they are essential for society. Discussions on the definition of 'essential uses' are therefore currently being held amongst Member States competent authorities, as well as under the ongoing revision of REACH, the conclusions of which may influence the PFAS restriction process, although both parallel processes are clearly distinct from each other.

Under current EU chemicals legislation REACH, national authorities at the ECHA can file their intention to develop a Regulatory Management Option Analysis (RMOA) in an effort to help authorities clarify whether regulatory action is necessary for a given substance and to identify the most appropriate measures to address a concern.

## 3.2 Not all PFAS are created equal

Functional groups in PFAS substances vary widely resulting in large number of PFAS and applications. A 2015 study reported that more than 3,000 PFAS were on the global market for commercial use[14]. In 2021, the OECD redefined PFAS substances[15] following controversy. A total of 4730 PFAS related CAS numbers have been identified[16], and the actual number could be as high as over 10,000 substances, as in some cases their identities are considered confidential business information and impurities and by-products are not declared.

According to the OECD[17,18] itself, EEAP 2022[19] and other independent researches[20], not all PFAS are created equal. The toxicity of various PFAS substances was evaluated using a variety of methods and then grouped into three categories based on their toxicity level – high, moderate and low. Grouping PFAS based on their toxicity could be a useful tool for assessing the risks of these chemicals and for developing strategies to reduce exposure. The EEAP report concludes that HFO related PFAS are unlikely to cause adverse effects out of 2100 while specifically stating that HFO 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.

The UK RMOA[21] clearly states that "there is no single globally adopted definition of PFAS for human health or environmental regulation". Using a different definition than the one proposed by the EU REACH, there are fewer fluorinated chemicals represented and considered for risk assessment and potential risk management measures

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13 Circabc (europa.eu)

14 Report 7/15: Occurrence and use of highly fluorinated substances and alternatives - Kemikalieinspektionen

15 A New OECD Definition for Per- and Polyfluoroalkyl Substances | Environmental Science & Technology (acs.org)

16 endicott-legal.oecd-report.may-4-2018.pdf (fluoridealert.org)

17 Figure1-classification-of-per-and-polyfluoroalkyl-substances -PFASs.pdf (oecd.org)

18 IMMC.SWD%282020%29249%20final.ENG.xhtml.7_EN_autre_document_travail_service_part1_v4.docx (europa.eu)

19 EEAP-2022-Assessment-Report-May2023.pdf (unep.org)

20 Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts - PubMed (nih.gov)

21 Analysis of the most appropriate regulatory management options (hse.gov.uk)

compared to the EU REACH proposal. **Most importantly, the UK RMOA suggests exemption of PFAS used in sealed systems, and specifically as a heat exchange fluid in refrigeration systems**[22].

## 3.3 Hydro-Fluorocarbon Olefin (HFO)

HFO, being a non-polymeric PFAS, is included in the OECD Group 11 as it includes a semi-fluorinated alkane group. Widely used in a variety of industrial uses, in this case as a refrigerant gas for heat transfer.

The EU F-Gas Regulation (517/2014)[23] aims to mitigate climate change and protect the environment, through managing the production, import, use, and disposal of F-gases. The regulation, aligned with the Montreal Protocol and its amendments, includes a phasedown plan to reduce the use and consumption of F-gases by 79% by 2030, compared to the average levels in 2009-2012. The regulation also outlines bans for specific sectors where lower Global warming potential (GWP) alternatives are available and restrictions to promote the adoption of lower-GWP alternatives. The GWP of HFOs used by Carrar, are 1[24] for the R1233 and 2[25] for the SF33 as well as a low atmospheric lifetime at 22[24] and 26[25] days respectively, making this gas an excellent replacement for other popular refrigerants such as R-134A or R-404A which have GWP at 1,430 and 3,922 respectively. However, a differentiation needs to be made between the use in AC systems and the use proposed by Carrar as an EV battery cooling in agent in volume and in annual leakage rates. While EPA allows for 10%-30% annual leakage rage from AC systems[26], Carrar's battery thermal regulation system allows for 0.14% annual leakage rate.

Moreover, The Classification, Labeling, and Packaging regulation (CLP) Regulation (EC) No 1272/2008 does not regulate HFO[27].

## 3.4 Conclusion

The European Union's Chemicals Strategy for Sustainability plans to ban and phase out most PFAS, except for essential uses, which will hinder the achievement of the EU's decarbonization objectives as certain PFAS, like the HFO used in EV battery thermal regulation, lack substitutes.

The strategy suggests regulating PFAS as a single class and seeks discussions on the definition of essential uses. However, not all PFAS are equal in toxicity and environmental impact, making risk assessment and management challenging. Furthermore, not all the EU regulations refer to HFO due to its unique characteristics and contribution to decarbonization.

Considering these complexities, a balanced approach is needed to ensure effective PFAS regulation while supporting decarbonization efforts. The use of HFO in a sealed system, as a heat exchange fluid is in line with the UK RMOA and F-gas regulation for phasing out high GWP refrigerants. With no real substitute in the visible future, **a general PFAS ban would thereby impact both directly and heavily impede achieving the EU's decarbonization objectives.** The use of HFO in this context should be defined as an essential use for society.

[22] Analysis of the most appropriate regulatory management options (hse.gov.uk), pg 175

[23] L_2014150EN.01019501.xml (europa.eu)

[24] forane-fba-1233zd-blowing-agent-technical-profile-en.pdf (arkema.com)

[25] A Better Environment with Next-Gen Solstice® zd Refrigerant | brochure (honeywell.com)

[26] https://www.epa.gov/section608/stationary-refrigeration-leak-repair-requirements

[27] https://osha.europa.eu/en/legislation/directives/regulation-ec-no-1272-2008-classification-labelling-and-packaging-of-substances-and-mixtures

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# 4 Risk Assessment

## 4.1 Legacy PFAS and HFO

Per- and polyfluorinated alkyl substances (PFAS) comprise a diverse group of chemicals with varying properties, applications, and environmental impacts. Within this category, Hydro-Fluorocarbon Olefin (HFO) stands out as a notable example, demonstrating distinct characteristics that warrant a comprehensive risk assessment when compared to other PFAS substances.

Current peer-reviewed scientific research acknowledge that exposure to long chain legacy PFAS may lead to adverse health outcomes such as decreased fertility, developmental effects or delays in children, increased risk of some cancers and more. These substances are known for their persistence in the environment and tendency to bioaccumulate in organisms owing to the long chain formula. **However, research is still ongoing to determine the effect of different levels of different substances[28].** It is already been determined that long-chain legacy PFAS compounds (eg Perfluorooctanic Acid (PFOA) and Perfluorooctanate Sulfate (PFOS)) are more harmful then short molecule PFAS, similar to the HFO compound used by Carrar. As such, this HFO can pose less severe environmental risks compared to certain long-chain PFAS substances.

HFO, as a subset of PFAS, demonstrates a wide variation in toxicity profiles when compared to legacy PFAS substances. While these have raised concerns due to their persistence, bioaccumulation, and potential adverse effects on human health, HFOs have been identified as having lower toxicity and bioaccumulation levels as well as shorter lifetime. Due to these characteristics, the risk of bio-magnification through the food chain is lower. This variability highlights the importance of differentiating between specific HFO compounds and the broader PFAS class.

The data gap remains in legacy PFAS and magnified in the new compounds. The understanding of HFOs' long-term behavior in the environment and potential health effects remains an ongoing area of research. More comprehensive studies are needed to evaluate the true extent of their risks and benefits, including their fate, transport, and potential transformation products. The REACH registration dossier for this substance list HFO as a low hazard material for inhalation, dermal and eye exposure[29].

One significant aspect of HFOs is their role as substitutes for high global warming potential (GWP) compounds in various applications, such as refrigeration and insulation. While HFOs can offer environmental benefits by reducing greenhouse gas emissions, HFO can degrade into under regulation levels of Trifluoroacetic Acid (TFA)[30]. In this respect, ECHA has already reviewed the issue and did not require further action[31].

In summary, a thorough risk analysis of HFO in comparison to other PFAS substances reveals a complex picture. HFOs' potential to serve as substitutes for high-GWP compounds presents a crucial opportunity for decarbonization efforts. However, their varying toxicity profiles and environmental behaviors necessitate careful consideration in regulatory decision-making. To effectively manage the risks associated with PFAS, including HFOs, a nuanced science-based approach that acknowledges their diversity while prioritizing human health and the environment is essential and still lacking.

[28] https://www.sciencedirect.com/science/article/pii/S0304389422009104#sec0010

[29] Substance Information - ECHA (europa.eu)

[30] ozone.unep.org/system/files/documents/EEAP-2022-Assessment-Report-May2023.pdf

[31] Registration Dossier - ECHA (europa.eu)

## 4.2 Thermal runaway

Lithium-ion batteries are widely regarded as the leading choice for powering electric vehicles, primarily due to their impressive energy and power densities. However, thermal runaway, a critical phenomenon characterized by successive exothermic reactions within the battery, presents a substantial safety concern. Thermal runaway is considered to be the main reason for fires in EV batteries[32], involving a chain of reactions that trigger a rapid elevation in internal temperature, potentially leading to battery failure. Thermal abuse of the battery pack, often caused by external or internal factors, is a central trigger for such runaway events. Elevated temperatures, both internally and externally, can cause the separator between the anode and cathode to melt, potentially resulting in an internal short circuit and subsequent ignition. Given these hazards, it is paramount to implement effective thermal management systems as a fundamental design consideration33. The associated risks include physical harm and the potential to impact public health on a larger scale through the emission of noxious gases[34] like hydrogen fluoride (HF), hydrogen fluoride nitrate (HFN), carbon monoxide (CO), carbon dioxide (CO2), and volatile organic compounds (VOCs), which are hazardous, pollutant-inducing, and environmentally contaminating substances. A recent study[35] clearly indicates that as thermal runaway occurs, regardless of preexisting conditions such as state of charge (SOC), initial ambient temperature or heating rates, large amount of gases were produced. The initial temperature at thermal runaway reactions can vary between 230ºc-450ºc[36,37], and the varying conditions had an impact on the concentration of the measured gases. Another important aspect of HFOs is their lack of ignition point, whereas cooling oils ignite at about 250ºc.

When addressing the prevention of thermal runaway in Li-ion batteries, the preference for HFOs stems from their advantageous heat transfer and thermal stability properties compared to traditional refrigerants. By integrating HFOs as coolants within battery thermal management systems, they can proficiently dissipate heat, uphold regulated battery temperatures, and mitigate the potential for overheating, thus diminishing the chances of thermal runaway occurrences in Li-ion batteries. Furthermore, owing to their low flammability and exceptional heat absorption capacity, HFOs hold promise as effective agents for suppressing[38] fires in various applications, including those involving Li-ion battery fires. This is inline with current research recommendations[39]. Moreover, the HFO-1336MZ and HFO1234YF, as used by Carrar, are non-flammable materials[40], therefore in the event of a leakage or accident, the risk of fire or explosion is minimized.

It's important to note that while HFOs offer several advantages, proper engineering, design, and integration are essential to harness their benefits effectively. Battery thermal management systems that use HFOs need to be carefully designed to ensure efficient heat exchange, adequate cooling, and reliable operation under various

[32] Electric vehicle battery fires, thermal runaway is the main reason (s-firefighting.com)

[33] https://doi.org/10.1016/j.ecmx.2022.100310

[34] Electronics | Free Full-Text | Thermal Runaway Characteristics and Gas Composition Analysis of Lithium-Ion Batteries with Different LFP and NCM Cathode Materials under Inert Atmosphere (mdpi.com)

[35] https://doi.org/10.1016/j.est.2020.101863

[36] (PDF) Fire behavior of lithium-ion battery with different states of charge induced by high incident heat fluxes (researchgate.net)

[37] Study of thermal runaway and the combustion behavior of lithium-ion batteries overcharged with high current rates - ScienceDirect

[38] Theoretical and experimental studies on the thermal decomposition and fire-extinguishing performance of cis-1,1,1,4,4,4-hexafluoro-2-butene - Wang - 2020 - International Journal of Quantum Chemistry - Wiley Online Library

[39] https://www.mdpi.com/1996-1073/11/9/2191

[40] https://nl.climalife.dehon.com/uploads/product/media/document/novexpans-hcfo-1233zd-en.pdf

conditions. As the EV industry continues to grow, the implementation of advanced thermal management solutions, such as those utilizing HFOs, can significantly contribute to improving the safety and performance of EV batteries, reducing the risk of thermal runaway, and ultimately enhancing the overall viability and adoption of electric vehicles.

## 4.3 Carrar's part in minimizing the effects of thermal runaway and delaying it

Utilizing the concept of pool-boiling, Carrar employs a thermal management system to effectively regulate battery cell temperatures using HFO-1336MZ and HFO1233YF. This technology, complemented by Carrar's patent, plays a pivotal role in maintaining optimal cell temperatures, thereby significantly mitigating the potential for initiating thermal runaway resulting from excessively high temperatures. Furthermore, Carrar's system demonstrates its capacity to dissipate more heat than the cells are generating and therefore to curtail the acceleration of cell temperature rise in scenarios involving overcharging or physical damage. Figure 1 shows the thermal runaway dynamics for several Li-ion battery types (differing in cathode materials) Note that once the reaction has begun, the temperatures rise quickly within 10 minutes to very high temperatures, over 100ºc in less than two minutes, all leading to a major safety hazard. Through Carrar's technology, the system not only curbs the propagation of thermal runaway, where the escalation could trigger neighboring cells into the same dangerous state, but also introduces a delay in the aggressive response of the cells (Figure 2). A noteworthy instance emerges during overcharging incidents, where the cooling system effectively postpones thermal propagation for another 50 minutes, ensuring the temperature remains under 43°C. This crucial intervention provides occupants ample time to safely evacuate the vehicle, thus reinforcing the protective capabilities of the technology. Furthermore, this time gap is ten (10) times higher than the UN/ECE[41] regulation

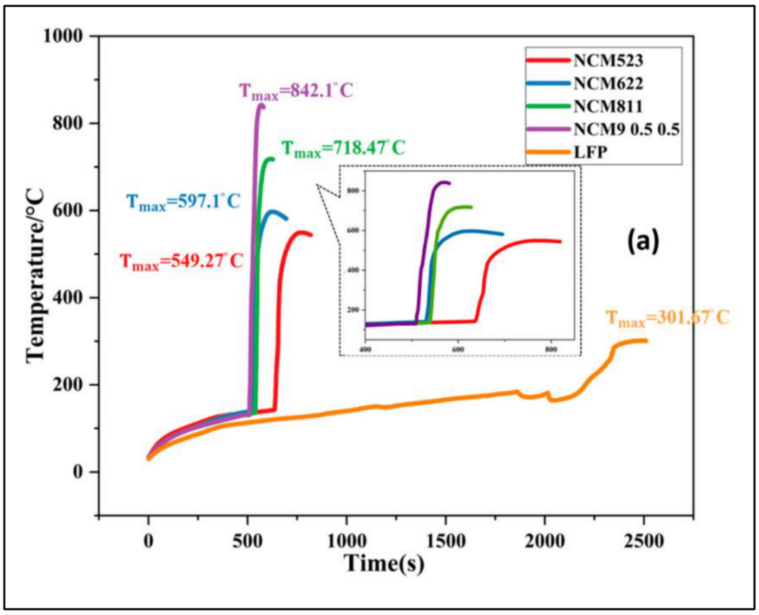


Figure 1 – Thermal Runaway dynamics –of different batteries[42]

[41] E/ECE/324/Rev.2/Add.99/Rev.3, Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train

[42] [Electronics | Free Full-Text | Thermal Runaway Characteristics and Gas Composition Analysis of Lithium-Ion Batteries with Different LFP and NCM Cathode Materials under Inert Atmosphere (mdpi.com)]

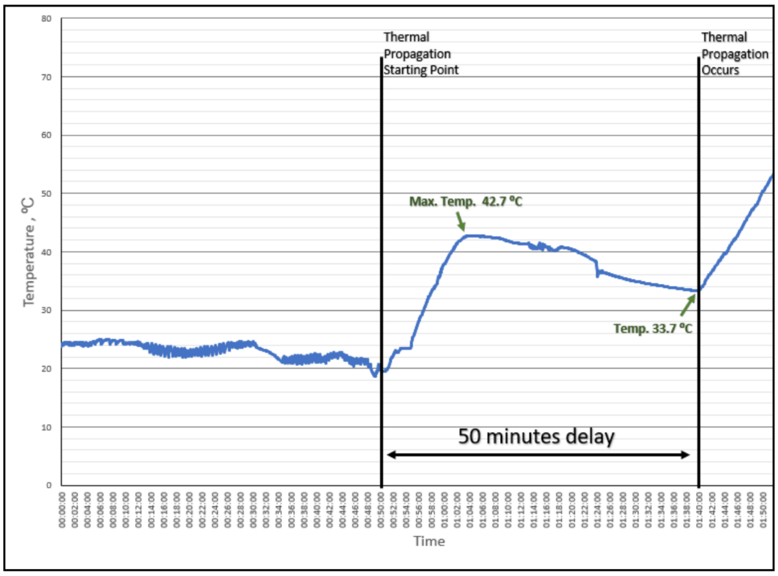


Figure 2 – Thermal Runaway dynamics – Carrar Solution[43]

## 4.4 Conclusion

In conclusion, a comprehensive risk assessment of HFOs as a subset of PFAS reveals a nuanced landscape. The potential of HFOs to serve as substitutes for high global warming potential (GWP) compounds offers a valuable opportunity for decarbonization efforts, but their varied toxicity profiles and environmental behaviors require careful regulatory consideration. The need for a nuanced, science-based approach that acknowledges their diversity while prioritizing human health and the environment remains imperative.

The highest bodily safety risk associated with EVs is thermal runaway of the lithium-ion batteries. Addressing this issue is of paramount importance for safe and sustainable EV technology. HFOs emerge as promising candidates for effective TMSs, exhibiting superior heat transfer and thermal stability properties compared to traditional alternatives. Integrating HFOs into battery thermal management not only efficiently dissipates heat and maintains regulated battery temperatures but also holds potential for suppressing fires.

Carrar's innovative approach, leveraging pool-boiling technology and HFOs, showcases a significant advancement in delaying and minimizing the effects of thermal runaway. By effectively mitigating the propagation of dangerous conditions and introducing delays in aggressive responses, Carrar's technology enhances the safety of EVs and bolsters the feasibility of widespread adoption.

In an evolving landscape of environmental and technological challenges, HFOs stand at the intersection of progress and responsibility, offering solutions that prioritize both human well-being and sustainability. Banning HFOs would disregard their pivotal role in advancing safety, suppressing thermal runaway, and supporting the sustainable growth of electric vehicles and technology.

[43] Carrar internal experiment

# 5 Impact assessment and Recommendations to policymakers

## 5.1 PFAS is essential to EV adoption

The concept of essential uses dates back from the Montreal Protocol on Substances that Deplete the Ozone Layer (1987), which defines a use as essential if it is "necessary for health, safety or is critical for the functioning of society" and if "there are no available technically and economically feasible alternatives".

Under the Chemicals Strategy for Sustainability[44], the European Commission has started a debate with all REACH Competent Authorities to define the term 'essential uses'. The debate is at an early stage and many questions are still open. Although the definition of such a concept is taking place under the ongoing revision of REACH and is therefore separate from the PFAS restriction process, it is still relevant for sectors consuming PFAS-based materials like the automotive industry to engage on this issue being discussed in parallel to the PFAS restriction process. One of the most controversial questions is if the term 'essential' refers to the broad application or product that the PFAS is used in or the specific use (functionality) of the PFAS within the product. The Strategy's action plan shows that the criteria for essential uses are planned to be defined in the period 2021-22, although as of today the process is ongoing and has not been finalized.

HFO stability translates to unique, durable, lasting performance in critical uses and applications. In the EV industry, as outlined above, HFO should be deemed essential, until alternatives with comparable KPIs become available. The Chemicals Strategy for Sustainability states that "the criteria for essential uses of these chemicals will have to be properly defined to ensure coherent application across EU legislation and will in particular take into consideration the needs for achieving the green and digital transition."

When REPowerEU[45] and Fit For 55[46] set ambitious GHG emissions reduction targets of 55% by 2030 compared to a 1990 baseline, reducing dependency on Russian fuels by 2027 and phasing out sales ICE vehicles by 2035, the EV battery technology development cannot be held back. Therefore, the use of HFO should be considered as an essential use for society, whether from an energy and climate perspective or from an industrial and geostrategic perspective. Allowing fluoropolymers use in this industry meets both criteria of Montreal Protocol definition of essential use and allowing it will indeed leave society better off from a socio-economic and environmental perspective. Overall, the EU must ensure consistency across its different policies and plans and avoid undue barriers. It is therefore not timely to add another barrier now. Without this, the EU will lose its industrial lead in this blossoming sector, to non-EU regions where PFAS could be less regulated.

## 5.2 Impact of an EV battery

In the dynamic realm of EVs, the innovation driving sustainable transportation is underpinned by the utilization of minerals crucial for battery production. However, this progress is accompanied by a range of environmental considerations stemming from battery production in general and minerals in particular as well as end of life treatment of the batteries.

### 5.2.1 Battery production

EV battery production forms a pivotal crossroads of sustainable mobility, merging advanced technology with vital rare-earth metal sourcing. Dissecting the environmental and social consequences entwined with mining and employing these minerals is crucial. Beneath the veneer of cleaner transportation, stark consequences emerge,

[44] Chemicals Strategy for Sustainability - ECHA (europa.eu)

[45] REPowerEU: affordable, secure and sustainable energy for Europe (europa.eu)

[46] Fit for 55 - The EU's plan for a green transition - Consilium (europa.eu)

caused by the extraction and processing of pivotal minerals like Lithium, Cobalt, and Nickel. The magnitude of mining's impact is undeniable:

1. Social impact - The mining of metals essential for EV batteries exerts profound social effects, spanning labor conditions, human rights, and community welfare. Cobalt mining is associated with child labor[47,48], Lithium extraction can displace local communities and harm their wellbeing[49,50], and the list goes on. The labor-intensive battery supply chain mirrors these concerns, impacting vulnerable societies. Environmental degradation exacerbates health and livelihood challenges through air, water, and land pollution.

2. Environmental impact[44,45,46,47] – Mineral extraction exacts a substantial environmental toll, causing deforestation and habitat loss; dispersion of toxic substances and heavy metals contaminates water, air, and land, adversely affecting downstream communities dependent on clean water. Diminished soil fertility and agricultural yields disrupt local food chains and human health. Airborne pollutants disperse beyond mining sites, impacting nearby ecosystems. The energy-intensive extraction process further exacerbates climate change. Other negative effects include mining waste, acid drainage, erosion, sedimentation, and land-use disputes, highlighting the complex ecological challenges posed by mineral mining.

### 5.2.2 End of life

While Lithium-ion batteries are a common choice for EVs due to their favorable characteristics, like all batteries, they have a limited lifespan. Over time, the capacity of a lithium-ion battery degrades, meaning it can hold less charge and provide less driving range. When an EV battery reaches the point where its capacity has significantly degraded, it's considered to have reached its end of life for use in an electric vehicle. Disposing in a landfill is not a responsible or sustainable option due to environmental contamination, fire hazards, regulatory compliance, and the potential for resource wastage. Therefore, it is imperative to consider end-of-life management. The common solutions are:

1. Second life applications – while unable to provide adequate driving range, the battery might still have a significant amount of capacity left and can be repurposed for other applications such as stationary energy storage for homes or businesses. As the market for electric vehicles and batteries grows, a secondary market for used EV batteries is emerging and companies are exploring business models that involve purchasing used batteries, refurbishing them, and selling them for various applications.

2. Lithium-ion batteries contain valuable materials that can be recovered for reuse, reduce the demand for mining new resources, and minimize the environmental and social impact of extracting and processing these materials.

### 5.2.3 Conclusion

In the realm of electric vehicles (EVs), the pursuit of sustainable transportation is closely linked to the utilization of crucial minerals for battery production. Yet, this drive for innovation comes hand in hand with significant environmental considerations. Battery production, driven by the need for rare-earth metals, forms a critical intersection of technology and sustainability. However, this progress is accompanied by stark realities, including the

47 https://www.sciencedaily.com/releases/2021/12/211217113232.htm#:~:text=Unintended%20consequences%20of%20decarbonization,physical%20and%20mental%20health%20challenges.

48 https://www.picoanalytics.co.uk/insights/lfguuras0xa8e3q4qkvijtl34fzm79

49 https://borrumenergysolutions.ca/blogs/blog/the-social-and-environmental-impacts-of-lithium-mining#:~:text=In%20addition%20to%20its%20environmental,environmental%20regulations%20are%20often%20weak.

50 https://www.frontiersin.org/articles/10.3389/fpace.2022.1058940/full

social impact of mining, such as child labor and community displacement. Environmental consequences are equally alarming, spanning habitat loss, toxic substance dispersion, and climate change exacerbation. The end-of-life stage of EV batteries adds another layer of complexity, emphasizing the imperative of responsible disposal and recycling. As the popularity of electric vehicles and battery technology grows, it becomes increasingly crucial to address these environmental challenges holistically and sustainably.

## 5.3 Impacts of a ban

### 5.3.1 Environmental Impact

Comparing Cradle to grave GHG emissions of an ICE vehicle to an EV performed by the IEA[51] (Figure 1) clearly shows while using an ICE vehicle 42t$CO_2$e is emitted during the vehicle's entire life time, an EV emits about 20t$CO_2$e based on current grid energy mix or 8t$CO_2$e when charged with 100% renewable energy. Based on market predictions by Bloomberg[52] stating that more than half the US car sales will be EV and will amount to a stunning 40M new EV in 2030[53], the result is over 1,000Mton of avoided $CO_2$ emissions by new car sales based on the use of renewable energy.

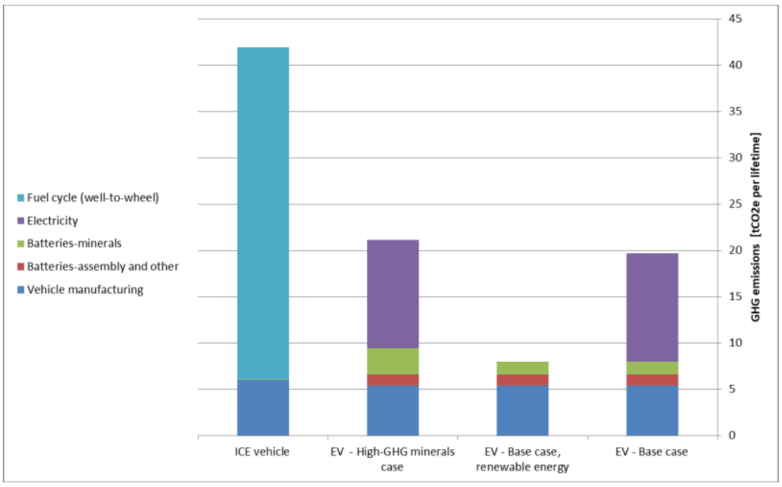


**Figure 3 – Comparison of GHG emissions per lifetime for ICE and EV vehicles[54]**

Another perspective worth exploring involves examining the impact of the regional energy composition. When comparing the life cycle GHG emissions of typical-sized ICE vehicles and EVs registered in 2021 and projected for 2030, it becomes evident that the local energy mix significantly influences the GHG emissions reduction in EVs (Figure 4). It's noteworthy that while expanding battery production can lead to a surplus effect on overall emissions, the key lies in extending battery lifespan rather than focusing solely on production scalability. In essence, the solution to reducing overall contributions lies not in amplifying battery production, but rather in increasing the longevity of batteries themselves.

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[51] Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle – Charts – Data & Statistics - IEA

[52] More Than Half of US Car Sales Will Be Electric by 2030 - Bloomberg

[53] Global EV sales by scenario, 2020-2030 – Charts – Data & Statistics - IEA

[54] IEA, Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle, IEA, Paris https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle, IEA. Licence: CC BY 4.0

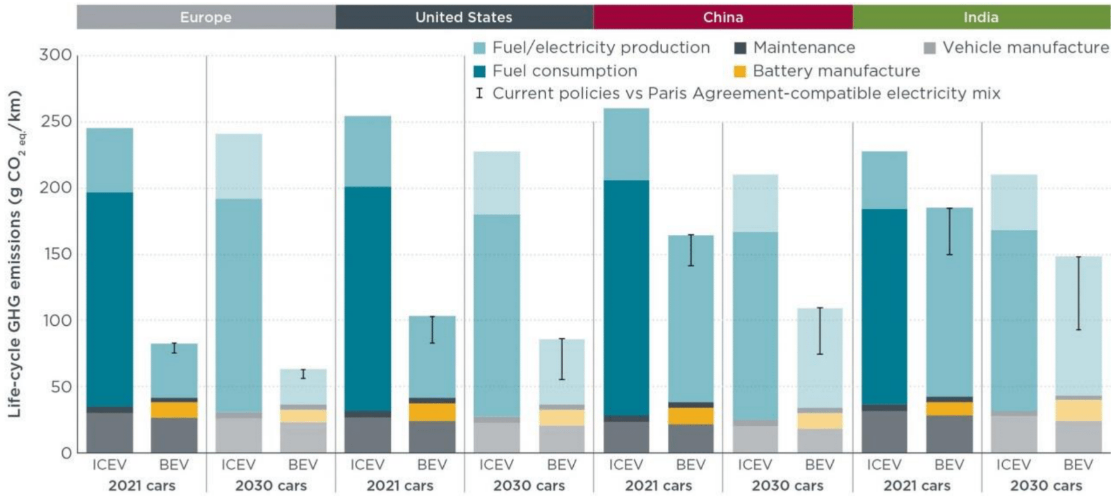



**Figure 4 – Comparison of GHG emissions per lifetime for ICE and EV vehicles[55]**

**Impeding the adoption of EVs will go against the ambitious emission reduction targets set in the EU**.

### 5.3.2 Socio-economic impacts

A report published by the International Energy Agency (IEA) estimates that the transition to electric vehicles could create in the USA up to 12 million new jobs in the transportation sector by 2030, with the majority of these are high quality positions in manufacturing and new technology development[56]. Average compensation will increase by 20% compared to the average annual wage[57]. The Automotive Industry Europe (AIE)[58] concluded the 200,000 new permanent jobs will be created annually in the EU alone, summing to 1.2 million permanent jobs by 2030. The report accounts for operations, manufacturing and sales jobs but does not account for R&D positions.

Moreover, impeding the spread of EVs would also impact:

- Air pollution – adoption of EVs reduces air pollution thus reducing associated health issues. A study published by the OECD[59] demonstrated that a decrease of 1 µg/m3 in the concentration of PM2.5 would increase the EU's GDP by 0.8% of a stunning €120 bln on a 2017 basis. With more than 96% of the urban population exposed to high concentrations of PM, WHO[60] estimates that 238,000 premature deaths occurred due to exposure to PM as well as high morbidity and associated direct and indirect costs.
- Noise pollution – This is the invisible threat causing health issues from diminished cognitive performance to cardiovascular effects[61].

The IEA report[62] clearly states that the global EV fleet is projected to emit 230MTCO2e in 2040 compared to a 350MTCO2e pure ICE fleet, reflecting a 120MTCO2e net saving. This number will increase with the rise of renewable energy in national energy mix.

[55] Life-cycle GHG emissions of an EV compared to an ICEV (cotes.com)

[56] Global Electric Vehicle Outlook 2022 (windows.net)

[57] Massive job creation by electric vehicles (electricbee.co)

[58] Powering a new value chain in the automotive sector - the job potential of transport electrification (dalicloud.com)

[59] pdf (oecd.org)

[60] Air quality in Europe 2022 — European Environment Agency (europa.eu)

[61] Noise (who.int)

[62] Prospects for electric vehicle deployment – Global EV Outlook 2021 – Analysis - IEA

## 5.4 Carrar's contribution to positive impact

### 5.4.1 Introduction

Carrar's technology enables ultra-fast charging. The physical characteristics of the HFO used, enable good temperature uniformity in the battery module regardless of the charging rate of the cells as well as exceptional temperature uniformity (Figure 5), all reduce cell degradation[63]. The low boiling temperature of the HFO used (around 15-30 degrees C) together with Carrar's unique technology work together to keep the battery cells in optimal temperatures and conditions. A test of 2,500 charging cycles at a 2C rate and ambient temperature of 40ºc was conducted and temperature of 12 cells was measured. As can be seen in Figure 6, temperature uniformity was at ±1ºc throughout the entire test. The result is a significant increase in the battery lifetime from a baseline of 500 charging cycles to over 2,500 charging cycles to reach a reduction of 80% in battery capacity, as can be seen in Figure 7 . Moreover, as the exothermal reaction is impeded by the use of the HFO's, it is expected the emissions of GHGs and other PMs will be significantly reduced[64]. The prolonged lifetime of Carrar cooled batteries dramatically reduces the environmental and social impact of battery production and end-of-life (EOL) treatment, as elaborated in the following sections.

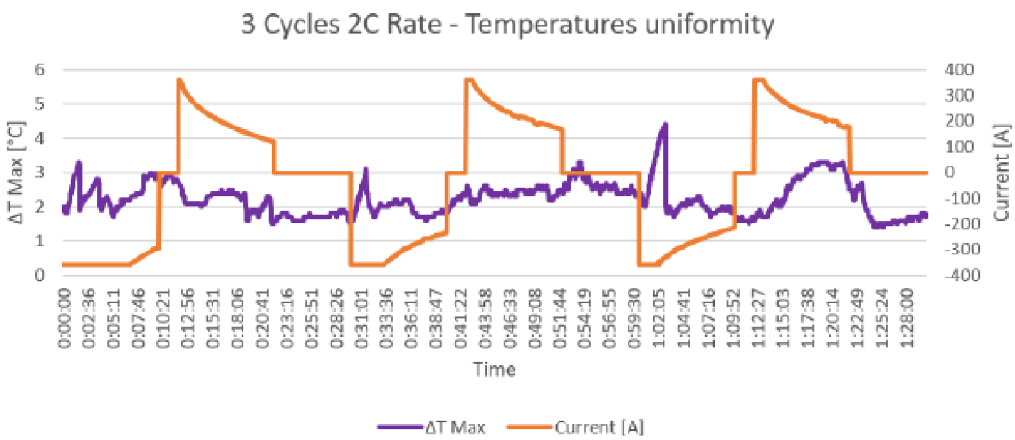
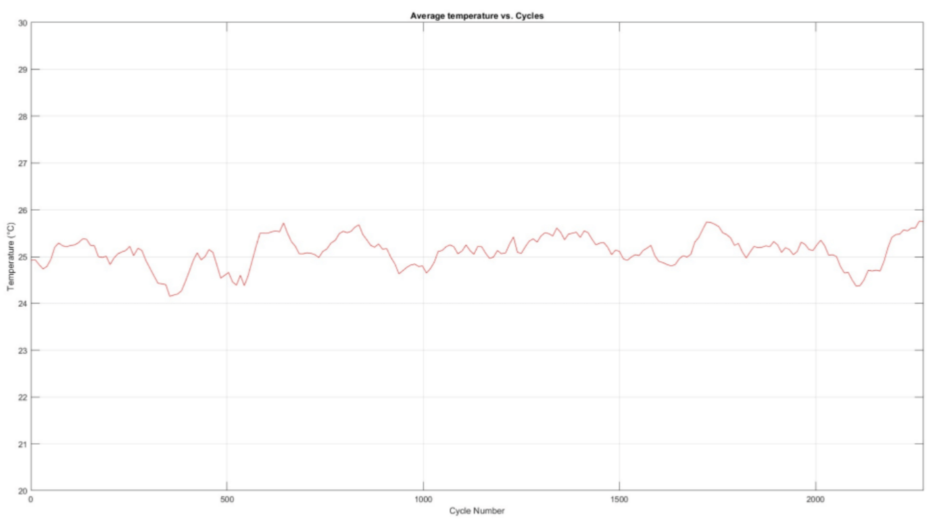



**Figure 5 –Temperature uniformity in 3 cycles at 2C rate[65]**




[63] https://louis.uah.edu/cgi/viewcontent.cgi?article=1304&context=uah-theses

[64] Internal Carrar roadmap

[65] Internal Carrar experiment

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Figure 6 –Temperature uniformity for 2,500 cycles at 2C rate, ambient temperature of $40^0c$[66]

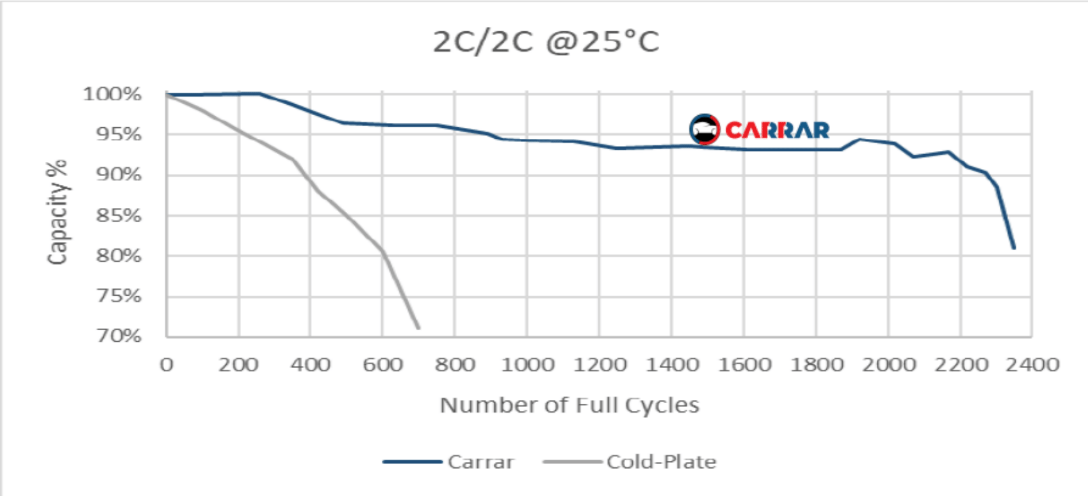


Figure 7 – Lifetime comparison of a cold-plate cooled battery and a Carrar cooled battery[62]

[66] Internal Carrar experiment

### 5.4.2 Avoided GHG emissions

The market can be separated into two major groups - the private sector and the commercial sector. Sales of private cars are also used as taxis. Noting the battery damage is related to use, charging methods and speed as well as ambient temperature, lifespan of a battery used for taxis is significantly shorter. Therefore, having a Carrar cooling battery will triple lifespan of the battery while reducing the total use phase GHG emissions by 24% per mile, as can be seen in Table 1[67].

**Table 1 – Comparison of GHG emissions for an EV and a Carrar EV**

| | Benchmark EV | EV with Carrar |
|---|---|---|
| tCO2e per mile | 0.0002 | 0.0002 |
| No. cycles | 500 | 2,500 |
| miles per charge | 215 | 236.5 |
| total miles over lifetime | 107,500 | 591,250 |
| total co2 per lifetime (production + use) | 30.3 | 127.05 |
| **intensity kgCO2/mile** | **0.28** | **0.21** |

Exploring the commercial market, based on the market forecasts as shown in section 2.3, **about 970Kton$CO_2$e can be saved by using Carrar technology** instead of other accepted technologies (Table 2).

**Table 2 –GHG emissions for an EV and a Carrar EV – commercial sector**

| | Total Vehicles (K) | Total EV (K) | T$CO_2$e over lifetime | Carrar SOM (K) | T$CO_2$e over lifetime | ton$CO_2$e saved |
|---|---|---|---|---|---|---|
| Buses and HD Trucks | 3,000 | 900 | 47,564 | 90 | 4,756.40 | 42,808 |
| Light Trucks | 11,000 | 4,400 | 232,535 | 30 | 1,585.47 | 230,949 |
| Other Commercial | 10,000 | 4,000 | 211,395 | 10 | 528.49 | 210,867 |
| Total Commercial | 24,000 | 9,300 | 491,494 | 130 | 6,870.35 | 484,624 |
| **Total** | | | **982,988** | | **13,740.70** | **969,248** |

To support aforementioned claims, an internal Life Cycle Assessment was made for Carrar's battery-pack[67]. Using the HFO used by Carrar does not increase the product's carbon footprint than the benchmark[68], comparing the 20.5 kg$CO_2$e/kg with a 18.2 kg$CO_2$e/kg. Taking into account that the battery-pack can be used for more than five times compared to a benchmark battery-pack, that would go to lower the carbon footprint of an average EV battery-pack from 42.8 g$CO_2$e/mile to 8.8 g$CO_2$e/mile.

This assessment goes to strengthen the claims that incorporating HFOs in EV temperature management systems is in line with the EU's GHG reduction ambition in both encouraging EV adoption and the use-phase of the EVs themselves.

[67] Internal Carrar information

[68] The environmental footprint of electric vehicle battery packs during the production and use phases with different functional units | SpringerLink

### 5.4.3 Implications to socio-economic impact

Carrar's groundbreaking technology, extends beyond mere battery performance enhancements; it also carries profound positive implications for the societal facets of electric mobility. By ensuring consistent temperature uniformity within the battery module, thus contributing to mitigating cell degradation, translates into extended battery lifespans, resulting in fewer instances of battery replacements.

The cascading effect of this longevity is a reduction in overall ownership costs for consumers, thereby augmenting the accessibility and affordability of electric vehicles to a wider demographic. Furthermore, the diminished requirement for frequent battery replacements has the potential to address the pressing social and environmental concerns linked to the mining and disposal of battery materials, thereby bolstering the sustainability and ethical accountability of the electric vehicle industry. Carrar's technology serves as a catalyst for not only enhancing EV efficiency but also for nurturing a future of sustainable and socially responsible transportation.

Mining needs come with paramount concern are the human rights violations pervasive in mineral mining, including instances of child labor, forced labor, and the financing of armed militias. The reduction in mining demands serves as a pivotal means to alleviate these social and ethical quandaries, fostering improved labor conditions and human rights safeguards for communities residing in proximity to mining operations.

Moreover, this reduced reliance on mined materials contributes to bolstering the resilience of the electric vehicle supply chain. It serves to mitigate vulnerability to supply disruptions stemming from geopolitical conflicts or market fluctuations in mineral prices, ensuring a more consistent and stable production of electric vehicles.

Furthermore, the transition towards electric vehicles holds the potential for substantial job creation. As the electric vehicle industry continues to grow, alternative employment opportunities rise, encompassing roles in battery research and development, sustainable technology innovation, battery recycling and repurposing endeavors, as well as the expansion of electric vehicle infrastructure. Additionally, the high-quality positions in manufacturing and technology development, as underscored in the International Energy Agency's report, are poised to play a pivotal role in shaping the future of the transportation sector.

### 5.4.4 Conclusion

Carrar's technology presents a promising avenue for addressing the environmental and social challenges outlined earlier. By facilitating aggressive fast drive cycles while maintaining optimal temperature conditions and uniformity therefore reducing cell degradation, Carrar's approach directly influences the environmental footprint of both EV battery production and utilization. The extended battery lifetime means a reduction in the demand for critical minerals, mitigating the negative consequences associated with mineral extraction. As the need for battery disposal declines so do EOL effects. Additionally, the HFO's influence on inhibiting exothermal reactions aligns with the goal of reducing GHG and PMs emissions, leading to yet another positive environmental outcome. By contributing to improved battery efficiency and longevity, this innovative technology holds the potential to address both the resource-intensive battery production process and the social issues connected to mineral extraction and disposal.

## 5.5 Conclusion

As evident from this section, EVs wield a substantial influence on both the environment and society. Detrimental effects are apparent during battery production, encompassing mineral mining, assembly processes, and the potentially harmful consequences of inadequate end-of-life treatment. Carrar's innovative technology offers the potential to triple the battery lifespan, thereby mitigating the severity of negative production and end-of-life stages. In terms of the usage phase, Carrar's market presence alone could prevent the emission of nearly 830,000 kilotons of $CO_2$ equivalent.

Hastily banning the use of PFAS could impede the widespread adoption of EVs, potentially hindering the EU's ambitious climate targets, especially concerning traffic and heavy-duty transport decarbonization outlined in the EU's climate change strategy. The abrupt prohibition of PFAS and HFO, lacking viable alternatives, has the potential to disrupt essential industries, suppress the adoption of green technologies, and worsen the environmental and social impacts of mineral extraction. Such actions could hinder the advancement of EV battery technology, exacerbate supply chain challenges, and compromise environmental objectives. Instead of rushed bans, a pragmatic approach should be taken, striking a balance between immediate concerns and long-term repercussions.

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# 6 Conclusion

The European Union has set an ambitious goal of achieving climate neutrality by 2050. In order to achieve this goal, the EU is committed to phasing out the use of fossil fuels and transitioning to a clean energy economy. Electric vehicles (EVs) are a key part of this transition, as they produce zero emissions and help to reduce air pollution.

However, the EU's recent decision to ban the use of PFAS in EV thermal management systems is a major setback for the EV industry and goes against its own interests for a number of reasons. EVs will become more expensive, less efficient and will impose safety hazards, all going against EV market penetration and reducing the production and use of ICE vehicles.

Furthermore, the ban on PFAS has a significant negative impact on society and the environment. As HFO help to significantly extend Li-ion battery lifetime, banning it will result in more metal mining for production on the one hand and more waste to dispose of at EOL.

In addition to the above, the ban on PFAS is also likely to have a number of negative consequences for the EU economy. The EV industry is a growing industry that is creating jobs and stimulating economic growth. The ban on PFAS is likely to slow the growth of the EV industry and lead to job losses.

The EU should also consider the impact of the ban on PFAS on its global leadership in the fight against climate change. While being a leading advocate for the adoption of EVs, this ban on PFAS is likely to damage the EU's reputation and make it more difficult to convince other countries to adopt EVs.

The EU's ban on PFAS is a short-sighted decision that will harm the EV industry and the environment. The EU should reconsider its ban and find a more sustainable solution to the problem of PFAS in EV thermal management systems.

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# 7 Glossary

| Acronym | Definition |
|---|---|
| AC | Air Conditioning |
| AIE | Automotive Industry Europe |
| CAS | Chemical Abstracts Service |
| CLP | Classification, Labeling, and Packaging regulation |
| CO | Carbon Monoxide |
| CO2 | Carbon Dioxide |
| ECHA | European Chemicals Agency |
| EEAP | European Environment Agency's PFAS Environmental and Health Assessment Program |
| EOL | End-of-Life |
| EPA | United States Environmental Protection Agency |
| EU Commission | European Commission |
| EU | European Union |
| EV | Electric Vehicle |
| F-Gas Regulation | Regulation (EU) No 517/2014 on fluorinated greenhouse gases |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GWP | Global Warming Potential |
| HFO | Hydro-Fluorocarbon Olefin |
| ICE | Internal Combustion Engine |
| IEA | International Energy Agency |
| IGBTs | Insulated Gate Bipolar Transistors |
| Li-ion | Lithium-ion |
| NEV | New Electric Vehicle |
| OECD | Organisation for Economic Co-operation and Development |
| OEMs | Original Equipment Manufacturers |
| PFAS | Per- and polyfluorinated alkyl substances |
| PM2.5 | Particulate Matter 2.5 |
| R&D | Research and Development |
| REACH | Registration, Evaluation, Authorization, and Restriction of Chemicals |
| RMOA | Regulatory Management Option Analysis |
| TFA | Trifluoroacetic Acid |
| TMS | Thermal Management System |
| UK RMOA | United Kingdom Regulatory Management Option Analysis |
| UN/ECE | United Nations Economic Commission for Europe |
| VOCs | Volatile Organic Compounds |
| WHO | World Health Organization |

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