ExxonMobil Petroleum & Chemical BV (EMPC) Comments on Annex XV restriction report on per- and polyfluoroalkyl substances (PFAS)

Additives in lubricants

21 September 2023

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Additives in lubricants

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Acronyms and Abbreviations

ACEA	European Automobile Manufacturers Association
ECHA	European Chemicals Agency
EEA	European Economic Area
EiF	Entry in Force
ELV	End-of-Life Vehicle
EMPC	ExxonMobil Petroleum & Chemical BV
EPR	Extended Producer Responsibility
EV	Electric Vehicle
FLSs	Fluorosilicones or Fluorosiloxanes
ICE	Internal Combustion Engines
IDIS	International Dismantling Information System
IMDS	International Material Data System
OEM	Original Equipment Manufacturer
PDMS	Polydimethylsiloxane
PFAS	Per- and Polyfluoroalkyl Substance
R&D	Research & Development
RPM	Rotation Per Minute
SEA	Socioeconomic Assessment
WFD	Waste Framework Directive

1. EXECUTIVE SUMMARY

This response is submitted on behalf of ExxonMobil Petroleum & Chemical BV ("EMPC"). For the purpose of this submission, EMPC is acting in its own name and in name and on behalf of the other affiliates potentially affected by the proposed REACH restriction (hereafter referred to as "ExxonMobil"). EMPC is a subsidiary of Exxon Mobil Corporation and part of the ExxonMobil group of companies ("ExxonMobil Group").

This report is being submitted in response to the EU's proposed restriction on uses of Per- and Polyfluoroalkyl Substances (PFAS) in the EU. Antifoam additives are an essential component of drivetrain lubricants, preventing the generation of foam that can lead to increased loss of lubricant and excessive wear of drivetrain components, such as gears and pumps. Drivetrain components are used in the automotive sector under harsh conditions, as temperatures can reach as high as 120 °C in electric vehicles (EV) and as high as 180 °C in Internal Combustion Engine (ICE) vehicles. In addition, drivetrain lubricants are subject to very high speeds and pressures, so they must withstand constant mechanical stress without degrading or migrating out of the closed system they are used in.

Identifying a potentially suitable alternative is a difficult task for suppliers of additives, lubricant manufacturers and OEMs, as the alternatives will need to be able to achieve the same surface tension reduction as the currently used fluorinated silicone, while at the same time retain resistance to harsh conditions such as elevated temperatures, mechanical stress and contact with a broad range of chemicals. All these technical criteria are met by the antifoam additive currently in use. Potential alternatives may have worse performance and could require a higher concentration in the lubricant to achieve the same performance, which could require a wider re-formulation of the lubricant to avoid unwanted interactions among the different additives and the base oil(s).

In any event, should a potentially feasible alternative be identified, the lubricant will need to undergo a lengthy certification process, as mandated for all components, sub-components and lubricants used in vehicles in the EU. This process involves manufacturers of additives and lubricants, as well as part and vehicle manufacturers and may also require the involvement of national authorities. At a minimum, it can take 5 years, but considering the strict requirements for performance and reliability of the lubricant, several iterations may be needed, and a timeline of 10 years or even longer is very likely.

If the currently proposed derogation for lubricants remains unchanged, it could mean that lubricant additives will not be covered by a derogation after the 18-month transitional period expires, and it will not be possible to be used in any process or sold or product containing them (even finished spare parts and vehicles) in the EEA.

Inability to use these additives in vehicle lubricants could lead to significant impacts for the EU automotive industry, including electric vehicles, which are an element of the European Union's strategy for low-emission mobility. The share of electric vehicles in the EU passenger and commercial fleets is increasing and battery-powered vehicles are expected to be the main type in the EU in the coming decades[1]. At the same time, the importance of ICE vehicles, which are still produced in significant numbers in the EU, should not be underestimated. In general, the EU automotive industry is among the largest in the world, employing more than 13 million people (in manufacturing, service and construction) and manufacturing more than 13 million cars each year.

Antifoam additives, while used in very small concentrations in the lubricants, contribute to vehicle efficiency, safety and reliability.

Therefore, it is suggested that the proposed derogation in paragraph 5(s) of the PFAS restriction proposal be reworded to a time-unlimited derogation as below:

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[1] European Commission website – Zero emission vehicles: first 'Fit for 55' deal will end the sale of new CO_2 emitting cars in Europe by 2035. Available online at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6462, accessed on 12 September 2023.

Lubricants <u>and lubricant additives</u> where the use takes place under harsh conditions or the use is needed for safe functioning and safety of vehicles and equipment.

Nevertheless, work on alternatives is ongoing, in an effort to improve the environmental footprint of the products, along with the overall performance of lubricants and lubricant additives. As such, and to capture the possibility that an alternative is identified in the future, the validity of the time-unlimited derogation can be re-evaluated at regular intervals, depending on the status and availability of alternative additives.

2. BACKGROUND INFORMATION

Exxon Mobil Corporation manages an industry-leading portfolio of resources, and is one of the largest integrated fuels, lubricants and chemical companies in the world. The ExxonMobil Group evolved an operating model and global organisation to better leverage the scale of its increasingly integrated company and global brands. There are three core businesses with operations around the world[2]:

- Upstream business - Focused on strengthening energy security by expanding low-cost-of-supply, high-return oil and natural gas operations.
- Product Solutions business - Integrating downstream and chemicals operations to develop lower emission fuels and innovative products needed by modern society.
- Low Carbon Solutions Business - Helping lower emissions by providing solutions to industrial and commercial customers in growing markets for carbon capture and storage, hydrogen and biofuels.

ExxonMobil´s history of operating in Europe is more than a century long and Europe has played an important role in some of the key milestones that marked their development into a manufacturer of the products that drive modern transportation, power cities, lubricate industry and provide petrochemical building blocks that lead to thousands of consumer goods.

The ExxonMobil Group's Corporate brands include:

- Esso: Customers around the world have come to respect and rely on Esso-branded fuels, services and lubricants for their personal and business needs;
- Exxon: Customers have also come to respect and rely on Exxon-branded fuels, services and lubricants for their personal and business needs;
- Mobil: Marketed around the world, Mobil is known for performance and innovation. Mobil is recognised for its advanced technology in fuels, lubricants and services; and
- ExxonMobil Chemical: There is a broad portfolio of petrochemical product brand and service solutions. These products play a key role in enabling the manufacture of affordable, sustainable and safe products that are helping meet the growing demands of an increasing global population.

With specific regard to chemicals and specialties, it has manufacturing capacity in every major region of the world, serving large and growing markets. More than 90 percent of the company's chemical capacity is integrated with refineries or natural gas processing plants[3]:

- The portfolio includes product and services (branched alcohols, branched higher olefins, butyl, EPDM rubber, linear alpha olefins, neo acids, plasticisers, polyethylene, polymer modifiers, polyolefin plastomers and elastomers, polypropylene, solvents & fluids, synthetic base stocks, tackifiers, transformer oils and thermoset systems);
- The industrial sectors supplied include: adhesives and sealants, agriculture, automotive, building and construction, compounding, consumer products, healthcare & medical, hygiene and personal care, industrial applications, energy, packaging, synthetic base stocks.

This document is being submitted by ExxonMobil in response to the public consultation on the universal PFAS restriction proposal, which was initiated by ECHA and runs until 25 September 2023.

The ExxonMobil Group does not manufacture per-and polyfluoroalkyl substances (PFAS). As part of their response, ExxonMobil wants to present relevant data on the uses and applications of certain PFAS and respond to ECHA's public consultation questions, which are applied in a number of

[2] https://corporate.exxonmobil.com/who-we-are/our-global-organization#Aglobalcompany

[3] https://www.exxonmobilchemical.com/en/

products in industry sectors and applications including, but not limited to, the uses identified in this report.

ExxonMobil will be submitting reports covering the following uses:

- Fluoropolymer use in upstream, refining, and petrochemical manufacturing
- Aviation hydraulic fluid additive
- Additives in lubricants
- Processing additive for polyethylene
- Clean agent in fire suppression systems

Please note that the information able to be submitted at this juncture is incomplete. The scope and potential impact of the proposed restriction is unprecedented and open-ended. Many thousands of substances would be subject to the restriction, and few of these substances are identified in the proposal on an individual basis. Accordingly, more time would be needed to do a more comprehensive and complete assessment. Due to the absence of identification of the individual substances that are in scope of the proposed restriction, the current assessment has been limited to those substances that are known to be used by ExxonMobil and are within the proposed restriction's scope. ExxonMobil reserves our rights in this context.

The information provided will describe in detail the sectors and sub-uses involved and the potential impact of the current restriction proposal, demonstrating the necessity of the use of certain PFAS in these applications, the potential for substitution, and the importance of the use, and continued use, with specific regard to the European Economic Area (EEA).

3. OVERVIEW OF THE USE

3.1 Sectors and Sub-uses

Exxon Mobil Corporation is one of the largest integrated fuels, lubricants and chemicals companies globally. Its business encompasses all aspects of the oil and gas industry, including Upstream, Products Solutions (including downstream and chemicals), and Low Carbon Solutions. The value chain of ExxonMobil businesses extends to end users of products and services, which can be found across all industry sectors in the EU, including, but not limited to, automotive and aerospace, building and construction, chemical processing, including agrochemicals and pharmaceuticals, packaging, etc.

3.1.1 Antifoaming agent in lubricant

Lubricants are commonly used to reduce friction and wear as well as extend the service life of equipment. In general, additives perform three roles in any lubricant[4]:

1. enhance the desirable properties of the base oil,
2. suppress the undesirable ones, and
3. add new properties to the lubricant that improve its overall qualities.

Foam formation is influenced by the chemical and physical properties of the lubricant as well as by the operating conditions (temperature, pressure, circulating rate of oil in the system, etc.) and in some cases, foaming may be caused by other additives in the formulation.

If not eliminated in time, foam can result in failure of equipment that must cope with an increasingly harsh working environment. To avoid this, an antifoaming additive needs to be added to the lubricants to avoid this risk and ensure the required performance[5]. An antifoaming agent reduces the surface tension of a solution or emulsion, thus inhibiting or modifying the formation of a foam. Generally, these agents have surface active properties and are insoluble in the foaming medium. These are less viscous, easily spreadable on the foamy surface, and possess affinity to the air–liquid surface where it destabilises the foam lamellas, which ruptures the air bubbles and breaks down the surface foam.[6]

Fluorosilicones or Fluorosiloxanes[7] (FLSs) are a class of fluoropolymers that act as antifoaming agents. They are generally composed of siloxane backbone polymers and fluorocarbon pendant groups. Fluorosilicones' outstanding properties include high thermal stability, good chemical and environmental resistance, flame resistance, and surfactant characteristics.

FLSs have the lowest surface energy because the outermost surface of fluorosilicone is closely packed with polyfluoroalkyl side groups and the flexibility of the Si–O backbone gives the polymer in the configuration lower surface energy.

Table 3-1 summarises the substance ID of the anti-foam additive used in ExxonMobil's lubricants.

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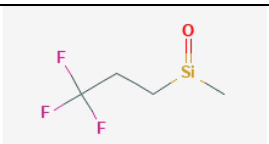
[4] Sniderman, D. (2017). The chemistry and function of lubricant additives. Tribol. Lubric. Technol. 73, 18–29. Available online at: https://www.stle.org/images/ pdf/STLE_ORG/BOK/LS/Additives/The%20Chemistry%20and%20Function %20of%20Lubricant%20Additives.pdf

[5] https://www.mdpi.com/1420-3049/28/7/3152

[6] https://www.sciencedirect.com/topics/medicine-and-dentistry/antifoaming-agent#:~:text=Antifoaming%20agents%20are%20added%20to,insoluble%20in%20the%20foaming%20medium.

[7] https://www.sciencedirect.com/topics/engineering/fluorosilicone

Table 3-1: Substance identification and notified hazards for typical substances used in lubricants and greases

	Additive in lubricant
EC number:	613-151-8
EC name:	Siloxanes and Silicones, Me 3,3,3-trifluoropropyl
CAS number:	63148-56-1
Structure	
Index number in Annex VI of the CLP Regulation	N/A
Hazard classification	Not classified (*Eye Irritation 2* *Skin Irritation 2* *STOT-SE 3*)
Source	CLI notifications [[8]]

3.1.2 Lubricants in vehicle drivetrains

The drivetrain is an essential part of any vehicle, whether Internal Combustion Engine (ICE) or electric (EV). Together with the engine, they constitute the powertrain.

The drivetrain is the vehicle component that transforms the power generated from the vehicle's engine into the kinetic energy of the wheels, through a driveshaft connected to the vehicle's transmission and a differential. The transmission distributes power to the drivetrain at different gear ratios, while the driveshaft in the end moves the wheels to the front and / or the rear of the vehicle (depending on its drive type) through the differential[9].

Use of the lubricant in the drivetrain minimises friction and wear in components such as the differential gears and the transmission.

The general design and sub-components of a drivetrain are similar in principle across the different vehicle types, whether ICE or EV, passenger or commercial vehicles or heavy vehicles such as trucks.

EV drivetrain systems are responsible for delivering power from the battery to the wheels. The system is made up of several different moving parts, which fall into three main components: electric motor, drive shafts, and transmission, which closely mirror the drivetrain components of ICE vehicles.

The electric motor or engine is the part of the system producing the power. It produces usable torque at about 1,200 rotations per minute (RPM) and peak torque at around 2,500 to 4,000 RPM. It also has an upper usable speed limit of 10,000 – 18,000 RPM. The electric motor is connected to the driveshafts coupled to the wheels. The drive shafts deliver the torque from the motor to the wheels and are also responsible for transferring power to the front or rear wheels, depending on the type of vehicle. The transmission helps regulate the electric motor's speed and torque and to keep the motor running at its most efficient speed [10].

8 https://pubchem.ncbi.nlm.nih.gov/compound/Methyl_3_3_3-trifluoropropyl_silanone

9 https://www.pearsonhighered.com/assets/samplechapter/0/1/3/4/0134616790.pdf

10 https://datamyte.com/ev-drivetrain/

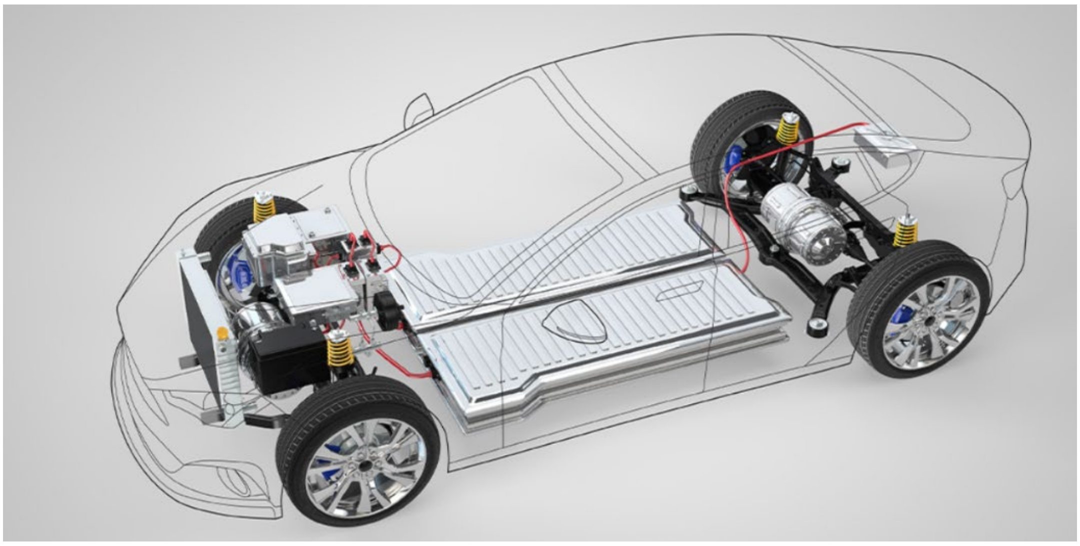


Figure 3-1: Electric Drivetrain System in an Electric Vehicle[11]

3.2 Performance requirements

Drivetrains can operate under very high speeds, entraining or driving air into the oil at very high rates. Foam control additives help release the trapped air driven into the lubricant without generation of foam. It is well documented that high foaming in drivetrains can lead to excessive leakage of the lubricant out of the drivetrain (spilling into the environment). Excessive foam can also drive higher wear rates in loaded gear systems due to cavitation wear (air bubbles bursting between gear contacts) and an effective lower bulk modulus of the lubricant.

In general, drivetrain lubricants are intended to be used under harsh conditions, including high temperatures and high speeds resulting in mechanical stress and exposure to corrosive chemicals. Therefore, when looking at alternatives to any component of the lubricant, the following technical criteria are expected to be considered[12]: These technical criteria are relevant for all types of vehicles, though the actual specifications may differ, depending on the engine power, whether it is front, rear or 4-wheel drive, etc.

- **Surface tension / surface energy**: The alternative must be able to reduce the surface tension of the oil sufficiently to prevent or reduce foam generation as per the performance specifications of the customer.
- **Chemical compatibility**: The anti-foaming additive is a component of a multi-component mixture, which includes the base oil and a number of other additives. All these components must be able to offer the desired properties to the lubricant throughout its lifetime and must not negatively affect each other's performance. An anti-foam additive must thus be compatible with all other chemicals in the lubricant, and not react with them, so that it can maintain its properties and function.
- **Durability at harsh conditions**: The drivetrain lubricants are exposed to harsh conditions during their service life. These conditions are typically elevated temperatures, corrosive agents, such as moisture, salts and acids, and constant mechanical stress. Any anti-foaming agent must be resistant to these conditions and maintain its function and performance at the extremes of the expected conditions, as specified by the customers' requirements. For temperatures in particular, a typical range of operating temperatures for the electric engine and other power electronics components, where they are most efficient and durable is between 60-80 °C, but for some short

[11] https://www.infineon.com/cms/en/applications/automotive/electric-drive-train/

[12] https://www.mdpi.com/2075-4442/9/4/40

intervals, they can reach 120 °C in areas of the rotor / stator. In ICE vehicles, temperatures may be even higher. It is the lubricants' job to provide a first-rate heat evacuation for temperatures as high as 180 °C[13].

Anti-foaming additives are purchased as part of the additive packages offered by ExxonMobil's suppliers[14]. These additive packages are then used within ExxonMobil's lubricant process formulation, according to the specifications set by OEM customers.

3.3 Control of potential emissions

3.3.1 Production of FLS

ExxonMobil does not manufacture PFAS and is not a manufacturer of the anti-foaming additive. Instead they purchase it already blended in the additive package, and the operating conditions of its manufacturing process are not known to ExxonMobil. As such, no specific information is available regarding the potential emission of FLS and precursors during the supplier manufacturing process.

3.3.2 Blending of lubricants containing anti-foam additive

Blending of the lubricants mostly takes place outside of the EEA, but there is a small number of products that are produced in EEA facilities. The manufacturing sites implement necessary risk management measures and other engineering controls to prevent exposure of workers and releases to the environment. These risk management measures are designed around the risks associated with the lubricant and additive components and, where necessary, also include personal protective equipment.

3.3.3 Service life

The lubricant in the transmission system is expected to degrade during the service life[15], while emissions are not considered likely, since the transmission is a closed system. In addition, the use of FLS itself as an antifoaming agent contributes to decreasing the risk of lubricant spillages during service.

Any potential for emission into to the environment is generally related to the maintenance of the vehicle, which is supposed to be carried out by professionals in dedicated facilities and with appropriate PPE and environmental release control measures. It should be noted that gear oils do not need to be drained as often as engine oils (once in 100,000 km compared to 10,000 to 15.000 km for engine oils)[16], so the frequency for potential for release is low.

In fact, in many conventional (ICE) drivelines in passenger cars the gearbox and axle fluids can be considered to be filled-for-life, i.e., there is no planned drain interval, and the lubricant remains in the component for the length of the vehicle's lifetime, which, for ICE, varies, depending on OEM, but may be as long as 240,000 km. Similar data is not available to the same extent for EV, but it is expected that they will follow a similar trend, based on the available information so far.

Based on the ELV directive (End of Life Vehicle Directive, 2000/53/EC), the International Material Data System (IMDS) ensures that PFAS can be potentially tracked along the supply chain until the OEM, being listed in the GADSL (Global Automotive Declaration Substance List). Nevertheless, due

[13] Bouvy, C., Baltzer, S., Jeck, P., Gißing, J., Lichius, T., and Eckstein, L. (2012). "Holistic vehicle simulation using modelica-an application on thermal management and operation strategy for electrified vehicles," in Proceedings of the 9th International MODELICA Conference; September 3-5; 2012 (Munich: Linköping University Electronic Press).

[14] https://www.exxonmobilchemical.com/en/products/synthetic-base-stocks/electric-vehicle-fluids/electric-vehicles-driveline-fluids

[15] https://www.tandfonline.com/doi/epdf/10.1080/10643389.2020.1771887?needAccess=true&role=button

[16] https://gandharoil.com/blog/difference-between-engine-oil-and-gear-oil/

to the large number of PFAS substances in the scope of the restriction, their identification upon the entry into force of the restriction may be challenging.

3.3.4 End-of-Life

In general, waste oils are managed according to the provisions of Art. 21 of Directive 2008/98/EC (and following amendments, including the Directive 2018/851/EC), also known as Waste Framework Directive (WFD)[17].

The WFD defines waste oils as hazardous waste, requiring the Member States to set rules for the separate collection of this specific waste flow, also in line with the Extended Producer Responsibility (EPR) principle. This follows the waste hierarchy of prevention, re-use, recycling, and the recovery of waste (including energy recovery), while the disposal (including landfill) should be followed as a last option.

In addition to the WFD provisions, the end of life of lubricants in vehicles is also regulated by the specific provision of Directive 2000/53/EC, also known as End-of-Life Vehicle (ELV) [18]. The ELV, based on the EPR framework, sets specific instructions for the dismantling of the vehicles at the end of life, including dealing with the fluids as well as specific targets for recyclability and recovery to be achieved by the early design of material and the implementation of end-of-life management.

Based on the ELV Directive, the International Dismantling Information System (IDIS) for the automotive sector ensures that the information related to the environmental and health management of lubricants during the dismantling operations is transmitted from the OEM to the dismantlers.

According to Pinheiro et al (2021), in 2016, the EU-28 generated 4,200 kt of Waste Lubricating Oil (WLO, waste category 01.3 according to Commission Regulation 849/2010). However, in 2019 the quantities of WLO treated achieved just 2,370 kt (Eurostat, 2019) which means that the management systems can be further improved [19].

Regarding the waste management options, the EU legislation is expected to set a target of 85% of recycling of waste oil including lubricants by 2025 for each Member State[20, 21], i.e., increasing the current average of 60%.

The incineration option is considered only for lubricants with a high degree of contamination from lubricant breakdown products, metals and dust (Pinheiro et al, 2021). A report from the Danish Ministry of the Environment (2005)[22] showed a 100% destruction of siloxanes by incineration.

[17] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

[18] https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en

[19] Carolina T. Pinheiro, Margarida J. Quina & Licínio M. Gando-Ferreira. (2021) Management of waste lubricant oil in Europe: A circular economy approach,Critical Reviews in Environmental Science and Technology, 51:18, 2015-2050, DOI: 10.1080/10643389.2020.1771887

[20] https://www.soc.chim.it/sites/default/files/chimind/pdf/2022_5_17_ca.pdf

[21] https://atiel.eu/rrbs-subgroup/

[22] https://www.ec.gc.ca/ese-ees/461AC049-D066-41B6-BCAD-796FEC116EF7/Batch%2011_68952-02-3_EN.pdf

4. OVERVIEW OF POTENTIAL ALTERNATIVES

The selection of the antifoam agent typically lies with the additive supplier, who generally carries out the R&D efforts to identify and implement a non-PFAS alternative.

To ExxonMobil's knowledge, additive suppliers have been actively working on identifying potential PFAS free alternatives, but extensive details on the progress are not available. Table 4-1 shows a number of potential alternatives that have identified by ExxonMobil´s suppliers.

Table 4-1: Known alternatives being assessed by additive suppliers

#	Alternative	Known properties	Comments
1	Acrylic defoamer in hydrocarbon solvent	Not available	No silicon content
2	40% solution of acrylic polymer in a petroleum solvent	Specific Gravity: 0.85 Viscosity@40C: N/A Viscosity@100C: N/A	High-performing defoamant additive for lubricants, according to marketing claims.
3	Polydimethyl silicone fluid diluted with kerosene	Not available	
4	Organo-modified siloxane anti-foam in ester diluent	Not available	
5	Acrylate polymer diluted in ~ 65% mineral oil	Mw~40,000. Dispersivity = 5.7 (So Mn = 7000)	No silicon content
6	Acrylic polymer in solvent preparation	N/A	Defoamer for industrial oils

Note that lubricants must meet strict specifications, which are set by the OEMs. As the additive package within the lubricant is a critical component of the vehicle equipment and consists of a group of chemicals that must all blend together to offer the required performance, additive and lubricant manufacturers must consider how any change to the product's constituents could impact the performance as a whole. Often, a change in one chemical can require adjustments in the concentrations or even the identities of the other additives, which would mean more extensive changes, and more extensive research. In the end, the new additive package may need to change more than just a single constituent.

4.1 Availability of alternatives

4.1.1 Quality standards and qualification procedure

In order to approve a lubricant containing an additive package for use in automotive parts, it must first be qualified for performance and safety. These specifications are set by the OEMs and vehicle manufacturers and refer to the performance of lubricants as a whole, relative to the overall vehicle performance.

Any lubricant offered to OEMs or placed in the market must therefore first be qualified against these specifications. In addition, changes in the composition of a lubricant, including in its additives, may trigger the need for a new qualification before it can be offered to OEMs.

Qualification for lubricants is usually carried out in two levels:

- First between the additive manufacturer and the OEM, testing the new additive package against a standard base oil to see if it meets the OEM's specifications.
- Then between the lubricant manufacturer and the OEM, in which the new additive package is tested in different base oils to verify it meets the OEM's performance specifications.

Only once both qualifications have been successful can the new lubricant be sold to the OEM customers. It is important to note that the tests required for lubricant approval must be carried out at dedicated facilities with limited capacity, which may not be available in case of a sudden increase in demand, e.g., as could be the case if all additive and lubricant manufacturers test potential alternatives to PFAS in their products.

4.2 Technical feasibility of alternatives

As described in section 3.2, harsh conditions are generated in the standard operation of EV and ICE transmission, and the lubricants used in this application are designed to perform under these conditions.

ExxonMobil is not the manufacturer of the additive, which arrives as a component in an additive package prepared by the supplier. The main work is being carried out at the suppliers' sites, with little information being available at the moment. It is understood, however, that, at the moment, none of the assessed alternatives is considered to be technically feasible. This can change in the future as testing and other R&D work progresses.

4.3 Economic feasibility of alternatives

The content of the antifoaming additive in the lubricants is very low, so its impact in the overall cost is relatively minor. As a result, the cost of any drop-in alternative is not expected to significantly impact the total cost of the final lubricant or the drivetrain equipment. It is expected that, any alternative that may eventually be considered suitable will not need new equipment or additional treatment or preparation, so the only difference in cost would be the cost of the substance itself.

4.4 Actions and time required for substitution

Identifying, developing and qualifying a new additive in a lubricant is a long, structured process. As shown in Section4.1.1, once a change in the formulation has been decided, the new additive package and lubricant must undergo a lengthy qualification process before they can be offered to customers. However, this process, requires at first that a suitable alternative that meets the required technical feasibility criteria has successfully been identified. The steps in such a process are listed below:

- **Identify a potential alternative anti-foaming additive**: This phase involves literature review and other research to identify potential alternative additives and define any potential changes to the formulation to avoid unwanted interactions between components. It may also include preliminary laboratory level tests to evaluate properties and performance.
- **Conduct a testing programme to confirm equivalent performance**: This phase is conducted by alternative additive manufacturer.
- **Conduct OEM performance / rig testing to demonstrate equivalent performance**: This phase is conducted by the customers.
- **Collect OEM and Industry approvals and commercialise.**

Table 4-2 summarises a high-level timeline of the substitution process.

Table 4-2: Substitution tasks and indicative timeline

Phase	Phase description	Typical duration
1	Identify possible alternative	~ 1 year
2	Conduct testing program to confirm equivalent performance	~ 1 year
3	Conduct OEM performance/rig testing to demonstrate equivalent performance	~ 2 years
4	Collect OEM Approvals and Industry Approvals	~ 1 year

Overall, a successful substitution campaign typically takes five years or more (if one or more iterations are required) from the moment that evaluation of a potential alternative begins, **assuming that a suitable alternative is successfully identified**.

Considering the unique combination of properties and the excellent performance offered by the PFAS-based anti-foaming additives, identifying a suitable alternative is a challenging effort. it is anticipated that several iterations of the substitution and qualification process may be needed, which could extend the substitution timeline to 10 years or even longer.

It should also be considered that different additive packages and lubricants may need to be developed to meet the different performance specifications of different OEM and Operators Vehicle Maintenance (OVMs). Although several substitution projects may be able to run in parallel, they will require significant resources and laboratory time, which are limiting factors.

4.5 Conclusion on alternatives

Overall, it is clear that currently, none of the potential alternative materials and technologies are suitable to substitute PFAS anti-foam additives used in ExxonMobil lubricants. ExxonMobil is aware that additive suppliers have been actively working on the identification of PFAS-free alternatives. Although a number of alternatives are being scrutinised and assessed by the suppliers, it is ExxonMobil's understanding that to date, none of the evaluated alternatives have proven successful.

A PFAS-free alternative may even require the vehicle industry to make engineering modifications to the driveline system to handle higher spillage rate of lubricants, and lubricant re-supply due to the increased lubricant volume drop from the leak. Additionally, new gear and pump materials may need to be developed to prevent catastrophic wear events due to cavitation wear from entrained air in the lubricants.

Considering the unique combination of properties and the excellent performance offered by the PFAS anti-foaming additive, identifying a suitable alternative implies a major effort, where several iterations of the substitution and qualification process may be needed, which could result in a substitution timeline of more than 10 years.

It should be noted the possibility that, even after such a long time period, a suitable alternative may still not be available, and not due to a lack of effort. Therefore, in case of a time-limited derogation, use of these important lubricant products may still be impacted. It would thus be more realistic to introduce an evaluation of the status of substitution at regular intervals, which would extend a potential time-limited derogation as needed, provided that sufficient effort to substitute can be demonstrated.

5. Socio-economic analysis

5.1 Continued use scenario (aligned with preferred derogation)

The continued use scenario assumes that the use of the antifoam additive in drivetrain lubricants will be covered by a derogation and will thus be allowed to be used in the EEA. Considering the uncertainty in the current wording of the derogation for lubricants, this would mean that it will change to match the requested time-unlimited derogation below:

> **Lubricants <u>and lubricant additives</u> where the use takes place under harsh conditions or the use is needed for safe functioning and safety of vehicles and equipment.**

5.1.1 Market and business trend considerations

5.1.1.1 Lubricant market

In 2017, the world lubricant market was estimated at around 35.7 million tonnes. Accounting for 43% of the global market, Asia-Pacific has the highest share and is the region with the fastest growth in the consumption of lubricants. Europe is responsible for 19% of the lubricants demand, consuming 6.8 Mt of lubricating oil every year. Depending on the particular application, lubricants may be classified into automotive, industrial, process, and marine oils. The automotive segment accounted for 57% of the total market in 2016[23].

5.1.1.2 Automotive Vehicles market in general

According the ACEA, the share of ICE vehicles in new cars purchased in the EU has been following a downward trend, in favour of electric vehicles. In 2018, more than 90% of new passenger cars used either petrol or diesel, with just 1% being battery EVs, and the remaining were hybrid-electric or other types. In 2022, the pure ICE vehicles' share in new cars was just over 50% (52.8%), but EVs accounted for 12% and hybrids for more than 30%[24].

Nevertheless, the market for ICE vehicles is still strong, especially in larger vehicles, such as buses and trucks. Approximately 96% of new trucks and two thirds of new buses in the EU used diesel in 2022[25].

In total, 13.1 million road vehicles were produced in the EU in 2022, accounting for approximately 15.3% of the global production. There were 10.9 million new registrations in the EU, of which 9.3 million were passenger cars. The EU was thus a net exporter of vehicles, having a positive trade balance of €101.9 million in 2022[26].

The vehicle market has not yet reached the levels of before the pandemic, but has been exhibiting growth recently, so the demand for drivetrain components and lubricants is expected to remain strong.

5.1.1.3 Electric Vehicles

The 'European Green Deal' presented by the Commission on 11 December 2019 sets the goal of making Europe the first climate-neutral continent by 2050. Within the context of the Green Deal, the 'Fit for 55' package is a set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament. Specifically, Fit for 55 refers to the EU's target of reducing net

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23 https://www.tandfonline.com/doi/epdf/10.1080/10643389.2020.1771887

24 https://www.acea.auto/figure/fuel-types-of-new-passenger-cars-in-eu/

25 https://www.acea.auto/figure/key-figures-eu-auto-industry/

26 Ibid.

greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels[27]). The proposed package aims to bring EU legislation in line with the 2030 goal.[28]

According to information presented by the European Council, passenger cars and vans are collectively responsible for around 15% of total EU emissions of CO_2[29]. The electromobility transition is therefore crucial to achieving the overall EU emissions reduction targets. Hence, the EU electric vehicle market is expected to show steady growth in the coming years, as described below. The Regulation (EU) 2019/631 currently sets EU fleet-wide carbon dioxide (CO_2) emission performance standards for new passenger cars and new light commercial vehicles (vans) registered in the European Union. As part of the Fit for 55 legislative package, the European Commission is proposing to revise Regulation (EU) 2019/631, setting more ambitious CO_2 emission reduction targets for new cars and vans from 2030 onward.

This is in line with the EU's more ambitious target of not only achieving net emission reductions of at least 55% by 2030 and from **2035 onwards**, the EU target for both cars and vans is a 100% reduction, meaning 0 g CO_2/km.[30]. Figure 5-1 illustrates the evolving emission limits for cars and vans as the goals set within the context of the Green Deal 'Fit for 55' package.

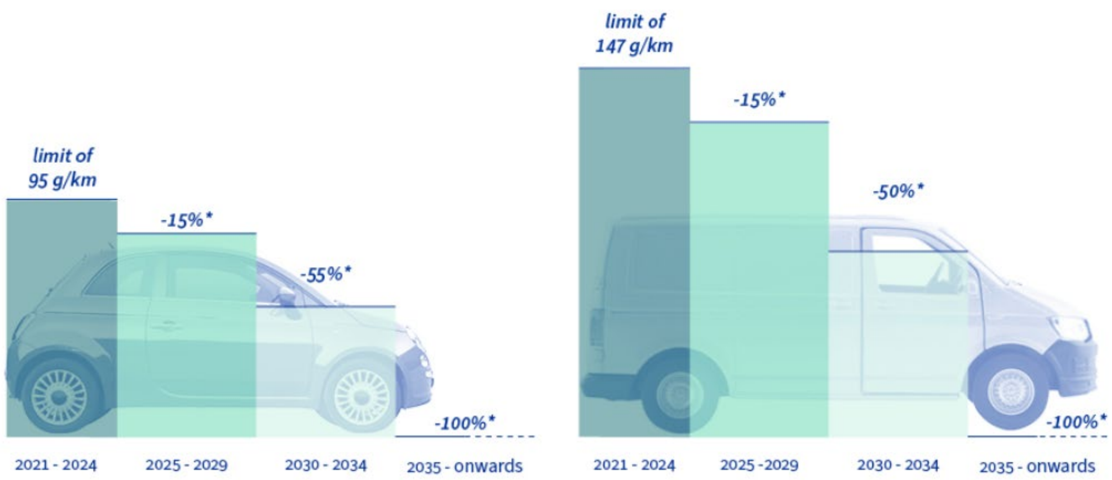

Figure 5-1: Evolving EU emissions limits

Source: European Council (n.d.)[31]

The current trend in new electric vehicle registrations in Europe can be summarised as follows, based on data presented by the European Environment Agency[32]:

- The growth trend in the share of electric car registrations continued in 2022, reaching 23% - according to preliminary data. This includes 13.4% full electric cars.

[27] https://kpmg.com/xx/en/home/insights/2021/11/the-european-green-deal-and-fit-for-55.html

[28] European Commission (2019): European Green Deal summary. Available at: https://www.consilium.europa.eu/en/policies/green-deal/.

[29] European Council (2022): Infographic - Fit for 55: why the EU is toughening CO2 emission standards for cars and vans. Available at: https://www.consilium.europa.eu/en/infographics/fit-for-55-emissions-cars-and-vans/

[30] European Commission (n.d.): CO_2 emission performance standards for cars and vans. Available at https://climate.ec.europa.eu/eu-action/european-green-deal/delivering-european-green-deal/co2-emission-performance-standards-cars-and-vans_en .

[31] European Council (2022): Infographic - Fit for 55: why the EU is toughening CO2 emission standards for cars and vans. Available at: https://www.consilium.europa.eu/en/infographics/fit-for-55-emissions-cars-and-vans/

[32] https://www.eea.europa.eu/en/topics/in-depth/electric-vehicles

- Electric car registrations for 2021 were close to 1.7 million, up from 1.1 million in 2020. This represents an **increase from 11% to 18%** in the share of total new car registrations.
- The uptake of **electric vans** also increased from 2.1% of total new registrations in 2020 to 3.1% in 2021.
- The number of **battery electric and plug-in hybrid cars** are comparable in 2021, while battery electric vehicles accounted for most electric van registrations in 2021.
- The highest shares of new electric vehicles were found in Norway (86%), Iceland (64%), and Sweden (46%). However, there are **large differences across Europe**, with countries in which the percentage of battery electric vehicle registrations remained around 1% of the total new fleet in 2021.

Figure 5-2 shows the new registrations of electric vehicles in the period 2010-2021 broken down by battery electric cars and plug-in electric cars[33].

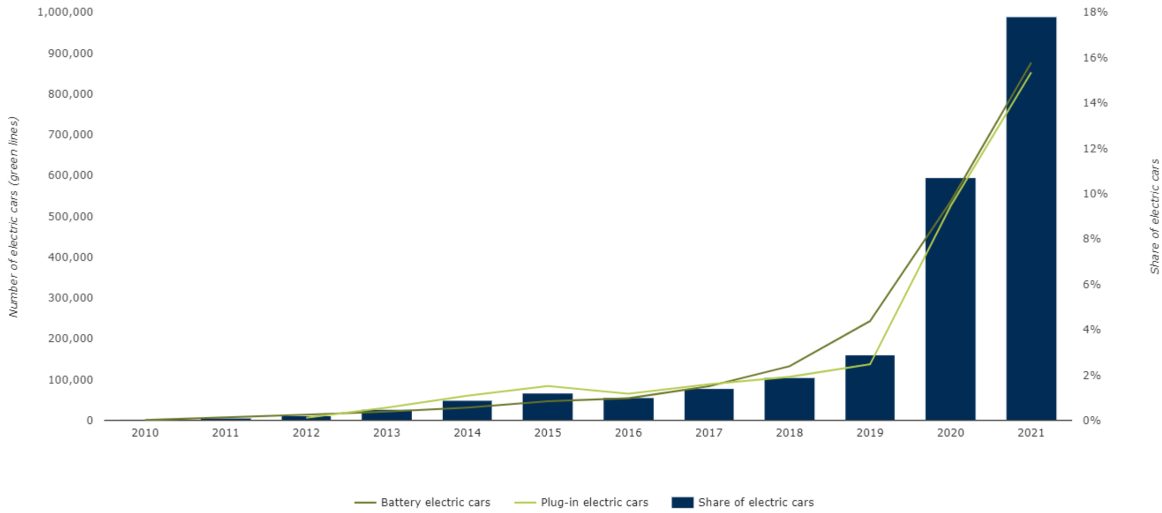

Figure 5-2 New registrations of electric vehicles in the period 2010-2021 (source: European Environment Agency)

The last available report from ACEA[34] confirm this trend also for 2023, where new registrations of battery-electric cars in the EU increased by a significant 66.2%, reaching 158,252 units. This resulted in a market share of 15.1% (up from 10.7% in June 2022) and positioned battery-electric cars as the third most popular choice among new car buyers, overtaking diesel for the first time.

Still according to ACEA, should the PFAS restriction enter into force in 2025/2026, about 18% of the market is expected to be fully electric vehicles, with the remaining fleet still using Internal Combustion Engines (ICE) technology at some level.

The implementation of a potential alternative would require customer requalification activities. As an indicative overview of the types of costs that can be associated with requalification in the automotive sector, Table 5-1 and Table 5-2 provide further details[35], where Table 5-2 looks at the costs

[33] https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles

[34] https://www.acea.auto/files/20230719_PRPC_2306-FINAL.pdf

[35] Please note that these figures were produced by the ACEA in 2017 in response to the public consultation on SEAC's draft opinion for the restriction proposal of diisobutyl phthalate (dibp), dibutyl phthalate (dbp), benzyl butyl phthalate (bbp), bis(2-ethylhexyl) phthalate (dehp) (available via RCOM document at: https://echa.europa.eu/documents/10162/39b71d49-e785-3924-0398-b873dbccc534). It is understood that the figures are considered a very rough estimation – to represent an order of magnitude concerning typical sectors revalidation costs. The figures are presented indicatively, in consideration of this context.

associated with new products, and Table 5-3 looks at the costs associated with changes to existing products.

Table 5-1: Release / validation of new materials and new semi-finished products

Process step	**Average costs (€)**
Administrative issues of product, (e.g. change of the part numbers, …)	10,000
Test of product / material (upper costs if lifetime and ageing have to be assessed)	3,000 – 5,000
Process validation and line trials at suppliers' facilities (can they produce the parts to the right quality and quantity?)	5,000 – 50,000
Functional testing of parts & test reports	3,000
Test of part inference with components in the surrounding area & test reports (migration)	5,000
In total (per material semi-finished product)	**20,000 – 150,000**
After that the components are tested during total vehicles development and are approved Source: ACEA (2017)	

Table 5-2: Changes in current application

Process step	**Average costs (€)**
Administrative issues (product data, changes of drawing / specifications quality control issues)	10,000
Test of product / material (ageing, durability, free of restricted substances, release of volatile organic components, compatibility with other components)	3,000 – 5,000
Process validation and line trials at suppliers' facilities (can they produce the parts to the right quality and quantity?)	5,000 – 50,000
Functional testing of parts & test reports	3,000
Test of part inference with components in the surrounding area & test reports (migration)	5,000
Process validation and line trials at each individual OEM facility (can we manufacture/assemble the parts to the right quality and quantity?) - Multiplication of effort because of decentralisation	5,000 – 50,000
Possible new investment into plant equipment	Not to specify
New part introduction: Use of old stock vs. scrapping old parts (0 to many hundreds of thousands, depending on the amount and value of parts on stock)	-
In total (per material semi-finished product)	**40,000 – 150,000**
Source: ACEA (2017)	

5.1.2 Risks associated with continued use

The lubricants containing the antifoam additive at very low concentrations are used in closed systems, with very low potential for release to the environment during service life. Replenishment and replacement of the lubricant, if required, takes place in professional settings.

In general, the ELV Directive and the WFD set specific instructions for the dismantling of vehicles at the end of life, including specifying waste treatment of the fluids as well as setting specific targets for recyclability and recovery to be achieved by the early design of materials and the implementation of end-of-life management. Nevertheless, collection and treatment of waste lubricant oils can still improve in the EU, and the envisaged target is 85% recycling by 2025.

In summary, it is expected that, if the efficiency of collection and recovery schemes for waste oils in the EU continues to improve, the potential for releases of the very low quantities of the antifoam additive to the environment is extremely low.

5.2 No derogation scenario

5.2.1 Summary of consequences of no derogation scenario

The proposed PFAS restriction includes a single proposed derogation for:

> Lubricants where the use takes place under harsh conditions or the use is needed for safe functioning and safety of equipment.

The wording of the derogation only refers to lubricants as if they were just the base oils and does not mention additives. Additives, which are essential components of a lubricant, are not mentioned in the derogation or in the discussion in the annexes to the restriction proposal. Furthermore, in the Q&A documents from the dossier submitters, published on ECHA's website, the response to question 13.1 does not mention additives at all, when defining "lubricants"[36].

It is thus the concern that the proposed derogation in paragraph 5(s) of the proposed restriction does not cover the antifoam additives.

In such a scenario, it will not be possible to blend, sell or use lubricants containing the particular antifoam additives in the EEA. It may not even be possible to import vehicles/vehicle components that have parts pre-filled with these lubricants, unless a different antifoam additive is used.

Considering that there do not appear to be technically feasible alternatives currently available, and the fact that work on introducing a change to the composition of the lubricant needs to undergo a lengthy certification process, it is very likely that a lubricant without the antifoam additive will not be available when the restriction enters into force.

As a result, all sales of drivetrain lubricants (for ICE and electric vehicles) in the EEA will have to stop. Vehicle manufacturers will either need to use a lubricant with an antifoam additive with different performance characteristics or without an antifoam additive at all. In any case, they will still need to certify their drivetrain components to use the new lubricant.

In the event that the lubricants derogation is not broadened to include additives, the required changes may need to be much broader than that, however. Foam control is a critical performance criterion for drivetrain lubricants, so if there is no viable alternative solution identified, the vehicle industry as a whole may need to make engineering modifications to driveline systems to handle excessive spillage of lubricants, and lubricant re-supply due to the lubricant volume drop from the spillage. Additionally, new gear and pump materials will need to be developed to prevent catastrophic wear events due to cavitation wear from entrained air in the lubricants.

5.2.2 Socioeconomic costs of no derogation scenario

If antifoam additives can no longer be blended into lubricants under a no derogation scenario, the impacts are expected to be twofold. On one hand, there are environmental impacts, as antifoam agents are very effective at releasing the trapped air in the lubricant without generation of bubbles, which can burst, or generation of foam that can rise and result in excessive leakage of the lubricant out of the drivetrain. Oil leakage during service life is released directly to the environment and cannot be contained. Therefore, use of an antifoaming additive can significantly reduce lubricant loss to the environment and also reduce the need for replenishment.

On the other hand, foam control additives also protect the gear systems from wear due to air bubbles bursting between gear contacts (cavitation wear). OEMs will need to re-design their components and

[36] https://echa.europa.eu/documents/10162/2156610/230405_upfas_webinar_qa_ds_en.pdf/3f47fdcc-17c5-4b37-b758-720bb7e462f3?t=1687893645025

parts to ensure that the gears and pumps are more resistant to cavitation wear and that risk of a breakdown or equipment failure is minimised. Another significant cost could be from the potential need for manufacturers to make engineering modifications in their drivetrain drainage systems to manage the higher lubricant spillage.

Such major changes in the design of an automotive part need to follow the same certification process discussed in Section 4.4, which can include several iterations and end up taking more than 10 years to complete. Indicative costs for such changes are presented in Table 5-1 and Table 5-2 above.

In summary, if antifoam additives are not available, this could result in a higher usage of lubricants and potentially greater wear in drivetrain components (e.g., gears, pumps), which could result in more material usage and potentially higher risk of equipment failure.

This is particularly important for the introduction of electric vehicles in the EU vehicle fleet, as redesigning components to ensure reliability and safety could push release of some models several years back or they could be shipped with worse performance and reliability. In any case, it could result in slower adoption of EV by European drivers, which would in turn impact the ability of the EU to meet its ambitions, as envisaged in the EU Green Deal and associated acts.

6. SUMMARY

Antifoam additives are an essential component of drivetrain lubricants, preventing the generation of foam that can lead to increased loss of lubricant to the environment and excessive wear of drivetrain components, such as gears and pumps.

Inability to use these additives in vehicle lubricants could lead to significant impacts for the EU automotive industry, and these consequences also strongly impact electric vehicles, which will impact the EU's climate ambitions as well at the Fit for 55 objectives. The share of electric vehicles in the EU passenger and commercial fleets is increasing and battery-powered vehicles are expected to be the main type in the EU's streets in the coming decades. This should not underestimate the importance of ICE vehicles, which are still produced in significant numbers. In general, the EU automotive industry is among the largest in the world, employing more than 13 million people and manufacturing more than 13 million cars each year.

Antifoam additives, while they are used in very small concentrations in the lubricants, are contributing to vehicle efficiency, safety and reliability, and to reducing loss of lubricants to the environment during vehicle use. Additives are very difficult to substitute, so if they are not included in the lubricants derogation in the PFAS restriction proposal, it may have significant impacts in the reliability and longevity of drivetrain components, if equally performing additives / lubricants are not available in the market.

Therefore, it is requested that the proposed derogation in paragraph 5(s) of the PFAS restriction proposal is reworded to a time-unlimited derogation as below:

> **Lubricants <u>and lubricant additives</u> where the use takes place under harsh conditions or the use is needed for safe functioning and safety of vehicles and equipment.**

Nevertheless, work on alternatives is ongoing, in an effort to improve the environmental footprint of the products, along with the overall performance of lubricants and lubricant additives. As such, and to capture the possibility that an alternative is identified in the future, the validity of the time-unlimited derogation can be re-evaluated at regular intervals, depending on the status and availability of alternative additives.