IAEG Review of Aerospace and Defense Dependencies and Regulatory Action relating to Per- and polyfluorinated alkyl substances (PFAS)

[Publish Date]

Version 1.0

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Contents

Glossary

Abbreviation	Definition
A&D	Aerospace and Defense
AIA	Aerospace Industries Association
APFO	Ammonium pentadecafluorooctanoate
ARN	Assessment of Regulatory Needs
ASD	Aerospace, Security, and Defence Industries Association
BMS	Boeing Military Specification
CAS	Chemical Abstracts Service
CLP	EU Classification, labelling, and packaging regulation[1]
CMR	Carcinogenic, mutagenic, and reproductive toxin
EAAC	Ethoxylates in Aerospace Authorization Consortium
EASA	European Union Aviation Safety Agency
ECHA	European Chemicals Agency
EPA	Environmental Protection Agency (US)
ETFE	Ethylene tetrafluoroethylene
EU	European Union
FAA	Federal Aviation Administration
FASA	Perfluoroalkane sulfonamide
FDA	Food and Drug Administration
FEP	Fluorinated ethylene propylene
FP	Fluoropolymer
FPG	Fluoropolymer Product Group
FPP4EU	Fluoro Products and PFAS for Europe
FT	Fluorotelomer

[1] https://echa.europa.eu/regulations/clp/legislation

Abbreviation	Definition
FTEOs	Fluorotelomer ethoxylates
FTMACs	Fluorotelomer methacrylates
FTOHs	Fluorotelomer alcohols
FTs	Fluorotelomer sulphonates
GCCA	Global Chromates Consortium for Aerospace
GHS	Global harmonized system of classification and labelling of chemicals
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HVACR	Heating, ventilation, and air conditioning
IAEG	International aerospace environmental group
IP	Intellectual property
IT	Information technology
ITRC	International Technology Regulatory Council
JSP	Joint Service Publication
LCD	Liquid crystal display
LED	Light emitting diode
MRO	Maintenance Repair and Overhaul organization
NATO	North Atlantic Treaty Organization
OECD	Organisation for Economic Co-operation and Development
ODSs	Ozone depleting substances
OEM	Original Equipment Manufacturer
PBT	Persistent, bioaccumulative, toxic
PCB	Printed circuit board
PEM	Proton-exchange membrane
PF	Perfluoro

Abbreviation	Definition
PFAAs	Perfluoroalkyl acids
PFAS	Per- and polyfluorinated alkyl substances
PFC	Perfluorinated chemical
PFCAs	Perfluorocaboxylic acids
PFDA	Nonadecafluorodecanoic acid
PFHpA	Perfluoroheptanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononan-1-oic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PFPEs	Perfluoropolyethers
PFSAs	Perfluorosulfonic acids
PLC	Polymer of low concern
POP	Persistent organic pollutant
PPE	Personal protective equipment
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
QPL	Qualified Products List
RAC	Committee for Risk Assessment
REACH	Registration, evaluation, authorization, and restriction of chemicals legislation (EU)[2]
SCCPs	Short chain chlorinated paraffins
SCFPs	Side chain fluorinated polymers
SDS	Safety data sheet

[2] https://echa.europa.eu/regulations/reach/legislation

Abbreviation	Definition
SEAC	Committee for Socioeconomic Analysis
STC	Supplemental Type Certificate
SVHC	Substance of very high concern
VOC	Volatile organic compound
vPvB	Very persistent, very bioaccumulative
WG	Working group
WTI	Weekly tolerable intake

1. Overview of this PFAS report

1.1 Introduction

Recent years have seen a rapid increase in the awareness of risks and harm potentially caused by fluorinated substances among the public and the regulators. Regulators in many jurisdictions are acting to limit usage and exposure. These restrictions are expected to have significant implications for the aerospace and defense (A&D) industry. PFAS are understood to be present across many different applications and fully understanding the nature and extent of uses in the Aerospace & Defense (A&D) industry is very challenging. This report seeks to add to the understanding of the impact global PFAS legislation would have on this industry.

1.1.1 Purpose of this report

The International Aerospace Environmental Group (IAEG) has commissioned this report to understand where PFAS are known to be present and where they may be present, but unknown. It will also illustrate the complexities facing this industry with regard to the identification and understanding of PFAS uses across the A&D supply chain. Finally, it will present the challenges facing the industry in terms of finding substitutes to PFAS across this wide range of applications. This is a preliminary report aimed at gaining an initial understanding of the scale of PFAS use. In particular, this report aims to:

- Highlight and map the key uses of PFAS within A&D currently covered under the proposed EU restriction proposal (both in relation to 'transport' and other related markets), as well as uses not explicitly discussed in the restriction proposal.
- Identify the 'critical' uses of PFAS within A&D, where alternatives may not currently meet specific performance or safety standards.
- Illustrate the challenges of identifying PFAS in specific products or components due to the complexity of the A&D supply chain.

1.1.2 IAEG

IAEG is a non-profit organization that collaborates and shares information regarding environmental solutions for the aerospace and defense (A&D) industry[3]. IAEG has more than 50 member companies that send delegates to multiple work groups (WGs) supporting topics that include substance declarations, replacement technologies, greenhouse gas reporting and REACH authorization and restriction, among others.

WG5 is the REACH Authorization and Restriction work group undertaking activities such as developing tools to help manage substances of very high concern (SVHCs) and supply chain mapping for SVHCs (typically for substances newly recommended or added to Annex XIV)[4]. Previous work has focused on bisphenol A, short chain chlorinated paraffins (SCCPs), hexavalent chromium substances (as listed in Annex XIV), cyclic siloxanes, terphenyl and others. After successful mapping was completed, interested parties involved in WG5 launched the Global Chromates Consortium for Aerospace (GCCA) in 2015 and the Ethoxylates in Aerospace Authorization Consortium (EAAC) in 2018, both of which went on to prepare Authorization applications to support the A&D industry.

[3] https://www.iaeg.com/about
[4] https://www.iaeg.com/workgroups/wg5

1.1.3 PFAS in the A&D Industry

Per- and polyfluorinated alkyl substances (PFAS) have been used widely since the 1950s in a wide variety of industries and products. Although they have been extensively used for decades and are agreed to be fluorinated compounds, there is no agreed definition of PFAS. Research shows that many fluorinated substances are environmentally persistent and bioaccumulative due to the strength of carbon-fluorine bond(s). However, different types of fluorinated chemical structures may not have the same the long-term environmental and human health effects[5]. The identification and definitions of PFAS are covered in Section 1.2.

Fluorinated compounds are used in manufacturing processes and in final products in many industries worldwide. These uses provide opportunities for environmental and human exposure to PFAS. Due to the persistence and bioaccumulation of PFAS, coupled with the varied effects of the different substances, many countries are looking to control the use of PFAS.

The current restriction proposal (2023) within the European Union (EU) encompasses a vast range of PFAS uses (including non-polymeric and polymeric PFAS, covering around 10,000 substances). However, it is noted that A&D uses are not specifically excluded within the restriction proposal, despite being a unique industry. As PFAS uses in A&D are not well understood, there is a risk that the restriction could have an unintentionally severe impact.

1.2 Identification

1.2.1 Overview of definitions

Although there is some disagreement on the definition of PFAS, there is general agreement that it is a large class of thousands of synthetic chemicals containing carbon-fluorine bonds. The specific definitions can be found below.

European Restriction Proposal

PFAS is defined by the EU restriction dossier submitters (Germany, Netherlands, Norway, Denmark and Sweden) as "fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon (without any H/Cl/Br/I atom attached to it)"[6].

Organisation for Economic Co-operation and Development

"PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e., with a few noted exceptions, any chemical with at least a perfluorinated methyl group ($-CF_3$-) or a perfluorinated methylene group ($-CF_2-$) is a PFAS"[7].

[5] https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm#:~:text=PFAS%20are%20used%20in%20the,or%20breathing%20air%20containing%20PFAS

[6] https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea

[7] https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/aboutpfass/

United States Environmental Protection Agency

The United States Environmental Protection Agency's (US EPA) working PFAS structure definition is "a structure that contains the unit R-CF_2-CF(R')(R"), where R, R', and R" do not equal "H" and the carbon–carbon bond is saturated (note: branching, heteroatoms, and cyclic structures are included)[8].

Others

Additional definitions used in other jurisdictions, such as by the US DoD[9] and by the United Kingdom[10].

PFAS can be split into two categories, non-polymeric and polymeric, as shown in Figure 1.1.

1.2.2 Non-polymeric PFAS

Non-polymeric PFAS can be further split into

- polyfluorinated alkyl substances in which not all carbons are fully fluorinated, such as fluorotelomer-based substances; and
- polyfluoroalkyl ether carboxylic acids and perfluorinated alkyl substances in which the carbons are fully fluorinated, such as perfluoroalkyl acids (PFAAs)[11] which include perfluoroalkyl carboxylic acids (PFCAs) and sulfonic acids (PFSAs).

PFAAs can be named using the following system:

PFXY

Where PF is perfluoro, X is the carbon chain length (using the hydrocarbon naming system), and Y is the functional group (with A for carboxylic acids and S for sulfonic acids).

For example, PFBA and PFBS, where B=*buta* (4 carbons); A = *carboxylate or carboxylic acid*; S= *sulfonate or sulfonic acid*.

For PFCAs, carbon chains of four to seven are considered short chain, and carbon chains of eight and above are long chain. For PFSAs, carbon chains of four to five are considered short chain, and carbon chains of six and above are long chain[12].

As polyfluoroalkyl substances are not fully fluorinated, the naming system used is slightly different as follows:

n:x FTZ

Where n is the number of fully fluorinated carbons, x is the number of non-fully fluorinated carbons, FT is fluorotelomer, and Z is the end functional group (with OH for alcohols, SA for sulfonic acids, and CA for carboxylic acids).

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[8] https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf

[9] 116th Congress Text - S.1790 - 116th Congress (2019-2020): National Defense Authorization Act for Fiscal Year 2020. 116th Congress. 2019. https://www.congress.gov/bill/116th-congress/senate-bill/1790/text.

[10] A narrower definition than the EU/OECD definition is used in the UK analysis of the most appropriate regulatory management options for PFAS from March 2023: https://www.hse.gov.uk/REACH/assets/docs/pfas-rmoa.pdf.

[11] https://pfas-dev.itrcweb.org/wp-content/uploads/2020/10/naming_conventions_508_2020Aug_Final.pd

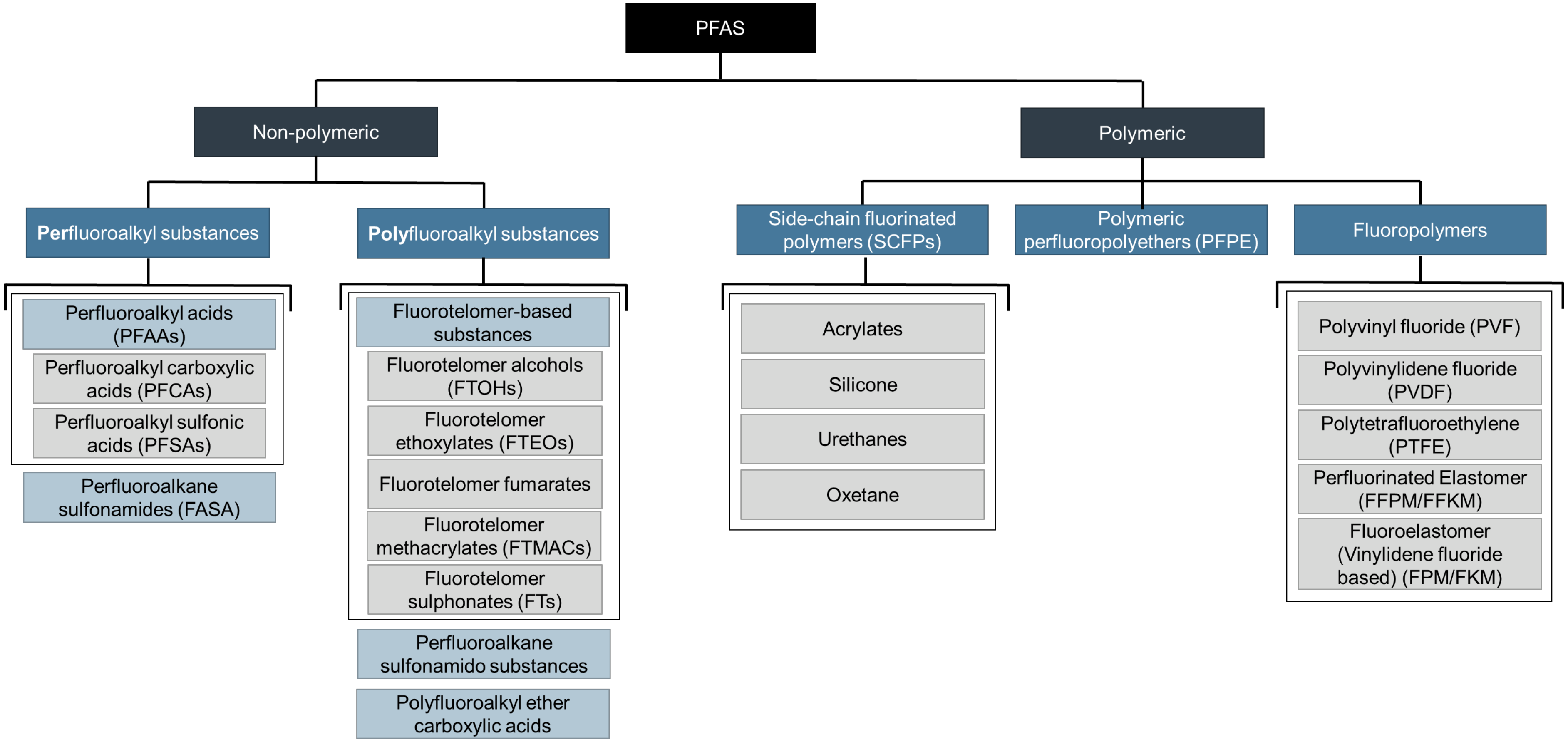
[12] See OECD. 2013. OECD/UNEP Global PFC Group, Synthesis paper on per- and polyfluorinated chemicals (PFCs). Paris: Health and Safety Environment, Environment Directorate, OECD. https://www.oecd.org/env/ehs/risk-management/PFC_FINAL-Web.pdf

There are several PFAS that are commonly referred to, such as perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonic acid (PFHxS).

1.2.3 Polymeric PFAS

Polymeric PFAS include fluoropolymers, side chain fluorinated polymers (SCFPs), and polymeric perfluoropolyethers (polymerics PFPE). Fluoropolymers are carbon only backbones with fluorine attached directly to the backbone, such as polyvinylidene fluoride (PVDF) and polytetrafluoroethylene (PTFE). SCFPs are nonfluorinated carbon backbones with polyfluoroalkyl (and sometimes perfluoroalkyl) side chains. Polymeric PFPE consist of backbones containing carbon and oxygen with fluorine directly attached to carbon.

Figure 1.1 Categories of PFAS (adapted from ITRC, 2020[13])



[13] Interstate Technology and Regulatory Council, 2020. Naming Conventions for Per- and Polyfluoroalkyl Substances (PFAS). Available at: https://pfas-dev.itrcweb.org/wp-content/uploads/2020/10/naming_conventions_508_2020Aug_Final.pdf

1.3 Properties of concern

1.3.1 Overview

The acronym PFAS encompasses a multitude of different molecules with various carbon chain lengths, side groups, and functional groups. The more soluble the PFAS is in water, the more mobile the PFAS is through the environment. The mobility contributes to the potential for long-range transport of the substance and can increase the exposure and absorption potential of the PFAS resulting in further bioaccumulation. Mammalian studies have found that PFAS are absorbed and distributed through various tissues, and that some PFAS have a long half-life in the body[6]. There is evidence that some PFAS interact with hormone systems, resulting in those substances being classified as endocrine disruptors. Some PFAS have been found to interfere with the liver, kidney, thyroid, immune system, and reproductive system. The way PFAS are metabolized in the body can also have an effect on human health, and it has been found that the human body does not metabolize PFAS the same way as in some other mammals. This has resulted in significant challenges understanding the impacts of PFAS on human health, as any testing in animals is not representative of the effects on humans and it is difficult to find humans that have no PFAS exposure to study during their lifetimes[14].

Polymeric PFAS may not have the same hazard properties or fate/transport tendencies of non-polymeric PFAS. Polymeric PFAS, such as fluoropolymers, are undergoing evaluation to understand if they meet the OECD definition of polymers of low concern (PLC) but the different environmental and health fates of the various substances present a unique challenge in easily classifying PFAS as PLCs[15, 16, 17]. However, over time the C-C bonds in polymeric PFAS can degrade, producing non-polymeric PFAS with strong C-F bonds remaining[6]. Some Non-polymeric PFAS has been shown to be environmentally persistent and bioaccumulative and have a high mobility in water and/or air[6]. Their persistence in the environment can lead to the transfer of PFAS from one environmental compartment to another (such as from soil to water) remaining in the environment for decades.

No single hazard classification can be assigned to the group.

1.3.2 Harmonized classification and labelling

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) proposes harmonized hazard communication elements and endpoints. However, any harmonized classifications themselves are the responsibility of the regulating authority in each jurisdiction[18].

Within the European Union (EU), the Classification, Labelling and Packaging Regulation (CLP) ((EC) No 1272/2008) is aligned with the GHS[19]. There are currently five PFAS that have a harmonized classification and labelling, and one additional substance group that is currently undergoing review (Table 1.1).

However, the vast majority of PFAS do not have harmonized classification and labelling, reflecting the sheer number (>10,000) of individual PFAS that exist. Some companies have classified the hazards of their

[14] Martyn, K., et al. The PFAS Health Study: Systematic Literature Review. ANU National Centre for Epidemiology and Population Health (NCEPH). ANU Research Publication, 2018. DOI: 10.25911/KW6T-7H44

[15] https://setac.onlinelibrary.wiley.com/doi/epdf/10.1002/ieam.4035

[16] Korzeniowski, S. H., et al. A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers. Integrated Environmental Assessment and Management (19) 2: 326-354. Available at https://setac.onlinelibrary.wiley.com/doi/epdf/10.1002/ieam.4646

[17] Lohmann, R., et. Al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environ. Sci. Technol. 2020, 54, 20, 12820–12828. Available at https://pubs.acs.org/doi/10.1021/acs.est.0c03244

[18] https://unece.org/about-ghs

[19] https://echa.europa.eu/regulations/clp/understanding-clp

substances (“self-classification); however not all have, which has led to a lack of overall harmonization amongst the substances. In the future, it is likely that there will be further classifications, both harmonized (where classification should be consistent among companies) or self-classification (where inconsistencies may arise).

Table 1.1 PFAS with EU harmonized classification and labelling

Substance name	CAS number(s)	Hazard	Labelling	Pictogram
Perfluorooctanoic acid (PFOA)	CAS no. 335-67-1	• Acute Tox. 4 H302 • Eye Dam. 1 H318 • Acture Tox. 4 H332 • Carc.2 H351 • Lact. H362 • STOT RE 1 H372 (liver) • Repr.1B H360D	• Corrosive (may cause severe skin and eye damage, may be corrosive to metals) (GHS05) • Irritant, sensitizing, harmful (GHS07) • Long-term health hazard (GHS08)	
Ammonium pentadecafluorooctanoate (APFO)	CAS no. 3825-26-1	• Acute Tox. 4 H302 • Eye Dam. 1 H318 • Acture Tox. 4 H332 • Carc.2 H351 • Lact. H362 • STOT RE 1 H372 (liver) • Repr.1B H360D	• Corrosive (may cause severe skin and eye damage, may be corrosive to metals) (GHS05) • Irritant, sensitizing, harmful (GHS07) • Long-term health hazard (GHS08)	

Substance name	CAS number(s)	Hazard	Labelling	Pictogram
Perfluorononan-1-oic acid (PFNA) and its sodium and ammonium salts	CAS no. 4149-60-4	• Acute Tox. 4 H302 • Eye Dam. 1 H318 • Acture Tox. 4 H332 • Carc.2 H351 • Lact. H362 • STOT RE 1 H372 (liver, thymus, spleen) • Repr.1B H360Df	• Corrosive (may cause severe skin and eye damage, may be corrosive to metals) (GHS05) • Irritant, sensitizing, harmful (GHS07) • Long-term health hazard (GHS08)	
Nonadecafluorodecanoic acid (PFDA) and its sodium and ammonium salts	CAS no.: 335-76-2; 3830-45-3; 3108-42-7	• Carc. 2 H351 • Lact. H362 • Repr. 1B H360Df	• Long-term health hazard (GHS08)	
Perfluoroheptanoic acid (PFHpA)	CAS no.: 20109-59-5; 6130-43-4; 21049-36-5; 375-85-9	• STOT RE 1 H372 • Repr. 1B H360D	• Long-term health hazard (GHS08)	
3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctan-1-ol (6:2 FTOH)*	CAS no. 647-42-7	No CLP/GHS		

**The European Commission is currently considering an opinion provided by the Committee for Risk Assessment (RAC) along with other EU countries for inclusion in CLP regulation.*

1.3.3 REACH Substances of Very High Concern

The Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulation (EC 1907/2006)[20] in the EU defines Substances of Very High Concern (SVHCs) as those that that are persistent, bioaccumulative, and/or toxic (carcinogenic, mutagenic, or reproductive toxicity (CMR)) (PBT) or very persistent very bioaccumulative (vPvB), or of equivalent concern[21]. Substances on the SVHC candidate list must be disclosed to the recipient if they are present above 0.1% in a mixture or an article. Candidate list substances can be added to the Authorization list (REACH Annex XIV) which prohibits their use unless companies have a specific authorization for a specific use.

A number of PFAS have been added to the EU SVHC candidate list in the past 10 years, as detailed in the table below (Table 1.2).

[20] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006R1907-20221217
[21] https://echa.europa.eu/-/chemicals-in-our-life-chemicals-of-concern-svhc

Table 1.2 PFAS on the SVHC Candidate List

Substance name	CAS number(s)	Year added	Reason for inclusion*
Pentadecafluorooctanoic acid (PFOA)	CAS no.: 335-67-1	2013	• Toxic for reproduction • PBT
Perfluorohexane-1-sulphonic acid (PFHxS) and its salts	Includes 39 distinct CAS no.	2017	• vPvB
Nonadecafluorodecanoic acid (PFDA) and its sodium and ammonium salts	CAS no.: 335-76-2; 3830-45-3; 3108-42-7	2017	• Toxic for reproduction • PBT
Perfluorobutane sulfonic acid (PFBS) and its salts	Includes 12 distinct CAS no.	2020	• Equivalent level of concern having probable serious effects to human health • Equivalent level of concern having probable serious effects to the environment
Perfluoroheptanoic acid (PFHpA) and its salts	CAS no.: 20109-59-5; 6130-43-4; 21049-36-5; 375-85-9	2023	• Toxic for reproduction • PBT • vPvB • Equivalent level of concern having probable serious effects to human health • Equivalent level of concern having probable serious effects to the environment
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid, its salts and its acyl halides (HFPO-DA)	Includes 6 distinct CAS no.	2022	• PBT • vPvB • Equivalent level of concern having probable serious effects to human health • Equivalent level of concern having probable serious effects to the environment

**https://echa.europa.eu/candidate-list-table*

1.4 Regulatory activity

1.4.1 Overview

PFAS have been gaining global consumer and regulatory attention for several years. Their widespread use across various industries, coupled with mounting research on their inherent persistent, bioaccumulative, and/or toxic properties, has prompted action to significantly decrease or eliminate PFAS manufacture and use. Regulatory action on PFAS is being undertaken at regional, national, and global levels[22].

As part of ongoing efforts to understand global regulatory activity, IAEG Emerging Global Regulation Work Group (WG) 9 has prepared a report of the regulatory status as of 2023 (see Appendix A[23]). For an overview, the reader is directed to Appendix A. This section (1.4) provides a brief overview of key information, based on the aforementioned report covering the history of regulatory activity on PFAS in different regions, additional supplemental information, and a summary of the current EU restriction proposal. Whilst there has been much activity on regulating PFAS, the primary focus has been on addressing concerns from non-polymeric substances.

1.4.2 History

1.4.2.1 Global

Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty adopted in 2001 (entry to force 2004) to protect human health and the environment from chemicals that are bioaccumulative, persistent, and have harmful impacts on human health or the environment[24]. There are currently 186 parties to the convention who have ratified, accepted, approved, or accessed, and 152 of those parties have signed a succession to signature[25]. In 2009, perfluorooctane sulfonic acid (PFOS) was added to Annex B, restricting the use of PFOS to the production, with exemptions for specified uses including hard metal plating, insect baits, and firefighting foams[26]. Perfluorooctanoic acid (PFOA), its salts and related compounds were listed under Annex A (elimination) of the Stockholm Convention in 2019 and perfluorohexane sulfonic acid (PFHxS), its salts and related compounds were added similarly in 2022[26]. While PFHxS has no production or use exemptions, PFOA has some derogations for the following uses: textiles for oil and water repellence as well as aviation hydraulic fluid. As of 1 January 2023, PFOA containing firefighting foams are prohibited if the foam cannot be contained or collected once the fire is extinguished, and from July 2025 onwards will be banned completely. Within the EU, chemicals listed under the Stockholm Convention are added to the EU POPs Regulation ((EU) No 2019/1021)[27]. Long chain PFCAs are currently proposed for listing under Stockholm Convention as well and could be listed as early as 2025.

Kigali amendment to the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in 1987 and aims to phase down the consumption and production of various ozone depleting substances (ODS) such as

[22] For example, see: https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/countryinformation/
[23] https://www.iaeg.com/binaries/content/assets/iaeg/wg9/iaeg_pfas_fact_sheet_wg9.pdf
[24] https://www.pops.int/TheConvention/Overview/tabid/3351/Default.aspx
[25] https://www.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx
[26] https://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx
[27] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02019R1021-20230610

hydrochlorofluorocarbons (HCFCs)[28]. Hydrofluorocarbons (HFCs) (a type of PFAS) were introduced as a substitute for HCFCs; however, it was noted that HFC emissions are rapidly growing and, without control, the global effort to keep temperatures from rising will be challenged. In 2016 the Kigali amendment[29] was introduced to phase down HFCs with a gradual reduction by 80-85% over the following 30 years. It should be noted that certain non-HFC alternatives, largely olefins such as R-1234YF, may contain fluorine and be classified as PFAS. These alternative refrigerants are identified as meeting the intent of the Kigali Amendments to reduce the impact to the Ozone as they contain no or low Ozone Depleting Potential and/or Global Warming Potential but are nonetheless PFAS.

1.4.2.2 Europe

Chemical regulations

The REACH regulation entered into force within the EU in 2007. REACH addresses the import, production, and use of chemical substances, along with impacts on human health and the environment[30]. The POPs regulation entered into force within the EU in 2019 and is the EU's implementation of the Stockholm Convention, adapting substances listed under the Convention and outlining the restriction on production, marketing, and use within the EU as well as the expectations for waste management[31]. Substances on the REACH Annex XVII list and SVHC candidate list can also be added to the POPs regulation, where the EU can further identify and propose new POPs to be added to the Convention[32].

The regulatory approach to addressing the risks posed by PFAS in the EU has thus far been on a substance-by-substance basis and has focused to a large degree on PFOS and PFOA.

At the EU level, PFAS are regulated by several pieces of legislation. These regulations cover the general production, sale, import and export of chemical products, the use of PFAS in specific products or applications, occupational exposure, presence in waste streams, and acceptable levels in the environment.

Several PFAS are listed in Annex XVII under REACH, which restricts the use of the substances with specific exemptions.[33] These restrictions and proposed restrictions are as follows:

- PFOS, which was amended in 2017 from Annex XVII to the EU POPs regulation;
- (3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl) silanetriol and any of its mono-, di- or tri- O-(alkyl) derivatives (TDFAs) placed on Annex XVII in 2019;
- PFOA, salts and related substances which was amended in 2021 from Annex XVII to the EU POPs regulation;
- C_9-C_{14} PFCAs placed on Annex XVII in 2021;
- PFHxS and related substances are expected to be included in the EU POPs Regulation as proposed in 2021;
- Aqueous firefighting foams placed on Annex XVII in 2023; and
- PFHxA salts and related substances has an Annex XVII restriction proposal awaiting decision as of 2023.

[28] https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol
[29] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-2-f&chapter=27&clang=_en
[30] https://environment.ec.europa.eu/topics/chemicals/reach-regulation_en
[31] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1021
[32] https://echa.europa.eu/understanding-pops
[33] https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

The European Commission has recommended that actions at the EU level should be taken to ensure that the use of all PFAS substances is phased out unless proven essential for society[34].

Despite leaving the EU at the start of 2020, the United Kingdom (UK) also carried over several EU regulations into UK law, such as the REACH and POPs regulations. The UK has published the outputs of its regulatory management position on PFAS, and any resulting UK PFAS restriction proposal will fall under UK REACH. It is important to note that the UK approach to PFAS regulation has differed from the EU approach; the UK regulatory management options analysis for PFAS[35] was only published in April 2023, two months after the EU restriction proposal was published, and suggests a different approach will be adopted.

Environmental legislation

A number of environmental directives also address PFAS, with the Water Framework Directive (WFD) listing PFOS and PFOA as priority substances and setting EQS values[36,37]. In addition, the Drinking Water Directive specifies the quality of water for human consumption, with over 70 PFAS covered under the directive[38].

Similarly, the Waste Framework Directive Annex III contains multiple PFAS (including PFHxS, PFHpA, PFBA, PFPeA, PFHxA, and PFBS) which meet the criteria for properties of waste set forth within the directive, rendering waste containing these PFAS as hazardous[39].

The UK has also adopted (or rather retained) a Drinking Water Directive, and a Waste Framework Directive similar to those within the EU; however, the concentrations and monitoring is different.

Specific product legislation

Along with specific chemicals and environmental legislation, the EU has also added some PFAS to the Food Contact Materials Regulation and the Cosmetic Products Regulation. Under the Food Contact Materials Regulation, materials that are intended to come in contact with food are regulated, with PFOA no longer permitted for use in food contact materials[40]. The European Food Safety Agency has set the weekly tolerable intake (WTI) to 4.4 ng/kg of body weight for PFOA, PFOS, PFNA, and PFHxS[37]. According to a position statement published by the Royal Society of Chemistry, the UK Committee on Toxicity has not yet recommended the same WTI be adopted[41].

The Cosmetic Products Regulation restricts the use of several PFAS (including PFOS, PFOPA, and PTFE) from use in cosmetics products[42]. The UK has also adopted (retained) the Cosmetic Products Regulation, including restrictions on these PFAS.

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[34] European Commission (2020) Chemicals Strategy for Sustainability - Towards a Toxic-Free Environment, https://echa.europa.eu/hot-topics/chemicals-strategy-for-sustainability#:~:text=The%20Commission's%20strategy%20provides%20an,chemicals%20when%20assessing%20chemical%20risks.

[35] https://www.hse.gov.uk/reach/assets/docs/pfas-rmoa.pdf

[36] https://eur-lex.europa.eu/eli/dir/2000/60/oj

[37] https://www.hbm4eu.eu/wp-content/uploads/2022/07/PFAS_Substance-report.pdf

[38] https://eur-lex.europa.eu/eli/dir/2020/2184/oj

[39] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705

[40] https://eur-lex.europa.eu/eli/reg/2004/1935/2021-03-27

[41] https://www.rsc.org/globalassets/04-campaigning-outreach/policy/environment-health-safety-policy/rsc-policy-position-on-pfas-in-uk-drinking-water.pdf

[42] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009R1223

1.4.2.2.1 Summary of EU Restriction Proposal (2023)

Outline of the problem

In early 2023, five EU Member States submitted a proposal to the European Chemicals Agency (ECHA) to restrict the manufacture, placing on the market, and use of PFAS under REACH[43].

The proposed restriction is intended to address the risks to human health and the environment posed by PFAS. The Member States highlight[44] that the PFAS in scope of the restriction – or their degradation products – are very persistent and may remain in the environment from decades to centuries. Many PFAS have adverse health and environmental effects, are bioaccumulative, mobile, and have been proven to reach remote and pristine areas of the world.

The Member States cite the high persistence, ongoing emissions, and lack of appropriate remediation measures, as being responsible for constant and irreversible increases in the environment and associated negative effects for human health and the environment.

Proposed scope

The scope of the restriction would cover around 10,000 individual substances, with PFAS being defined as "Any substance that contains at least one fully fluorinated methyl (CF_3-) or methylene (-CF_2-) carbon atom (without any H/Cl/Br/I attached to it)". Some structural elements are excluded[45].

The scope of the restriction includes both **polymeric** and **non-polymeric** PFAS. The restriction proposal highlights that polymeric (and oligomeric) PFASs may generate and/or release non-polymeric PFAS, at any point in their life cycle, in particular at end-of life. Polymeric PFAS are therefore considered to contribute to the overall exposure to and risks of non-polymeric PFAS. Some scientific studies support this position[46].

Proposed conditions

Under the proposed restriction, it would not be possible to manufacture, use or place on the market these PFAS as substances on their own; as a constituent in another substance; in a mixture; or in an article. Specific concentration limits would apply[47]. This would apply from 18 months after entry into force of the restriction, which is expected to be 2025 at the earliest.

Relevant proposed derogations

The restriction proposal includes a wide range of derogations for different uses of polymeric and non-polymeric PFAS.

- Proposed and 'possible' derogations for non-polymeric PFAS.

[43] https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal

[44] Information note: Consultation on a proposed restriction on the manufacture, placing on the market and use of per- and polyfluoroalkyl substances (PFAS), prepared by the authorities of Germany, the Netherlands, Denmark, Norway, and Sweden, 22 March 2023.

[45] A substance that only contains the following structural elements is excluded from the scope of the restriction: CF3-X or X-CF2-X', where X = -OR or -NRR' and X' = methyl (-CH_3), methylene (-CH_2-), an aromatic group, a carbonyl group (-C(O)-), -OR'', -SR'' or –NR''R'''; and where R/R'/R''/R''' is a hydrogen (-H), methyl (-CH3), methylene (-CH2-), an aromatic group or a carbonyl group (-C(O)-).

[46] *Environ. Sci.: Processes Impacts***,** 2024, https://doi.org/10.1039/D3EM00426K

[47] (i) 25 ppb for any PFAS as measured with targeted PFAS analysis (polymeric PFASs excluded); (ii) 250 ppb for the sum of PFASs measured as sum of targeted PFAS analysis, optionally with prior degradation of precursors (polymeric PFASs excluded); (iii) 50 ppm for PFASs (polymeric PFASs included).

- Proposed and ‘possible’ derogations for polymeric PFAS.

The ‘possible’ derogations relate to cases where the evidence base is currently considered too weak and where additional evidence is needed from the Annex XV consultation to justify the derogations.

However, all these derogations are time-limited, with the longest derogation proposed to expire 13.5 years after entry into force of the restriction.

There are, however, full derogations (i.e., exempted from the proposal without time limit) for active substances in biocidal products, plant protection products and medicinal products.

The tables below summarize the proposed derogations and possible derogations. Derogations related to medical devices are not included.

Table 1.3 Proposed and possible derogations for non-polymeric PFAS[48]

Use	Timescale (after EIF)
Proposed derogations	
a. polymerization aids in production of polymeric PFAS (exc. PTFE, PVDF and FKM)	6.5 years
b, c, d. textiles used in certain personal protective equipment (PPE) and their re-impregnation	13.5 years
e. textiles for certain filtration and separation media	6.5 years
f. refrigerants (for below -50 °C)	6.5 years
g, h. refrigerants in laboratory test and measurement equipment, centrifuges	13.5 years
i. maintenance and refilling of existing HVACR equipment with no drop-in alternative	13.5 years
j. refrigerants in HVACR required by national safety standards/codes	No time limit specified
k. industrial precision cleaning fluids	13.5 years
l. cleaning fluids for oxygen-enriched environments	13.5 years
m. certain clean fire suppressing agents	13.5 years
n. diagnostic laboratory testing	13.5 years
o. additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry	13.5 years
p. refrigerants in certain mobile air conditioning systems	6.5 years

[48] The lettering corresponds to the lettering in the ‘Proposed restriction – Annex XVII entry PFASs (Restriction Option 2)’ table starting on page 4 of the Annex XVII report.

Use	**Timescale (after EIF)**
q. refrigerants in non-marine transport refrigeration	6.5 years
r. insulating gases in high-voltage switchgear	6.5 years
s. lubricants used in harsh conditions or required for safety	13.5 years
t. calibration of measurement instruments / analytical reference materials	No time limit specified

Possible derogations	
v. hard chrome plating	6.5 years
x, y. certain 3D printing applications	13.5 years
z. propellants for aerosols requiring non-flammability / high technical performance	13.5 years
dd. refrigerants and mobile A/C in military vehicles	13.5 years
ee. semiconductor manufacturing	13.5 years

Source: Annex XV report, proposal for a restriction, Per- and polyfluoroalkyl substances (PFASs), 22 March 2023. Note, some uses are excluded from this table where they are clearly not relevant to aerospace and defense uses.

Table 1.4 – Proposed and possible derogations for polymeric PFAS

Use	Timescale (after EIF)
Proposed derogations	
e. proton-exchange membrane (PEM) fuel cells	6.5 years
f. petroleum and mining industry	13.5 years
Possible derogations	
o. applications affecting the proper functioning related to the safety of transport vehicles, and affecting the safety of operators, passengers or goods	13.5 years

Source: Annex XV report, proposal for a restriction, Per- and polyfluoroalkyl substances (PFASs), 22 March 2023. Note, various medical and bakeware uses are also included among the proposed/possible derogations in the restriction proposal. These are excluded from the above table.

Current status and timeline for restriction

At the time of writing (February 2024), the public consultation for the proposed EU restriction has closed. Over five thousand comments have been submitted for the consultation and are currently being reviewed by the proposing countries. The Committee on Risk Assessment (RAC) and the Committee on Socioeconomic Analysis (SEAC) are expected to publish opinions in early 2024 regarding the proposed restriction. The restriction proposal may also undergo revisions based on the opinions of the Committees and the public consultation responses before going to the Commission for a decision. The Commission is provisionally expected to make a decision in 2025, and if the restriction proposal is accepted, the restriction will enter into force the same year. The restriction would become effective in 2026/2027.

1.4.2.3 Other regions

Information for other PFAS restrictions in other regions is presented below. More detailed information can also be found in the WG9 report in Annex A, mentioned above.

United States

While the risks of PFAS have long been recognized within the USA, the first PFAS ban was in 2016 by the Food and Drug Administration (FDA), covering long-chain PFAS in food contact materials. In 2019, the US EPA introduced the PFAS Action Act which establishes destruction and disposal guidelines for a range of materials and requires five-year reviews of all PFAS (according to the OECD definition) to assess further needs[49]. The National Defense Authorization Act of 2019 restricts the Pentagon's usage of fluorinated firefighting foam after 2022 and prohibits use after 2023[50]. Section 347 of the 2020 NDAA prompts certain federal contractors to likewise cease use of PFAS-containing AFFF by October 2024. In January 2023, NAVSEA published an alternative Military Standard for Fluorine Free Foams (F3) to be used in conjunction with the 2020 NDAA. In October 2024, the US Department of Defense (DOD) published a report to Congress outlining critical uses of PFAS by the Military[51].

In October 2021 the US EPA shared the PFAS Strategic Roadmap, which provides a timeline over which the US EPA aims to take specific actions and implement new policies to protect human health and the environment[52]. The US EPA also announced draft maximum contaminant levels (MCL) for a national primary drinking water regulation under the Safe Drinking Water Act in 2023. The draft MCL is tentatively scheduled for finalization around September 2024 per the Unified Agenda [53].at

EPA recently amended its community right-to-know law, EPCRA to add a list of PFAS subject to release reporting.

EPA is also working on draft rulemakings to classify PFAS as hazardous substances under its broad Superfund laws and classification as a hazardous constituent under its hazardous waste law, the Resource Conservation and Recovery Act or RCRA.

While there are no current Federal restrictions on the use of PFAS, a number of US states (such as Minnesota[54]) have passed laws on PFAS (both non-polymeric and polymeric), but case-by-case) in consumer and commercial products, and further regulations and restrictions are currently being drafted.

Canada and Mexico

Canada's Federal Government found that PFOA is of ecological concern in 2012, and in support of the Stockholm Convention prohibited PFOS (aside from specified exemptions) in 2016. However, Health Canada has maintained that PFOS and PFOA are not a concern at current exposure levels[6]. Transport Canada allowed for the use of PFAS-free firefighting foams in 2019 alongside the use of traditional PFAS-containing firefighting foams, which is seen as a precautionary approach to the potential restriction of PFAS.

The Mexican Ministry of Environment has also proposed restriction of the import and export of PFOA and PFOS as of 2022; however, the current status of the regulation is unknown[55].

[49] https://www.epa.gov/sites/default/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf

[50] https://www.armed-services.senate.gov/imo/media/doc/FY19%20NDAA%20Executive%20Summary%20FINAL.pdf#:~:text=The%20NDAA%20supports%20a%20total,billion%20for%20Overseas%20Contingency%20Operations.

[51] https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/reports/Report-on-Critical-PFAS-Substance-Uses.pdf.

[52] https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024

[53] https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202310&RIN=2040-AG18

[54] https://www.saferstates.org/press-room/first-in-nation-ban-on-pfas-forever-chemicals-in-menstrual-products-cleaning-ingredients-cookware-and-dental-floss-signed-by-minnesota-governor-today/#:~:text=The%20new%20law%20bans%20all,several%20products%20starting%20in%202025.

[55] Appendix A

Australia

Australia banned the use of PFAS firefighting foams for training or demonstration purposes in early 2021, followed by the restriction of the use of PFAS firefighting foams in late 2022. The restriction outlines the definition of a 'catastrophic' fire in which the use of PFAS firefighting foams is allowed[56].

New Zealand

As of 2023, the use of firefighting foams containing non-polymeric PFAS in uncontained systems is prohibited, with a complete ban on PFAS containing firefighting foams after December 2025[57].

Asia

China, Japan, and South Korea are currently working to restrict and manage the use of PFOA, PFOS, and PFHxS (along with some other PFAS) in accordance with the Stockholm Convention[55].

[56] https://www.epa.nsw.gov.au/your-environment/contaminated-land/regulation-of-pfas-firefighting-foams#:~:text=The%20Protection%20of%20the%20Environment,relevant%20authorities%20and%20exempt%20entities.

[57] https://www.fireandemergency.nz/research-and-reports/per-and-poly-fluoroalkyl-substances-pfas/

2. Identified critical uses of PFAS for Aerospace and Defense

2.1 Introduction

As discussed in Section 1.4.2, in the proposed EU restriction there is a broad coverage of PFAS used in 'transport'. While this will include some if not many uses relevant to A&D, it should not be considered that the uses of PFAS in A&D are limited to this part of the restriction proposal. Many of the other uses covered in the restriction proposal outside of, or overlapping with, the transport industry, will be of relevance to A&D industries[58].

As part of the preliminary research conducted into the implications of a restriction proposal on the A&D industry, IAEG WG5 membership[59] has been surveyed to ascertain:

- which of the use categories covered in the restriction proposal are relevant to their membership,
- which uses include products/components that are known to or likely to contain polymeric or non-polymeric PFAS; and
- which uses are considered critical in their operations.

In some cases, uses of products that are known/likely to contain PFAS have been identified by IAEG that are not explicitly covered in the restriction proposal. This is an indicator that more investigation and mapping of the supply chain is needed to fully understand the uses of PFAS in the A&D Industry, and the implication of the proposed restriction (and potential need for derogations) in their supply chain. It is understood that uses which are not explicitly specified and included in a derogation in the proposal (and potential final restriction) will be included in the scope of the proposal, i.e., will be restricted.

2.2 Aerospace and Defense critical uses

2.2.1 Overview of uses relevant to the A&D industry under the restriction proposal

A discussed in Section 1.4.2 of this paper, it is noted that the restriction proposal considers 'transport' as an industry, but not A&D specifically.

The Fluoropolymer Product Group (FPG) of PlasticsEurope has identified aerospace and defense applications as a 'missing' use of PFAS within the restriction proposal, with respect to the derogations outlined in the proposed restriction[60].

The uses of PFAS (or more specifically, the products or components that contain them) cover a much wider and more complex range than the narrow view of 'transport' would suggest. Not all products are made for a specific industry. While there are products produced specifically for the A&D industry, many products are general industrial products that are used within the final A&D product. The machinery used during manufacturing could use PFAS in components even if the products being manufactured do not contain PFAS themselves.

[58] Including - Semiconductor fabrication; Lubricants and dry film lubricants (including additives/oils/grease /wax/solvents) ; Seals; Coatings; Electrical engineering and information technology products; Hydraulic fluids ; Corrosion inhibitors; Heat transfer fluids; Lifesaving equipment; Fire supressing agents ; (Insulated) wires/cables ; LCD/LED displays; Optical fibres; Industrial food and feed production equipment; Fluorinated gases; Foam-Blowing Agents; Solvents; Textiles; High performance membranes; Metal plating additives; Metal manufacturing additives; Other uses.

[59] The primary respondents to the survey are members of WG5, however WGs 1, 2, and 9 were also invited to provide responses. It is also important to note that there is membership overlap within the WGs.

[60] https://fluoropolymers.plasticseurope.org/application/files/1316/7957/3228/21_March_FPG_Statement_on_the_PFAS_REACH_restriction_report.pdf.

As part of the research and analysis underlying this paper, the relevant uses of PFAS have been mapped, according to key use (and sub-use) categories that will be relevant to, and important in, A&D. Use categories used for the assessment were assigned based on a consideration of expected A&D applications and the uses that are (and are not) discussed within the proposed EU restriction. The entire IAEG membership represents 70% of the global aerospace and defense industry[61] and roughly a third of IAEG members have membership to WG5. It is expected that the uses identified in the course of the survey are common across the industry; however, the survey may not represent all uses.

A high-level summary of PFAS use within the A&D industry can be seen below in Table 2.1. Note: Table 2.1 may not be all inclusive.

Table 2.1 PFAS uses in the A&D industry

Use	Subcategories
Semiconductor fabrication	• General use • Cooling fluids • Flushing fluids • Photoresist
Lubricants and dry film lubricants (including additives/oils/grease /wax/solvents)[62]	Lubricants are used in the following applications/products: • Engines (oil/grease) • Hydraulic systems/pumps (incl. control valves) (oil/grease) • Bearings/Gears/Ball screws (oil/grease) • Actuators (oil/grease) • Fuel Pumps (oil/grease) • Brake Systems (oil/grease) • Breathing / Oxygen Delivery systems (oil/grease) • Heat transfer fluids (oil/grease) • Electronics/electrical systems (oil/grease)
Seals	• O-rings • Seals for valves, gaskets • Shaft or piston seals • Seals for electronic devices
Coatings	Coating use in/for: • Cables and wires, fiber optic cables (coating) • Hoses/coolant/chemical process lines • Brake pads • Electrical components e.g., PCBs, switches, transistors Insulation materials • Windshield wipers • Primers • Topcoats • Insulation material • Glass surface treatment

[61] https://www.iaeg.com/binaries/content/assets/iaeg/2023/iaeg_intro_09_2023.pdf

[62] Use of lubricants/coatings ON/FOR these sub-category products rather than the products themselves

Use	Subcategories
Electrical engineering and information technology products	• General use • Batteries • PEM in Fuel Cells • Computer systems • Optical Fibers
Hydraulic fluids	• High temperature application • Low temperature application
Corrosion inhibitors	• Corrosion inhibitors
Heat transfer fluids	• Fluids used in Steering systems. • Fluids used in Brake systems. • High temp cooling in electronic systems • Closed system heat pipes
Lifesaving equipment	• Air bags • Seatbelts (retractor mechanism) • Life jackets • Life raft
Fire suppressing agents	• Firefighting foams and suppressants • Fire extinguishers
(Insulated) wires/cables (insulated)	• Wire • Cables
LCD/LED displays	• Lighting/computer displays
Optical fibers	• Various electrical components e.g., autopilot systems
Industrial food and feed production equipment[63]	• Piping and tubing for drinking water applications • Filters in food processing • Seals, O-rings, gaskets, tubing and pipes, expansion joints • Other - incl. Valves and fitments, conveyor belting, chutes, guiding rails, rollers, funnels and sliding plates, tanks, funnels, rollers, linings, blades of knives and scissors, springs, filter membranes and sensor covers, lubricants.
Fluorinated gases	• Refrigeration • Air conditioning (static) • Air conditioning (mobile)
Foam-Blowing Agents	• Insulation materials
Solvents	• Cleaning products

[63] This use has been identified by IAEG members but is considered to be 'low priority' based on the results of the survey.

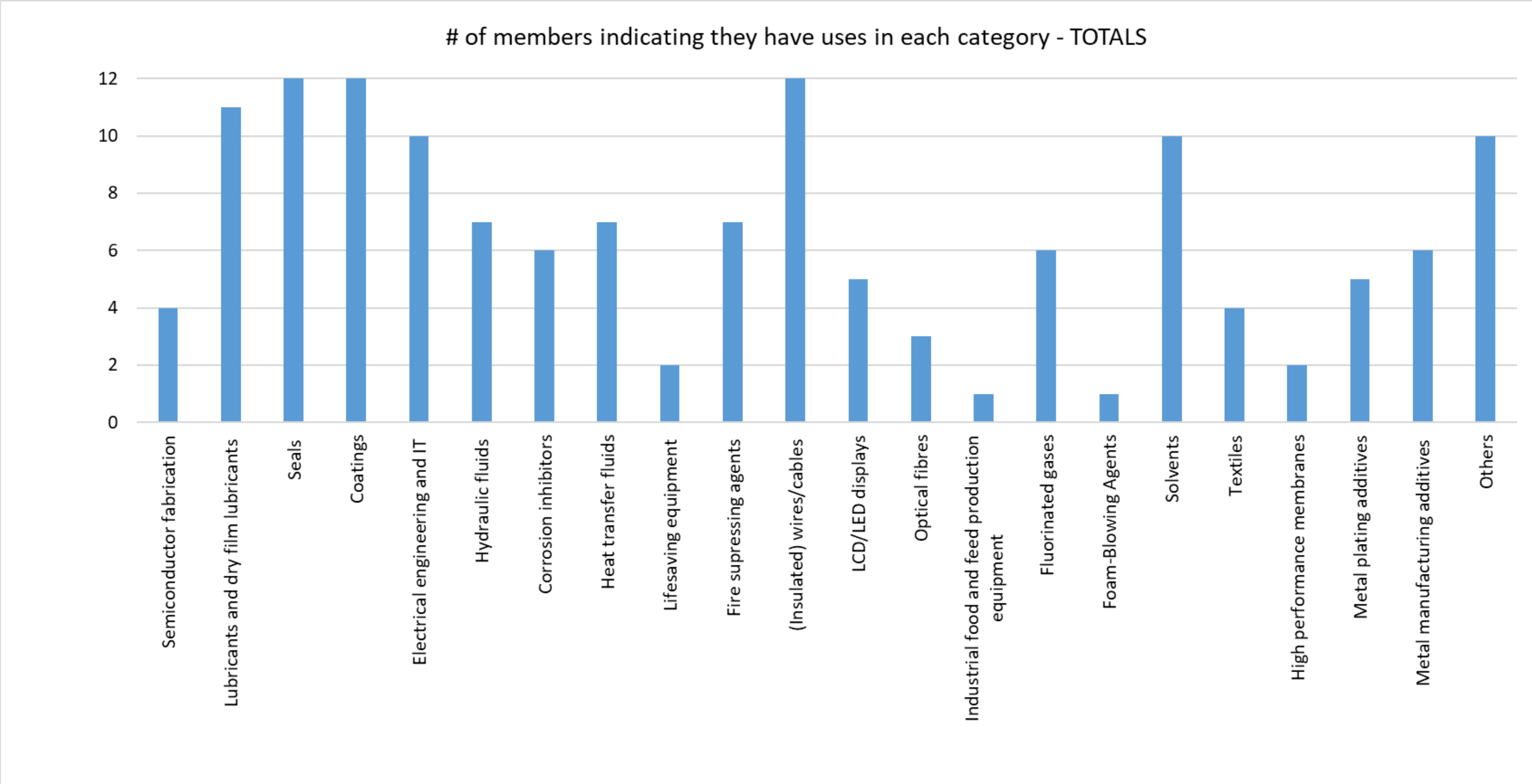
Use	Subcategories
Textiles (TULEC)	• Fibers/coatings in: • Seats • Carpet • Roof linings
High performance membranes	• Acoustic insulation (e.g., inside the vehicle engine compartment) • Gas and water filter membranes
Metal plating additives	• Components of electrolytics and electroless nickel, copper, chromium plating baths; components of plastic/fluoropolymer tank liners with electroplating [see above], mist/fume suppressants
Metal manufacturing additives	• Metal components e.g., steel, aluminum • Other • General use • Seals, valves, bearing coating, hose products, tank liners, gaskets • Coating of processing tools or molds
Other uses	Specific examples identified include: • Flotation fluids in gyroscopes • Wheel weights • Adhesive tapes for marking of aircraft • Composite release films • Composite bonding adhesive films • Semi-conductor manufacture • Photographic coating applied to films

A key point to note is that many of the uses of polymeric and non-polymeric PFAS in A&D are not covered by any proposed (or possible) derogations despite using products that fall into other restriction categories. IAEG members were surveyed on the uses identified, covering both uses covered explicitly in the restriction proposal and further consideration of 'missing' uses, to understand the following:

- Uses of PFAS the members currently cover (i.e., in terms of products procured),
- Which of these uses contain PFAS (either non-polymeric or polymeric),
- Whether these products are 'critical' to their operations, and
- Information on the supply chain for these products.

An overview of the number of members indicating at least one product procured across these categories is provided below in Figure 2.1. This based on the responses of 12 IAEG member companies.

Figure 2.1 Overview of use categories of the IAEG WG5 membership



2.2.2 Presence of PFAS in A&D

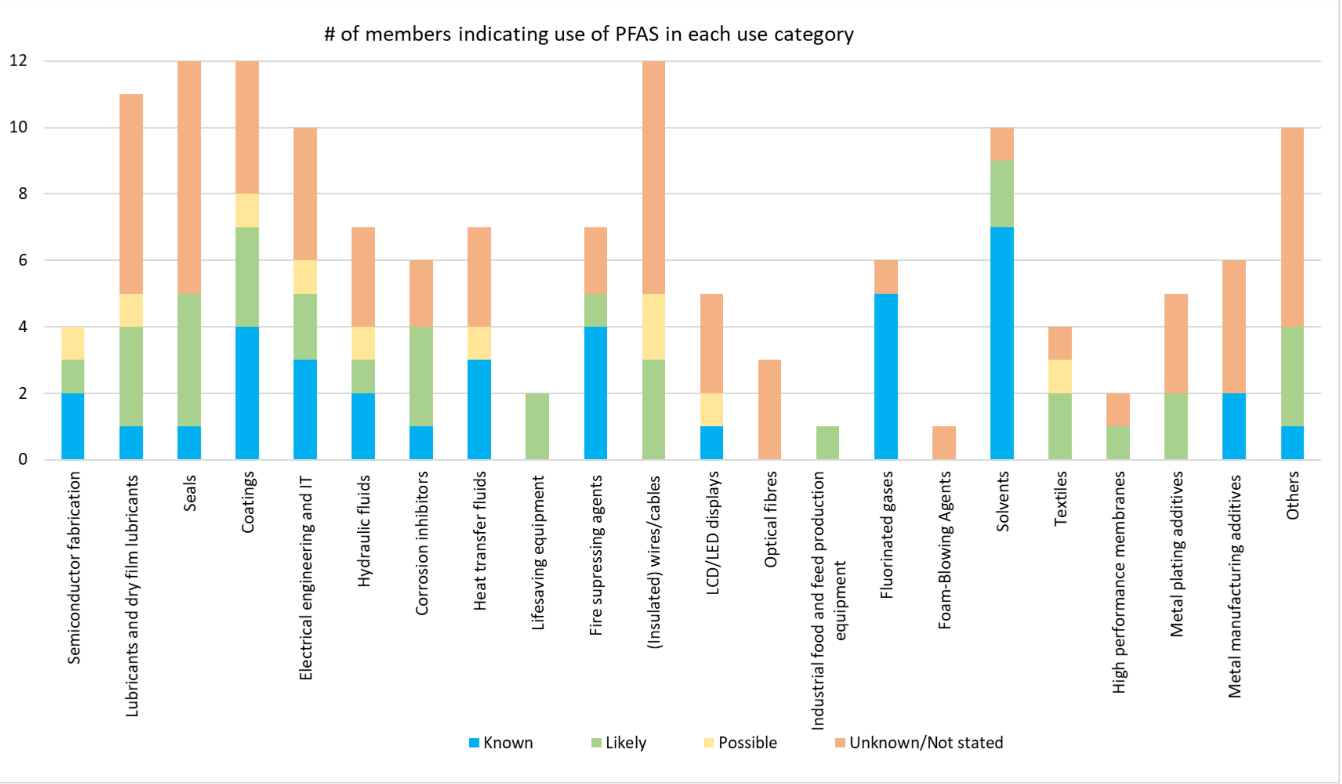
This section further investigates, based on input from the IAEG members (and further consultation with the wider industry), the uses of polymeric and non-polymeric PFAS across these different use categories, where their presence is known (or unknown) and where the uses are considered critical for the A&D industry.

Uses of non-polymeric PFAS

For each of the broad use categories identified above, the IAEG WG5 members have indicated if they have use(s) that contain (non-polymeric) PFAS and the level of confidence in their assessment (known/likely/possible/unknown or not stated).

Figure 2.2 below presents the result of this assessment, indicating the number of IAEG members identifying at least one non-polymeric product type procured in each category.

Figure 2.2 Overview of non-polymeric PFAS in the uses of the IAEG WG5 membership



Based on the above, the following observations are highlighted:

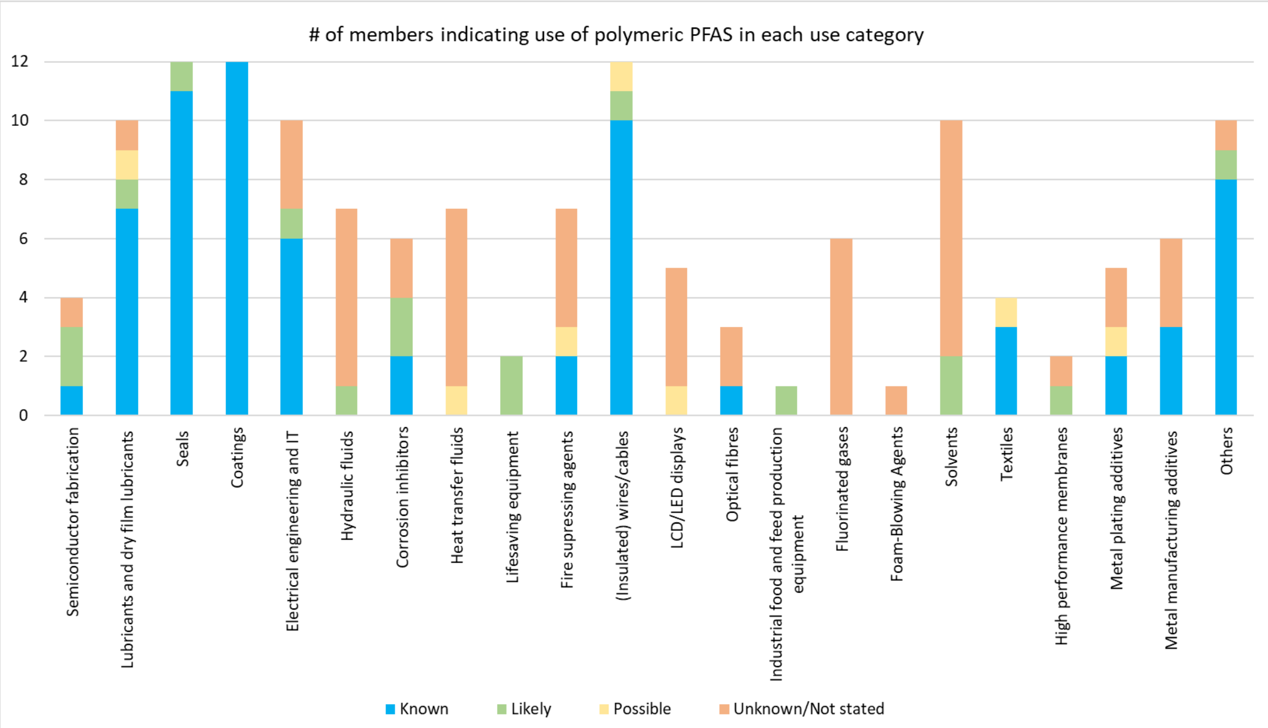
- There is considerable uncertainty and/or lack of information in making an assessment of the presence of non-polymeric PFAS in products, noting the large number of responses of 'unknown/not stated'. This could be due in part to of the lack of sufficient time to make a detailed assessment for the IAEG members and challenges in identifying where PFAS is used throughout what is a complex supply chain. It is also important to note that PFAS is often not listed on safety data sheets in most cases, further obstructing transparency of information. This could be due to the fact that only a small number of PFAS have a harmonized C&L, or that where a PFAS is present, it does not meet the criteria to be classified according to C&L/GHS, and thus they don't appear listed on the SDS.

- There are a relatively large number of IAEG members identifying F-gases and solvents as uses known to contain non-polymeric PFAS in A&D. It may be more straightforward to identify PFAS in these types of products, since there is typically expected to be more available information on chemical composition e.g., from safety data sheets, unlike many other (potential) PFAS uses.
- There are fewer IAEG members using PFAS in other categories where there are known/likely presence of PFAS, including a small number of cases where, e.g., coatings, seals, electrical and IT equipment are noted by some members.

Uses of polymeric PFAS

For each of the broad use categories identified above, the IAEG members have indicated if they have use(s) that contain polymeric PFAS and the level of confidence in their assessment (known/likely/possible/unknown or not stated). Figure 2.3 presents the result of this assessment, indicating the number of IAEG members identifying at least one product type procured in each category.

Figure 2.3 Overview of polymeric PFAS in the uses of the IAEG WG5 membership



Based on the above, the following observations are highlighted:

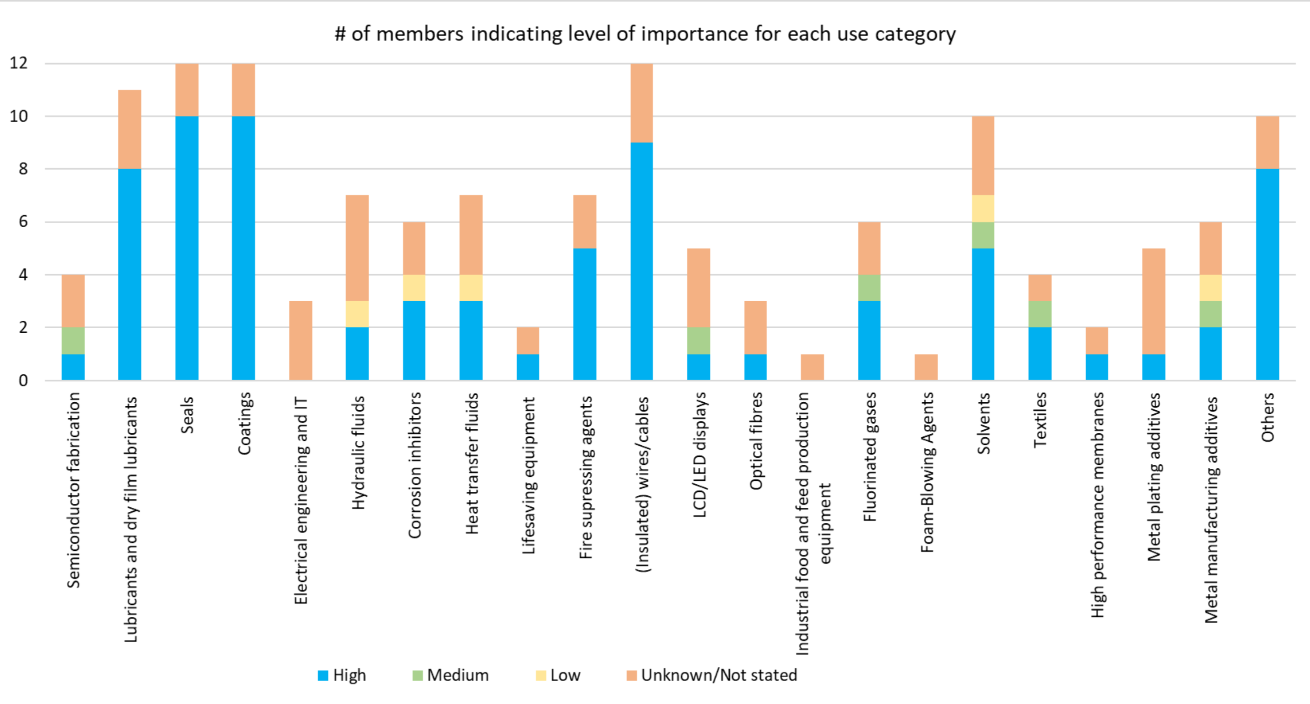
- In general, there is more confidence in the assessment for many use categories across the IAEG membership in terms of the use of polymeric PFAS in a number of use categories (compared to non-polymeric PFAS).
- Many of the IAEG member respondents highlight known/likely use of polymeric PFAS in seals, coatings, lubricants, insulated wires/cables, electrical and IT equipment, and other uses (see further discussion below and in Appendix B).
- There are fewer members indicating use (and/or more members indicting uncertainty) for the other use categories.

2.2.3 Critical uses of PFAS identified in A&D

For each of the broad use categories identified above, the IAEG members provided an indication of the importance of identified products/components in their business (e.g., based on the volume/value/critical nature of the uses).

Figure 2.4 below presents the result of this assessment, indicating the number of IAEG members identifying at least one product type procured in each category.

Figure 2.4 Overview of the level of importance for use categories as indicated by the membership



Based on the above, the following observations are highlighted:

- There is a clear indication that several key categories across the restriction proposal are of high importance to many – if not most – of IAEG WG5 members, e.g., seals, coatings, lubricants, insulated cables/wires, electrical and IT equipment, as well as 'others' (see further discussion below).
- The categories identified by IAEG members span various industries and are not just limited to 'transport' uses.
- There appears to be a stronger knowledge or indication on which uses are 'critical' in the industry, with fewer 'unknown/no response' answers provided.
- Combining the observations in this section on the known or likely presence of PFAS and the uses that are of high importance to IAEG members, a number of 'critical' uses for PFAS in A&D can be identified. These will be discussed in further detail in later sections of this paper and include:
  - Coatings;
  - Seals;
  - Lubricant;

- Insulated wire/cables;
- Electrical and IT equipment; and
- Others.

2.2.4 Highlighting specific critical uses of non-polymeric and polymeric PFAS in A&D

2.2.4.1 Overview

This section provides further details on the use(s) of non-polymeric and polymeric PFAS across the main critical use categories highlighted, based on input of IAEG members and wider industry consultation[64]. Further disaggregation of information on the use of non-polymeric and polymeric PFAS at sub-category level is provided in Appendix B of this report.

2.2.4.2 Seals

A number of different types of seals are required in aircraft. For example, input from IAEG members has highlighted that seals are required for fluid-tight requirements of integral fuel tanks, which requires malleability of material to compress on installation, as well as fluid resistance to aviation fuels. Polymeric PFAS, such as fluoropolymers (e.g., PTFE, fluorosilicones), have been highlighted as being particularly effective materials in providing the required performance and function of these components.

Key properties cited by the IAEG members include:

- Chemical resistance, including fuel and oil resistance and resistance to biological contaminants including chemical weapons (fluorine creates the polarity that provides resistance to nonpolar fluids);
- Wider range of thermal capabilities- high (and low) temperature stability;
- Mechanical properties,
- Hydrophobic, oleophobic; and
- Life extension and performance i.e., reduced friction and wear, low power losses.

Key sub-use categories have been indicated by the IAEG membership in terms of the known/likely presence of PFAS and the high importance of those uses. Key sub-uses identified within this category include O-rings and seals for valves/gaskets. It is noted that this is based on the use of polymeric PFAS in these applications (see Appendix B). For example, one IAEG member noted the use of O-rings and conductive sealing strips with electrically conductive filler material is used to reduce the electromagnetic emissions in defense products.

IAEG members have highlighted that any alternative to polymeric PFAS parts must not have a higher frictional co-efficient because this could cause extra stress on other engine components, leading them to bend or shear and thus fail in service. It is also indicated that there are no alternatives that can meet the temperature and material compatibility requirements. Since polymeric PFAS materials are often more costly than alternatives, they are typically reserved for uses where there is no alternative.

The European Sealing Association (ESA) has highlighted the use of fluoroelastomers as sealing elements in gas turbine engines in aircraft as a key use for their products[Error! Bookmark not defined.]. The ESA indicated that higher engine operating temperature helps increase efficiency and reduce emissions, which has driven

[64] Including initial submissions made to the ECHA consultation.

temperature in some sealing locations well above 200°C[65]. To ensure sealing at such elevated temperature, the use of fluoroelastomer or perfluoroelastomers is required to meet the combination of durability, fluid compatibility, and temperature requirements; IAEG members indicate that other elastomeric solutions would not withstand the thermal and/or chemical exposure load. A series of case studies by the ESA have shown that other elastomeric solutions did not perform sufficiently well during testing.

2.2.4.3 Lubricants

IAEG members have highlighted the use of PFAS-containing lubricants (including additives/oils/grease/wax/solvents) and antifriction dry lubricants for A&D.

Due to the limited information provided at a more disaggregated level, it is not possible to gain detailed insights regarding the different types and applications of lubricants used in A&D that contain PFAS. However, several IAEG members have highlighted the importance of these products, including in facilitating assembly, protecting seals from possible small tears during storage, and preventing sticking during startup.

For example, for dry film lubricants, the primary use is to provide a stable lubricating film to the surface of parts to prevent galling, hence these need to remain stable and ensure that slip surfaces have little friction at high operating temperatures (>200 ºC) and pressures. They also must have compatibility with the substrates where they are applied and remain in place during use (i.e., not be washed off by fluids). The specific requirements may vary depending on the part/process/product in which the dry film lubricants are used.

Performance requirements that dry film lubricants need to meet include:

- Chemical resistance;
- Thermal stability;
- Low surface tension;
- Non-reactive, residue free; and
- High-dielectric properties.

These products commonly include polymeric PFAS such as fluoropolymers (e.g., PTFE) in the grease itself.

2.2.4.4 Coatings

Polymeric PFAS are used in coatings for many different components of aircraft and defense equipment.

Key sub-use categories for polymeric PFAS in coatings have been indicated by the IAEG membership in terms of the known/likely presence of polymeric PFAS and the high importance of those uses. These include coatings for cables and wires, fiber optic cables as well as hoses/coolant/chemical process lines. Further details on the use of polymeric PFAS in these applications is provided in Appendix B.

Similarly, Oxsol, a non-polymeric PFAS, has been used in coatings as a volatile organic compound (VOC) reduction solvent since the 1990-2000s.

Key properties cited by the IAEG members include:

- Abrasion and corrosion resistance;
- Chemical/solvent/fuel resistance;

65 https://www.esaknowledgebase.com/wp-content/uploads/2022/03/ESA-Position-Statement-on-proposed-PFAS-regulation-March-2022-1.pdf.

- Bonding prevention;
- Resistance to vibration;
- Thermal resistance;
- Low friction; and
- Flammability properties.

For example, it is noted by some IAEG members that PTFE-based and Teflon-filled polyurethane coatings are used in A&D.

Anti-static spray coatings typically consist of a conducting polymeric PFAS (fluoropolymer) and a solvent made from deionized water and alcohol. When the solvent evaporates, it leaves behind an invisibly thin fluoropolymer conducting "skin" on the surface of the object that prevents static build-up. Here, the fluoropolymer is the key component of the coating that prevents static build-up, with the overall spray coating formulation acting as a carrier and dispersal agent for the fluoropolymer.

2.2.4.5 Electrical engineering and information technology products

Non-polymeric and polymeric PFAS are used in a number of different applications across the broad category of electrical and IT equipment within A&D. For example, IAEG members highlight that polymeric PFAS are used for cladding of individual plastic optical fibers. It is noted that inner and outer jacket material is often extruded polymeric PFAS. Also, connectors include various components that are made from polymeric PFAS, including filler, filler rod, filler insulator, insulator, seals, seal rods, seal plugs, insulation strip.

Key sub-use categories for electronic and IT equipment have been indicated by the IAEG membership in terms of the known/likely presence of non-polymeric and polymeric PFAS and the high importance of those uses. In particular, the use of polymeric PFAS in batteries is important for a number of IAEG members (see Appendix B).

RECHARGE (the industry association of the advanced rechargeable and lithium batteries value chain in Europe) has indicated that polymeric PFAS are utilized in the battery industry and can be divided in two main use categories i) Use at electrode level as binders: PVDF (polyvinylidene fluoride) and PTFE (polytetrafluoroethylene), and ii) Other uses at cell/battery level: separator coatings, additives in the electrolyte, gaskets/seals, pipes, valves and sealings (for instance FEP and PTFE[66]).

Key properties cited by the IAEG members include:

- Thermal stability / temperature resistance;
- Resistance to chemicals (including chemical weapons; hydrogen, coolants) and biological contaminants;
- Electrical properties;
- Hydrophobic and oleophobic properties; and
- Higher robustness.

[66] https://rechargebatteries.org/wp-content/uploads/2022/09/Call-for-Evidence_RECHARGE-_-PFAS-restriction-V1.pdf.

It is highlighted by some IAEG companies that these properties are important for ensuring safety of the equipment, for example by enabling monitoring and control as well as ensuring regulatory and safety critical labelling remains indelible.

2.2.4.6 Insulation for wire and cables

As noted above, non-polymeric and polymeric PFAS are widely used in a number of electrical engineering and information technology products. Input from IAEG members has specifically highlighted that assembled wires and cables used in A&D are constructed with a combination of metallic wires/strands, metallic shields, copper alloy conductors, aluminum conductors, PTFE insulating tapes, PTFE insulating fillers, and composite insulating tapes with polyimide and fluoropolymer blends. Outer jackets can be wrapped PTFE tape or extruded FEP.

Polymeric PFAS are often specified for this use, for their electrical insulating properties. For example:

- PTFE has been cited specifically by multiple IAEG members as being used in general purpose high temperature wire, coaxial cables, fire wire, separation wire, database cables, and power feeders in several components of the wire/cable (i.e., filler, wire insulation, jacket, tape, fiberglass coating).
- ETFE is used on low temperature general purpose wiring as well as large gauge power feeders.
- FEP is used in many components of BMS wire/cable. For example: it is used to coat polyimide tape and is used as the outer jacket material on the data bus.

Key properties cited by the IAEG members include:

- Flexibility;
- Thermal resistance: -55 ºC to 150 ºC;
- Chemical inertness/resistance to attack from biological contaminants, acids, alkalis, fuels, hydrocarbons and solvents;
- Mechanical properties maintained in harsh environments;
- Low moisture absorption;
- Uniform electrical properties over frequency;
- Hydrophobic and oleophobic properties;
- Coefficient of friction stability;
- Dimensional stability; and
- Electrical performance (high dielectric strength).

The price and availability of polymeric PFAS materials have also been highlighted as being an important factor when identifying their criticality in this use. Polymeric PFAS materials are often more expensive than other materials; and IAEG members noted a lack of lower cost alternatives that perform as well as polymeric PFAS materials.

Key sub-use categories for wires and cables have been indicated by the IAEG membership in terms of the known/likely presence of non-polymeric and polymeric PFAS and the high importance of those uses. This highlights that use of polymeric PFAS in both wires and cables is critical to A&D as indicated by the large number of IAEG members indicting both known use of polymeric PFAS and high importance of this use (see Appendix B).

2.2.4.7 Other uses

As shown in Appendix B, two key sub-uses of PFAS (polymeric and non-polymeric) under the broad category of 'other' have been highlighted by IAEG members:

Composite release films/agents

PFAS are used as manufacturing aids to form composite parts for release purposes: when the material needs to be removed from the mold so that it does not stick to the tool. PFAS play a key role in this type of product, as they are responsible for the non-stick properties, easing the removal of the final material from the mold. Although release films are not intended to be incorporated into products, there is evidence that some polymeric PFAS can be left on the part surface, especially when release films are reused multiple times. In any case, use of PFAS is important in the production of components, even if PFAS is not present when the component is utilized by the A&D industry.

Key properties cited by the IAEG members include:

- Low adhesion to resins in composites / releasability;
- Non-reactive, residue free, low surface tension; and
- Release agent, residue-free.

Adhesive films for composite bonding

PFAS is used in manufacturing of adhesive films used during fabrication of composite bonded assemblies typically used in aerospace vehicles' moving control surfaces that require high strength with low weight. PFAS are assumed not present in the final film therefore the final structure and sustainment of the final structure presents no known risk.

Key properties cited by the IAEG members include:

- High shear strength;
- Extremely high peel strength;
- Extreme temperature performance from cryogenic to elevated; and
- Flexible and tailorable cure cycles from 275-350°F.

Adhesive tapes for marking of aircraft

It is indicted that PFAS are considered the best solution regarding balance of weight and electrical performance in this use.

Key properties cited by the IAEG members include:

- Chemical resistance to aggressive fluids such as fuels/hydrocarbons;
- Dimensional stability;
- Mechanical properties maintained in harsh environments;
- Coefficient of friction; and

- High thermal capabilities.

2.2.5 Additional uses of PFAS identified in the A&D industry

The above sections have demonstrated that the uses of PFAS and polymeric PFAS across the A&D industry are clearly very wide ranging. However, as noted by the FluoroProducts and PFAS for Europe (FPP4EU) group of Cefic[67], despite the level of detail in the current EU restriction proposal, this reflects only a fraction of the current uses of PFAS, including niche uses, further complicated by the unprecedented number of substances covered. Therefore, a complete consideration of all PFAS uses across any individual industry, including A&D, is clearly extremely challenging.

In August 2023, the US DOD submitted the attached report to Congress outlining critical uses of PFAS[68].

[67] https://www.fpp4eu.eu/wp-content/uploads/2023/04/FPP4EU-Position-Paper-April-2023-final-1.pdf
[68] https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/reports/Report-on-Critical-PFAS-Substance-Uses.pdf

Several uses that were not explicitly mentioned in the PFAS restriction proposal have also been identified by IAEG members:

- Dampers, wear pads and cushions (for anti-friction and wear resistance);
- Other types of connectors such as fasteners, grommets and screws;
- Adhesives/tapes;
- Polymeric PFAS engine parts e.g., rub-strips, moldings, tubes, hoses, bushes;
- Polymeric PFAS in chemical processing e.g., tank liners, seals (not limited to metal plating/manufacturing);
- PTFE/Teflon in various products / systems e.g., coated glass fabric (composite manufacture); hydraulic systems; tubing; fuel hoses;
- Polymer synthesis (surfactants or emulsifiers); and
- Ammunition (e.g., plastic bonded explosives).

3. A&D supply chain

3.1 Supply chain visibility and complexity

3.1.1 The A&D supply chain

Aircraft and defense systems are comprised of thousands of parts that are designed and manufactured globally. An added complexity in tracing or mapping the use of individual chemical constituents is that not all the parts are designed specifically for aircraft/defense systems but are general industrial products. Standard items such as cable sheathing and O-rings, that may not be specifically designed or supplied with the A&D industry in mind. For example, a polymeric PFAS O-ring as used in a coffee machine may also be used in an aircraft or radar system as noted during discussions with one supplier.

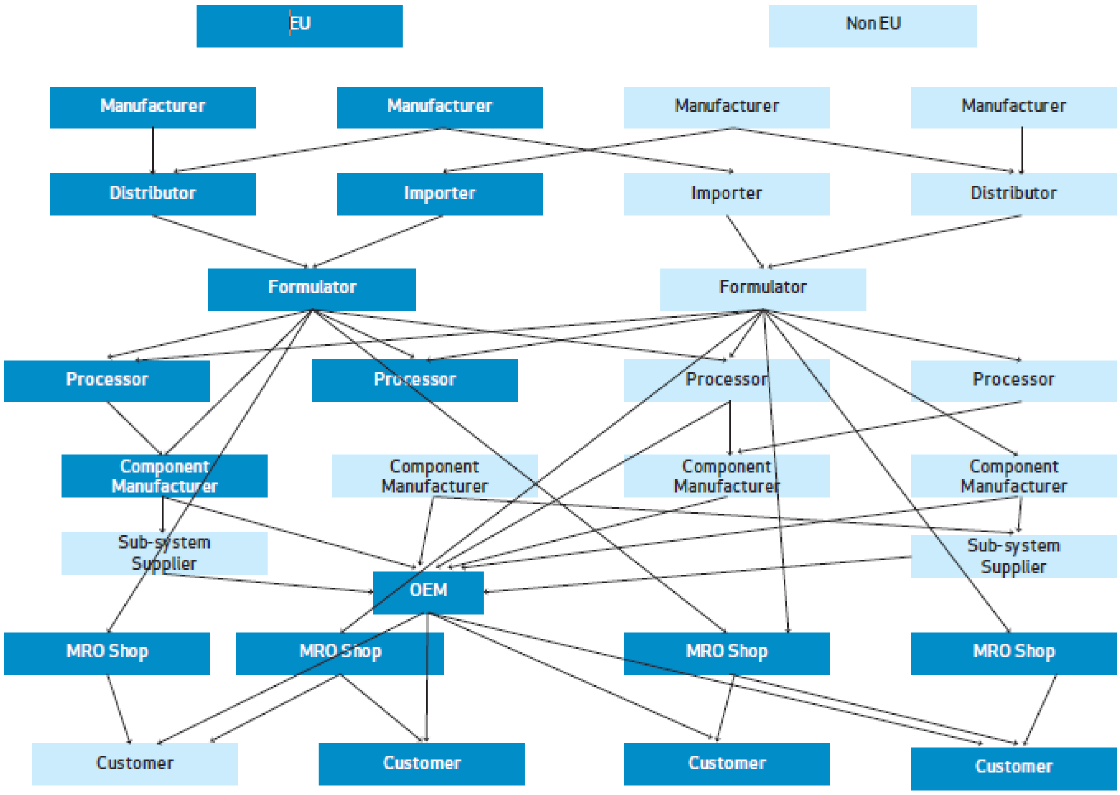
The ECHA RAC and SEAC have previously acknowledged (in an opinion on a proposed EU REACH restriction on terphenyl in March 2023[69]):

"The aerospace supply chains are long and complex with many actors involved at different levels - including suppliers (importers, formulators, and distributors), downstream users (original equipment manufacturers (OEMs), design to build (DtB)) or maintenance, repair, and overhaul (MRO) providers (civilian and military) within the industry".

The general 'flow' of this supply chain can be represented, as follows: formulator -> processor -> component manufacturer -> OEM -> MRO shop -> final A&D customer. However, the linkages between different actors in the supply chain can be more complex, as demonstrated in Figure 3.1.

[69] https://echa.europa.eu/documents/10162/ec938800-0137-44f3-a329-c227f837a2fc

Figure 3.1 A&D supply chain overview (from ECHA/EASA, 2014[70])



The total number of individual companies that are involved in the production, supply, and use of products within the A&D industry globally is substantial, however there is no quantified estimate available. For example, from the brief assessment carried out for this report, across 12 IAEG WG5 members providing input, there are indicated to be over 150 different suppliers (ranging from large multi-national companies supplying products across many different uses within A&D, to SMEs with very niche applications). These are also only direct suppliers to the IAEG members, and do not include suppliers further up the supply chain. These are also only suppliers who may be likely to supply PFAS-containing items.

3.1.2 Visibility of PFAS in the supply chain

Given the nature and complexity of the A&D supply chain, for end users (such as IAEG members, the Ministries of Defense, airlines, etc.) of specific products gaining a good understanding of specific chemical constituents in products they use, requires a good level of communication and transparency of information throughout the supply chain. The complexity of the supply chain often makes it difficult for manufacturers, OEMs, or MRO companies to identify where substances are used within final parts or assemblies (or in the early stages of their production). This is particularly challenging when dealing with a very large group of substances like PFAS (~10,000 individual substances covered in the restriction proposal). For context, when IAEG has previously conducted mapping exercises to fully investigate their uses of a chemical substance across the supply chain, the approach generally used a targeted search of CAS numbers. In the case of PFAS, that is simply not feasible due to the sheer number of substances and the wider range of use categories (see Section 2), which leaves substantial gaps in their knowledge. Even with access to PFAS CAS numbers, there would still be a lack of visibility of the uses of PFAS as there is no SDS reporting requirement for the majority of these substances. In addition, because the majority of polymeric PFAS uses supplied to IAEG members are found in polymeric PFAS-based articles, the identification on PFAS presence

[70] ECHA/EASA(2014) An elaboration of key aspects of the authorisation process in the context of aviation industry.

is based on company expert knowledge of the material types typically in use for certain applications, rather than identifying the presence of certain CAS numbers.

In addition to PFAS added to a product, many processes make use of PFAS that are not retained in the final product. As discussed by FluoroProducts and PFAS for Europe (FPP4EU), a sector group of Cefic[71], in general, the number of products that rely on PFAS, either during their production phase and/or in the final products is largely unknown. Indeed, many Downstream Users (DUs) may place on the market non-PFAS containing products that rely on PFAS in their production process at some point. Many of them may not realize that PFAS have been involved. **Furthermore, there is currently no traceability system that ensures that complete information is received by the end user when multiple parties are involved in complex supply chains**. This can be further exacerbated where parties are established in different (sometimes non-EU) jurisdictions. This makes the mapping of substance uses throughout supply chains extremely complicated.

The information on uses of PFAS outlined in Section 2 highlights the number of IAEG members that have indicated 'unknown' or 'not stated' for the responses to the survey on which of their uses include PFAS. This could reflect both the supply chain complexity and/or poor transparency of information for these substances (coupled with minimal time availability to map/trace use of PFAS across their supply chains).

The survey of IAEG members also highlights that, the respondents are generally not confident in knowing all of the PFAS uses that are relevant for their companies. They cite the lack of supply chain and/or supplier information as the reason for this lack of knowledge; disclosure of the use of PFAS is simply often not required under legal or other obligations. Key factors suggested for this include:

- Lack of reporting regulations regarding PFAS disclosure in articles;
- Lack of reporting of when PFAS are used in processes by suppliers;
- Lack of supply chain information in general;
- Quantity of PFAS could be under a reporting obligation threshold, so is not reported or disclosed in safety data sheets; and
- The scope of the proposed restriction is vague/broad, so it is hard to determine what to include when investigating PFAS uses.

Key constraints are related to information gathering from suppliers on where PFAS are used and whether/why their use is important include, for example:

- The direct suppliers do not always know where PFAS are used, particularly in manufacturing, due to the methods of reporting used throughout the supply chain and have found that asking further up the supply chain does not always provide the necessary answers.
- There is no mandatory reporting for PFAS.
- Prior to this activity, the A&D focus was on performance, not chemical usage.

IAEG members also provided insight into how feasible it is, in practice, to obtain information regarding the use of PFAS in materials/products/components procured. For example:

- Members noted it is more feasible to obtain information if PFAS is used in the end product, and less feasible if PFAS is only used in production.
- To understand all uses of PFAS, timing will play a role. The more time the industry is allotted to map their supply chain, the more feasible it becomes to understand all roles of PFAS.

[71] https://www.fpp4eu.eu/wp-content/uploads/2023/04/FPP4EU-Position-Paper-April-2023-final-1.pdf

- To date, members that have asked for more information regarding potential uses of PFAS within the supply chains have been largely unsuccessful.

As discussed by the FPP4EU[72], despite specific actions in place to improve supply chain communication and transparency of information[73], it is indicated that this is still not reaching everyone. This supports the suggestion that more time is needed to completely map the use of PFAS across the A&D industry (and more widely) and to identify the potential impact on some (currently unidentified) critical uses.

During supply chain mapping and consultation efforts, it was found that due to the vast number of substances covered under PFAS (10,000 substances) there are significant challenges in understanding all uses of PFAS in a brief time period. The challenge exists not only with the number of substances, but also a lack of resources available to members of the supply chain to understand and assess the impacts of a potential PFAS restriction. Alongside this, not all uses of PFAS are visible to the supply chain, such as the use of PFAS as processing aids or other aspects that are not carried through to the final product.

The complexity of the supply chain often makes it difficult for A&D manufacturers, OEMs, or MRO companies to identify where substances are used within final parts or assemblies (or in the early stages of their production). This is particularly challenging when dealing with a very large group of substances like PFAS. For context, when IAEG has previously conducted mapping exercises to fully investigate their uses of a chemical substance across the supply chain, the approach generally used a targeted search of CAS numbers. In the case of PFAS, that is simply not feasible due to the sheer number of substances and the wider range of use categories (see Section 2), which leaves substantial gaps in their knowledge. In addition, because the majority of polymeric PFAS uses supplied to IAEG members are found in polymeric PFAS-based articles, the identification on PFAS presence is based on company expert knowledge of the material types typically in use for certain applications, rather than identifying the presence of certain CAS numbers.

In accordance with REACH and CLP Regulations, information on the presence and concentration of PFAS within a mixture would only need to be included in safety data sheets if they are known to display hazardous properties, i.e., listed as SVHCs under REACH or classified as hazardous according to CLP classifications[74]. As noted in Section 1, many PFAS are not appearing on SDSs, making it hard to trace them across the supply chain and know if PFAS are present. Additionally, many PFAS are used in small quantities that would make reporting a challenge.

3.2 Implications of PFAS restriction

Input received from SAE International (formerly the Society of Automotive Engineers) has provided insight into the complexities and uncertainty around how the restriction on PFAS may impact the standardization and qualification of components used in the A&D industry.

It should be mentioned that within SAE, expert committees are assembled specifically for a product or product class within the larger consideration of standards (~190 committees in all) and it is indicated that at the time of writing (September 2023), a detailed investigation into the use of PFAS relating to the proposed PFAS restriction is currently only at a preliminary stage, with results not expected to be available for several months. However, an initial review of the aerospace standards portfolio has indicated a number of specific products that would be impacted by a complete ban on the use of PFAS, including:

[72] https://www.fpp4eu.eu/wp-content/uploads/2023/04/FPP4EU-Position-Paper-April-2023-final-1.pdf

[73] Such as the FPP4EU Collaboration Platform - which aims to raise awareness of the PFAS regulatory action whilst building a broader understanding of the variety of PFAS uses for all stakeholders

[74] E.g., carcinogenic category 2 or toxic to reproduction category 1A, 1B and 2, skin sensitiser category 1, respiratory sensitiser category 1, or has effects on or via lactation or is persistent, bioaccumulative and toxic (PBT) in accordance with the criteria set out in REACH Annex XIII or very persistent and very bioaccumulative (vPvB) in accordance with the criteria set out in REACH Annex XIII

- Airframe bearing-liner material;
- Hydraulic hoses and other hydraulic components;
- Seals for hydraulic and fuel systems;
- Electrical cable insulation;
- Engine lubrication products for the installation of fasteners at high temperature;
- Cushion materials for harness clamps; and
- Coatings, adhesion promoters for sealants, sealing gaskets, and release agents.

It should be noted that there is good agreement here between the key uses highlighted and those identified as 'critical' or 'high priority' uses by the IAEG WG5 members (see Section 2). This suggests significant disruption relating to many key uses across the A&D industry could occur (as discussed below).

While not all current performance standards do not always specify the chemical constituents required to meet a particular performance standard, in many cases PFAS/ polymeric PFAS are indicated to be needed to meet particular standards on the basis of the function and properties outlined in Section 2 above.

It was suggested in early conversations with SAE that the likely practical result of such a restriction, is that standardization of individual parts will no longer be feasible. Individual end user A&D companies would need to specify their own standards and procure specialist parts/products to meet their own unique specifications. This could ultimately be more time consuming and costly to the industry, as it is noted that standardization is a driver of competition. As parts are currently standardized across many manufacturers, these parts can be used interchangeably for different OEMs. The internalization of standards within one company could lead to a decrease in available supply and increasing waiting times for parts when repairs are needed.

As was highlighted in section 1.2, a range of different definitions of PFAS are currently in use globally. This adds an additional degree of complexity in terms of the A&D industry's response to restrictions on the use of PFAS.

4. Conclusions

Non-polymeric and polymeric PFAS are widely used across many different products and components used within the A&D industry. Some of these are specific to A&D but, in many cases, these uses interlink with many other industries (e.g., electronics, coatings, lubricants, cables and wiring). The current EU restriction proposal does not consider A&D as a discrete industry, instead covering the 'transport' industry more broadly. This runs the risk of missing unique uses of PFAS that are important to the A&D industry and does not consider at all, any non-transport uses.

Based on input from the IAEG WG5 members, a number of 'critical' uses of both polymeric and non-polymeric PFAS have been identified across the A&D industry. While many of these are explicitly mentioned in the restriction proposal, a number of 'additional' or 'missing' uses have been identified. For the member companies IAEG WG5, a knowledge gap exists regarding the products using PFAS, either contained in the product or used during the manufacturing process. The supply chain for the A&D industry is complex and given the large number of individual substances and uses, it is extremely challenging to map the use of all PFAS in all use categories, especially in a relatively short (6 month) consultation period.

For non-polymeric PFAS uses, the following challenges are identified:

- There is considerable uncertainty and/or lack of information in making an assessment of the presence of non-polymeric PFAS in products, noting the large number of responses of 'unknown/not stated'. This could be due in part to of the lack of sufficient time to make a detailed assessment for the IAEG members and challenges in identifying where PFAS is used throughout a complex supply chain. It is important to note that only a small number of PFAS have a harmonized C&L, and PFAS are often not listed on safety data sheets, further obstructing transparency of information.
- There are a relatively large number of IAEG members identifying F-gases and solvents as uses known to contain non-polymeric PFAS in A&D. It may be more straightforward to identify PFAS in these types of products, since there is typically expected to be more available information on chemical composition e.g., from safety data sheets, unlike many other (potential) PFAS uses.
- There are fewer IAEG members using PFAS in other categories where there is known/likely presence of PFAS, including a small number of cases, e.g., coatings, seals, electrical and IT equipment as noted by some members.

For polymeric PFAS uses, the following challenges are identified:

- In general, there is more confidence in the assessment for many use categories across the IAEG membership in terms of the use of polymeric PFAS in a number of use categories (compared to non-polymeric PFAS):
    - IAEG membership noted that non-polymeric uses of PFAS are usually far removed in the supply chain from the end products they receive or are used as processing aids, further reducing the availability of information.
- A large number of the IAEG members highlight known/likely use of polymeric PFAS in seals, coatings, lubricants, insulated wires/cables, electrical and IT equipment, and other uses (see further discussion below and in Appendix B).
- There are fewer members indicting use (and/or more members indicting uncertainty) for the other use categories.

Along with challenges mapping within the supply chain, PFAS-based products are often used in order to meet the safety expectations of the various standards authorities and have been approved for use in aircrafts and defense equipment, adding further complications to the potential for a restriction.

The process of implementing an alternative is rigorous, especially in A&D. It takes multiple years of development and testing and the current timelines in the restriction are not compatible with this, particularly as many uses of PFAS relevant to the A&D industry are not recognized as used in the industry in the restriction proposal (instead being covered under other industries of use). The implications of a restriction on PFAS for the process of (re)-standardizing products is potentially significant and could have important consequences on the access to, and cost of, important products for the A&D industry. The restriction could also impact the ability of airlines to undertake on-site service repairs within Europe, and to go through long and costly processes to find alternatives (which could result in manufacturers moving to internal standards and driving up prices). According to a 2022 article by Korzeniowski et. al., it is unlikely that an alternative will ever truly replace polymeric PFAS, but rather alternatives will have to sacrifice properties that polymeric PFAS inherently provide[16].

During consultations with suppliers and manufacturers, some noted that efforts are ongoing to find alternatives for PFAS but have yet to be successful, while others have taken the stance that there are no alternatives to PFAS (specifically polymeric) that would not mean significant steps backwards in terms of innovation and the performance of products. This paper provides an indication of the scale of PFAS use within the A&D industry, but it is likely that it barely scratches the surface in terms of identifying the range of products that are currently dependent on PFAS use. A more detailed mapping, over a longer period, would be needed to have confidence that the implications of a restriction are properly understood.

Appendix A – WG9 report on PFAS regulatory status

IAEG WG9 – *Impact Analysis of Global Environmental and Chemical Regulations, Policies and Standards* monitor and report on emerging regulations that have the potential to affect the Aerospace and Defense industry. As part of their work they have produced a fact sheet on PFAS which can be found at the following linl:

https://www.iaeg.com/workgroups/wg9/fact-sheets

Appendix B – Further disaggregation of PFAS uses in the A&D industry

This appendix, presents information on the number of IAEG members that have indicated of presence of PFAS/ polymeric PFAS and the importance of each use, for different sub-categories highlighted as being of high priority. This is based on the survey input of 12 IAEG members.

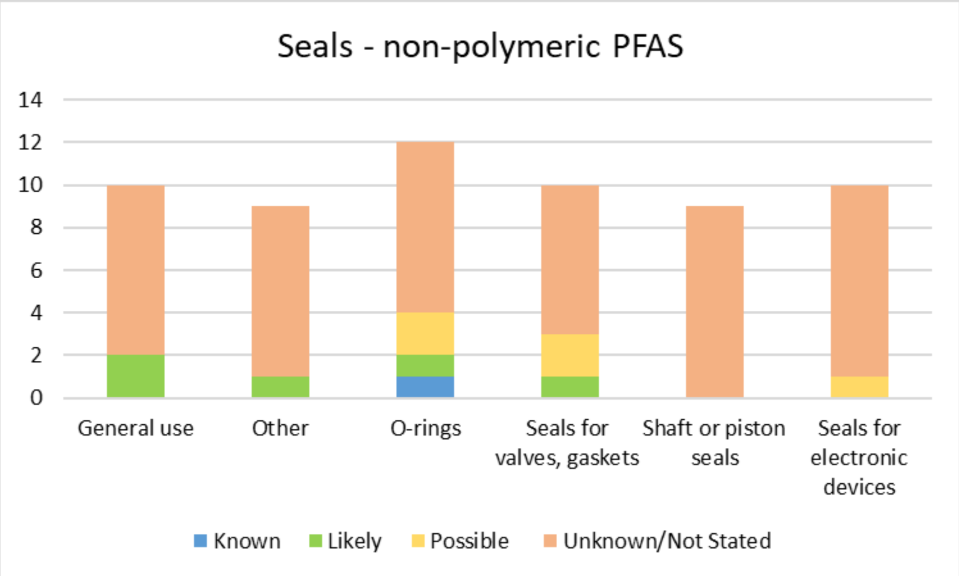
Separate subsections are included for a number of key use categories, highlighted by the members as being of high importance. Within each subsection, information is presented in tables and charts for each sub-use covering:

- **Presence of PFAS in products** –shows the number of members indicating if the presence of PFAS is known/likely/possible/unknown or not stated within these product types.
- **Presence of polymeric PFAS in products** –shows the number of members indicating if the presence of polymeric PFAS is known/likely/possible/unknown or not stated within these product types.
- **Level of importance of that sub-use** –shows the number of members indicting if a type of (sub) use is of high/medium/low/unknown importance.

B.1 Seals

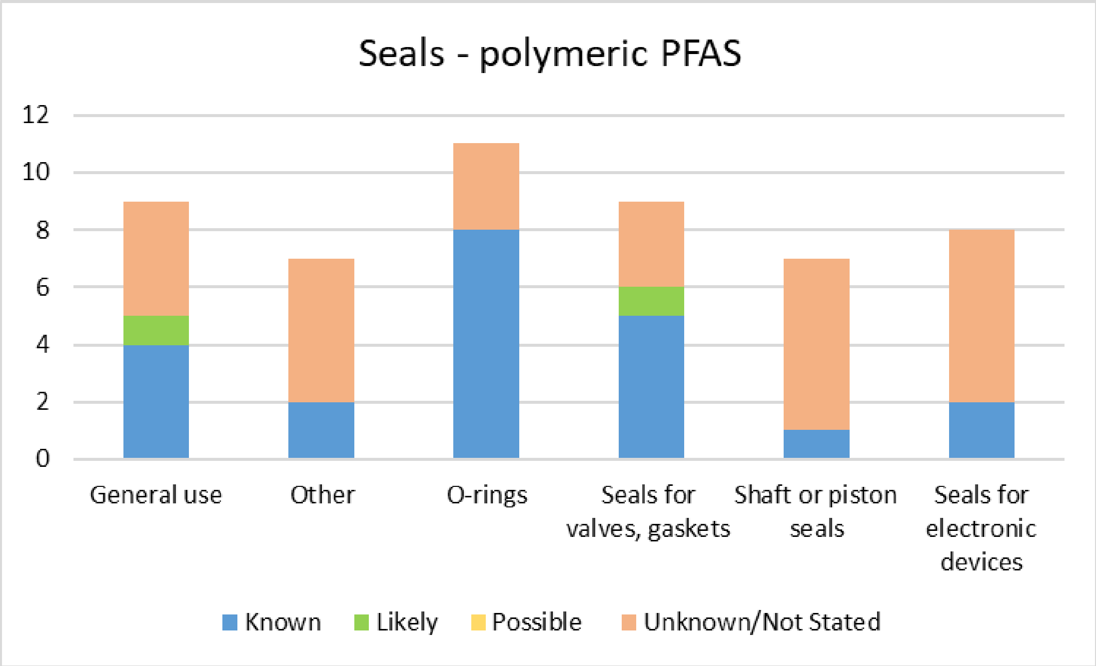
Presence of non-polymeric PFAS

Seals	Known	Likely	Possible	Unknown/Not Stated
General use	0	2	0	8
Other	0	1	0	8
O-rings	1	1	2	8
Seals for valves, gaskets	0	1	2	7
Shaft or piston seals	0	0	0	9
Seals for electronic devices	0	0	1	9



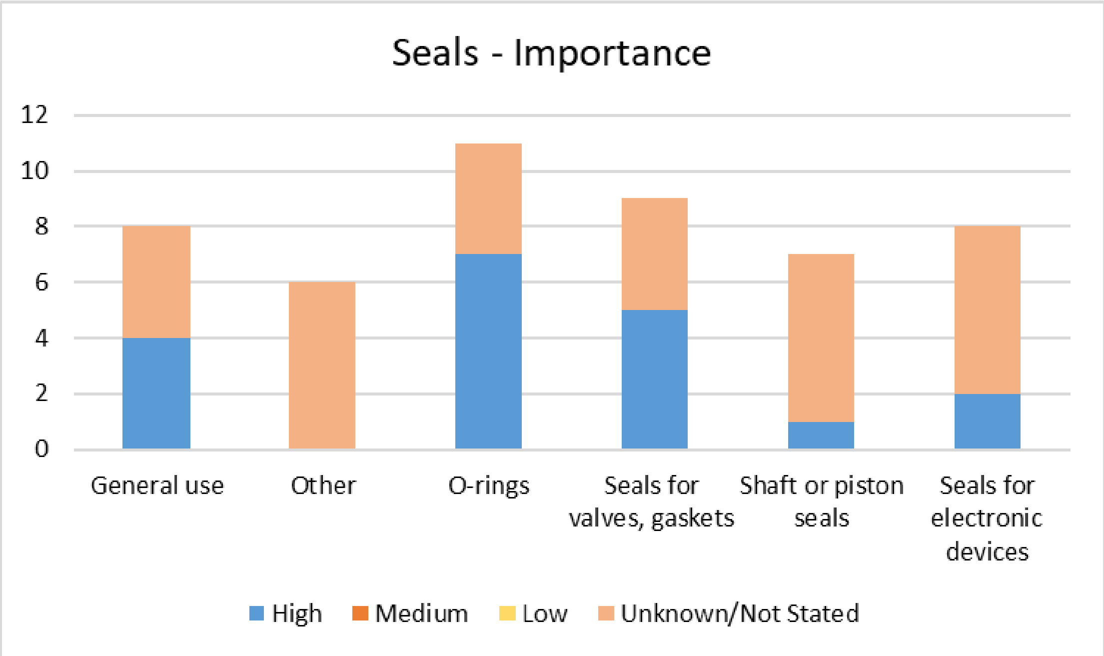
Presence of polymeric PFAS

Seals	Known	Likely	Possible	Unknown/Not Stated
General use	4	1	0	4
Other	2	0	0	5
O-rings	8	0	0	3
Seals for valves, gaskets	5	1	0	3
Shaft or piston seals	1	0	0	6
Seals for electronic devices	2	0	0	6



Importance of use

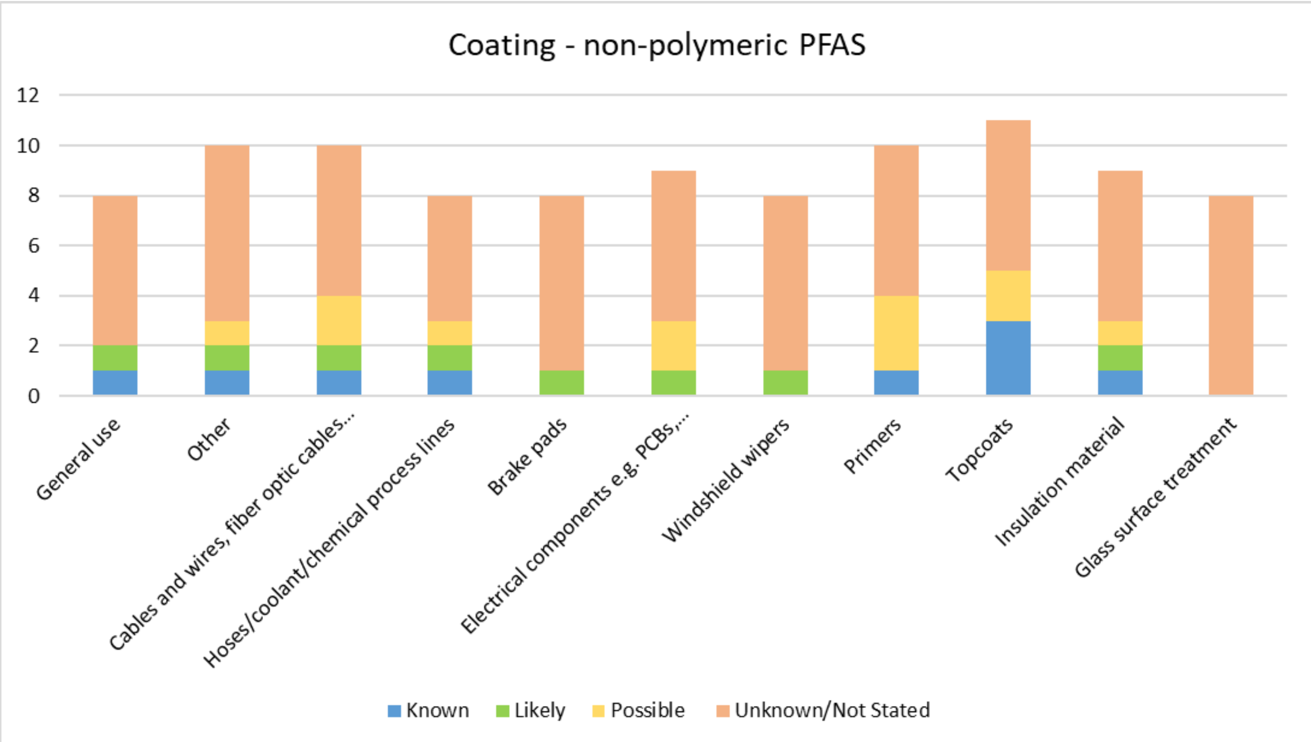
Seals	High	Medium	Low	Unknown/Not Stated
General use	4	0	0	4
Other	0	0	0	6
O-rings	7	0	0	4
Seals for valves, gaskets	5	0	0	4
Shaft or piston seals	1	0	0	6
Seals for electronic devices	2	0	0	6



B.2 Coatings

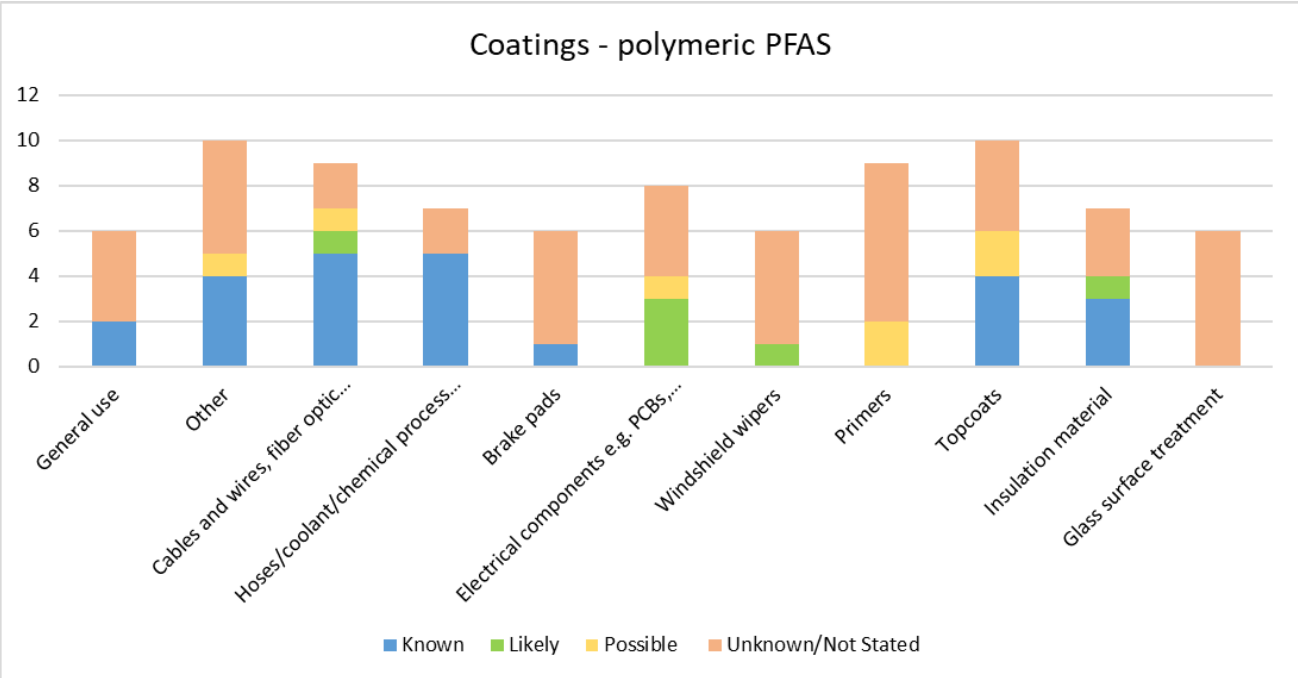
Presence of non-polymeric PFAS

Coatings	Known	Likely	Possible	Unknown/Not Stated
General use	1	1	0	6
Other	1	1	1	7
Cables and wires, fiber optic cables (coating)	1	1	2	6
Hoses/coolant/chemical process lines	1	1	1	5
Brake pads	0	1	0	7
Electrical components e.g., PCBs, switches, transistors Insulation materials	0	1	2	6
Windshield wipers	0	1	0	7
Primers	1	0	3	6
Topcoats	3	0	2	6
Insulation material	1	1	1	6
Glass surface treatment	0	0	0	8



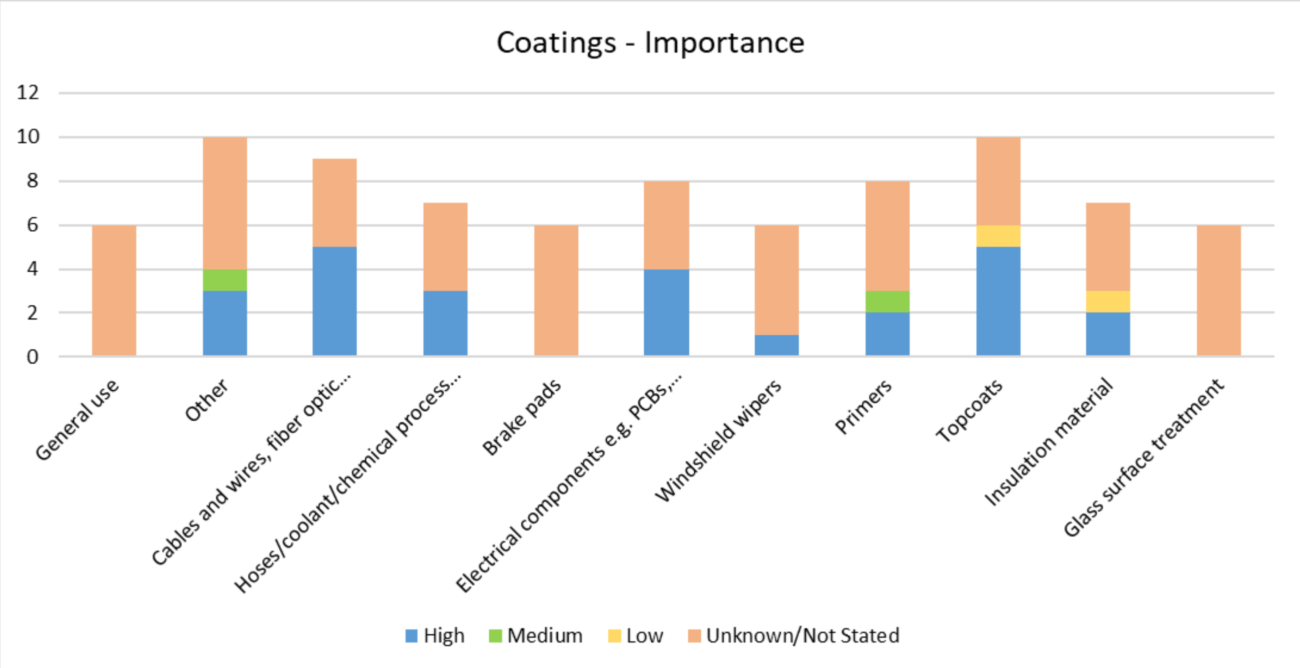
Presence of polymeric PFAS

Coatings	Known	Likely	Possible	Unknown/Not Stated
General use	2	0	0	4
Other	4	0	1	5
Cables and wires, fiber optic cables (coating)	5	1	1	2
Hoses/coolant/chemical process lines	5	0	0	2
Brake pads	1	0	0	5
Electrical components e.g., PCBs, switches, transistors Insulation materials	0	3	1	4
Windshield wipers	0	1	0	5
Primers	0	0	2	7
Topcoats	4	0	2	4
Insulation material	3	1	0	3
Glass surface treatment	0	0	0	6



Importance of use

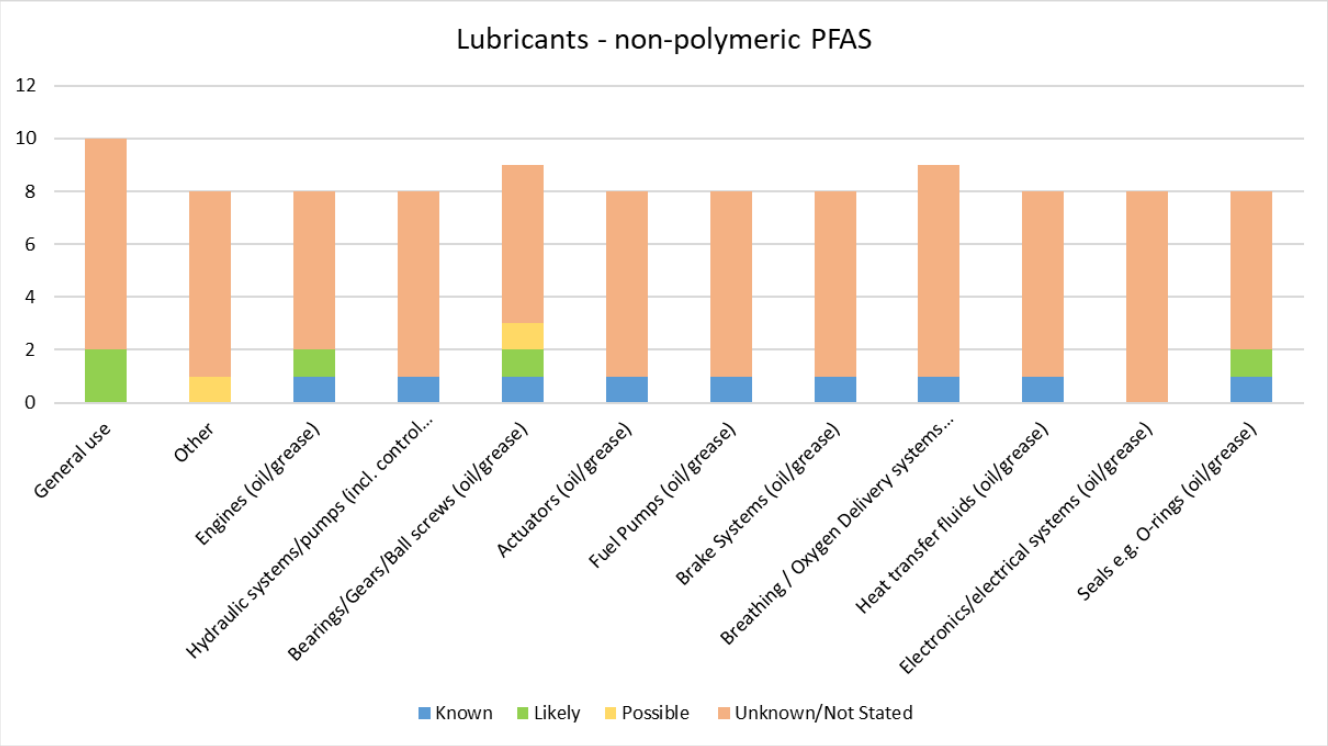
Coatings	High	Medium	Low	Unknown/Not Stated
General use	0	0	0	6
Other	3	1	0	6
Cables and wires, fiber optic cables (coating)	5	0	0	4
Hoses/coolant/chemical process lines	3	0	0	4
Brake pads	0	0	0	6
Electrical components e.g., PCBs, switches, transistors Insulation materials	4	0	0	4
Windshield wipers	1	0	0	5
Primers	2	1	0	5
Topcoats	5	0	1	4
Insulation material	2	0	1	4
Glass surface treatment	0	0	0	6



B.3 Lubricants

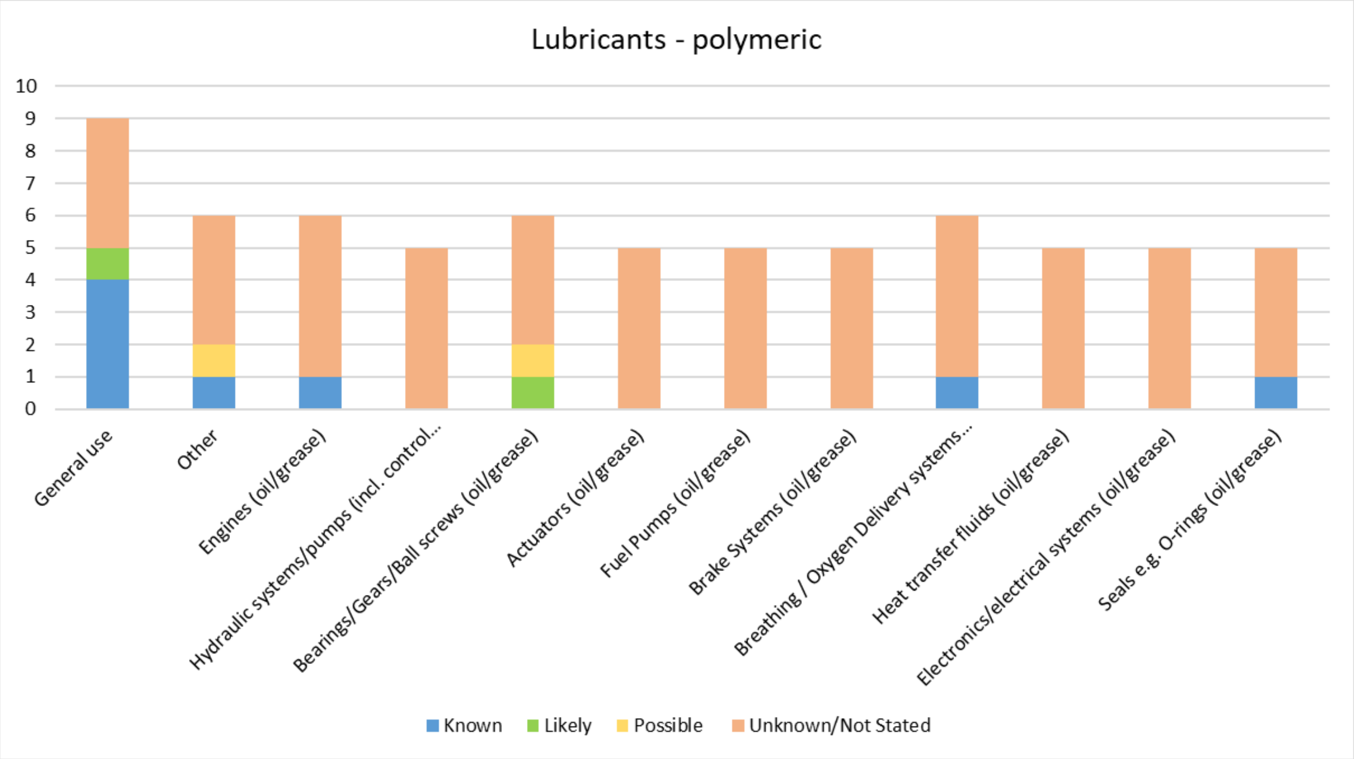
Presence of non-polymeric PFAS

Lubricants and dry film lubricants	Known	Likely	Possible	Unknown/Not Stated
General use	0	2	0	8
Other	0	0	1	7
Engines (oil/grease)	1	1	0	6
Hydraulic systems/pumps (incl. control valves) (oil/grease)	1	0	0	7
Bearings/Gears/Ball screws (oil/grease)	1	1	1	6
Actuators (oil/grease)	1	0	0	7
Fuel Pumps (oil/grease)	1	0	0	7
Brake Systems (oil/grease)	1	0	0	7
Breathing / Oxygen Delivery systems (oil/grease)	1	0	0	8
Heat transfer fluids (oil/grease)	1	0	0	7
Electronics/electrical systems (oil/grease)	0	0	0	8
Seals e.g., O-rings (oil/grease)	1	1	0	6



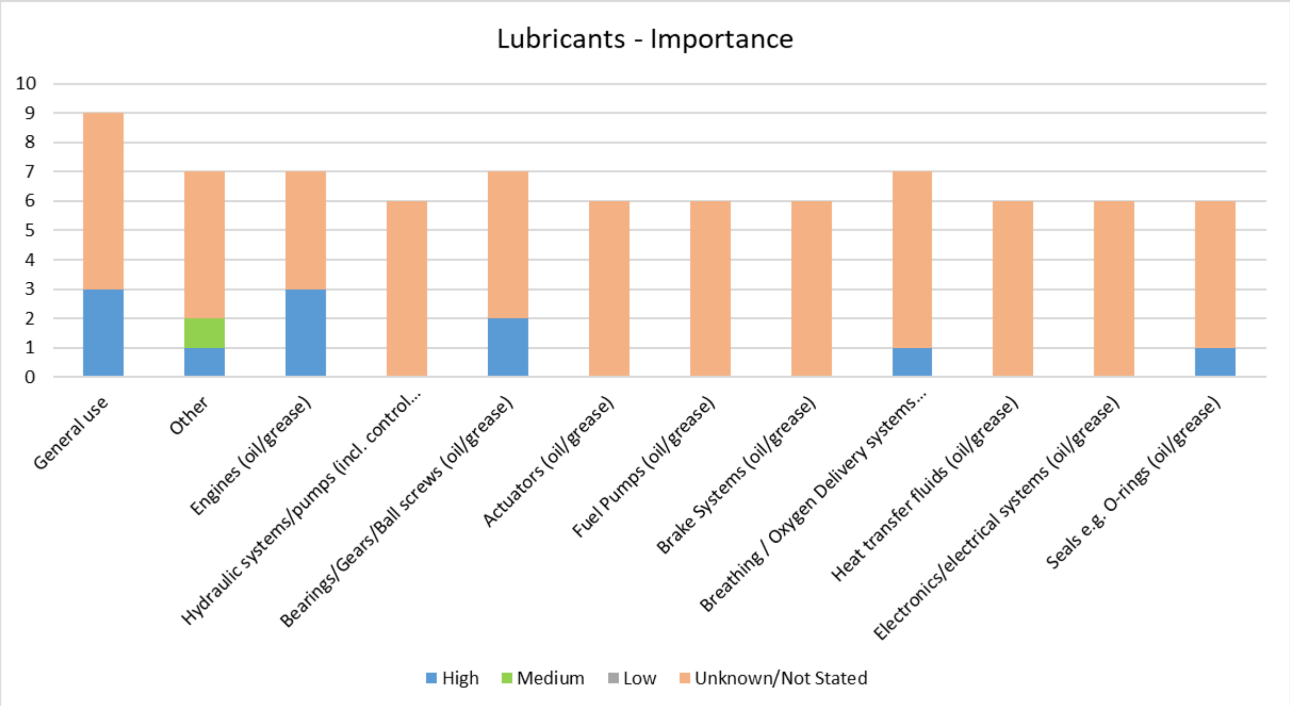
Presence of polymeric PFAS

Lubricants and dry film lubricants	Known	Likely	Possible	Unknown/Not Stated
General use	4	1	0	4
Other	1	0	1	4
Engines (oil/grease)	1	0	0	5
Hydraulic systems/pumps (incl. control valves) (oil/grease)	0	0	0	5
Bearings/Gears/Ball screws (oil/grease)	0	1	1	4
Actuators (oil/grease)	0	0	0	5
Fuel Pumps (oil/grease)	0	0	0	5
Brake Systems (oil/grease)	0	0	0	5
Breathing / Oxygen Delivery systems (oil/grease)	1	0	0	5
Heat transfer fluids (oil/grease)	0	0	0	5
Electronics/electrical systems (oil/grease)	0	0	0	5
Seals e.g., O-rings (oil/grease)	1	0	0	4



Importance of use

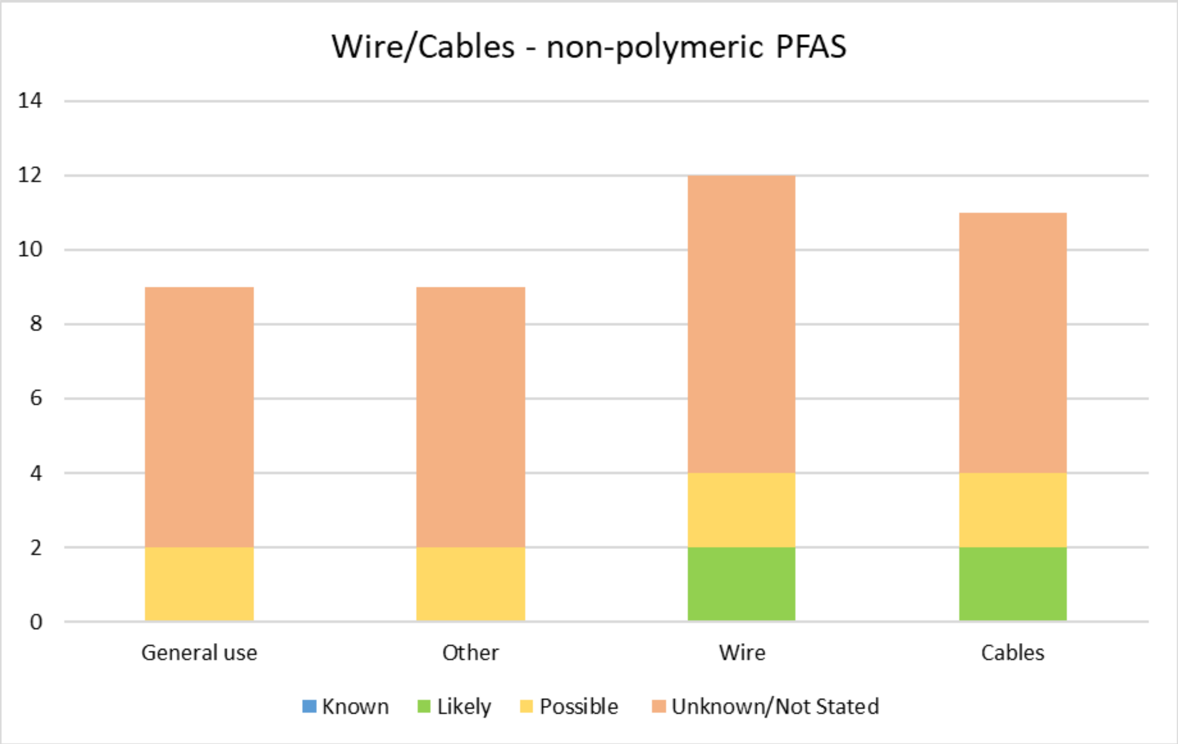
Lubricants and dry film lubricants	High	Medium	Low	Unknown/Not Stated
General use	3	0	0	6
Other	1	1	0	5
Engines (oil/grease)	3	0	0	4
Hydraulic systems/pumps (incl. control valves) (oil/grease)	0	0	0	6
Bearings/Gears/Ball screws (oil/grease)	2	0	0	5
Actuators (oil/grease)	0	0	0	6
Fuel Pumps (oil/grease)	0	0	0	6
Brake Systems (oil/grease)	0	0	0	6
Breathing / Oxygen Delivery systems (oil/grease)	1	0	0	6
Heat transfer fluids (oil/grease)	0	0	0	6
Electronics/electrical systems (oil/grease)	0	0	0	6
Seals e.g., O-rings (oil/grease)	1	0	0	5



B.4 (Insulated) wires/cables

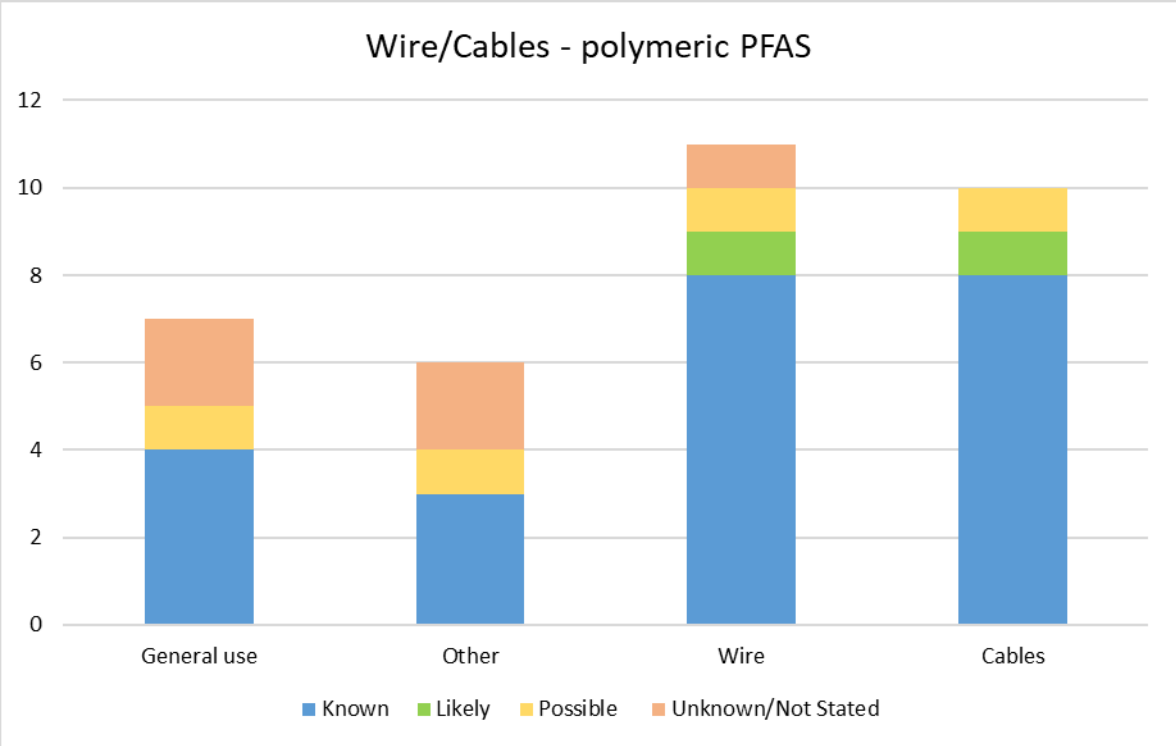
Presence of non-polymeric PFAS

(Insulated) wires/cables (insulated)	Known	Likely	Possible	Unknown/Not Stated
General use	0	0	2	7
Other	0	0	2	7
Wire	0	2	2	8
Cables	0	2	2	7



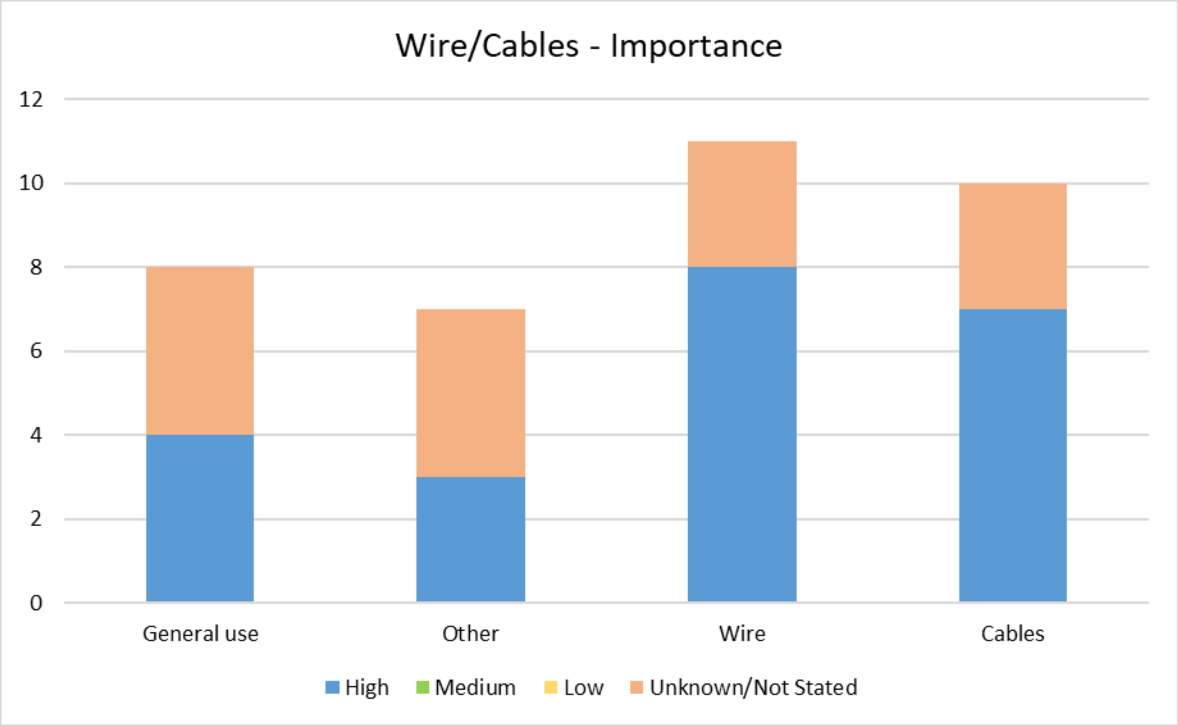
Presence of polymeric PFAS

(Insulated) wires/cables (insulated)	Known	Likely	Possible	Unknown/ Not Stated
General use	4	0	1	2
Other	3	0	1	2
Wire	8	1	1	1
Cables	8	1	1	0



Importance of use

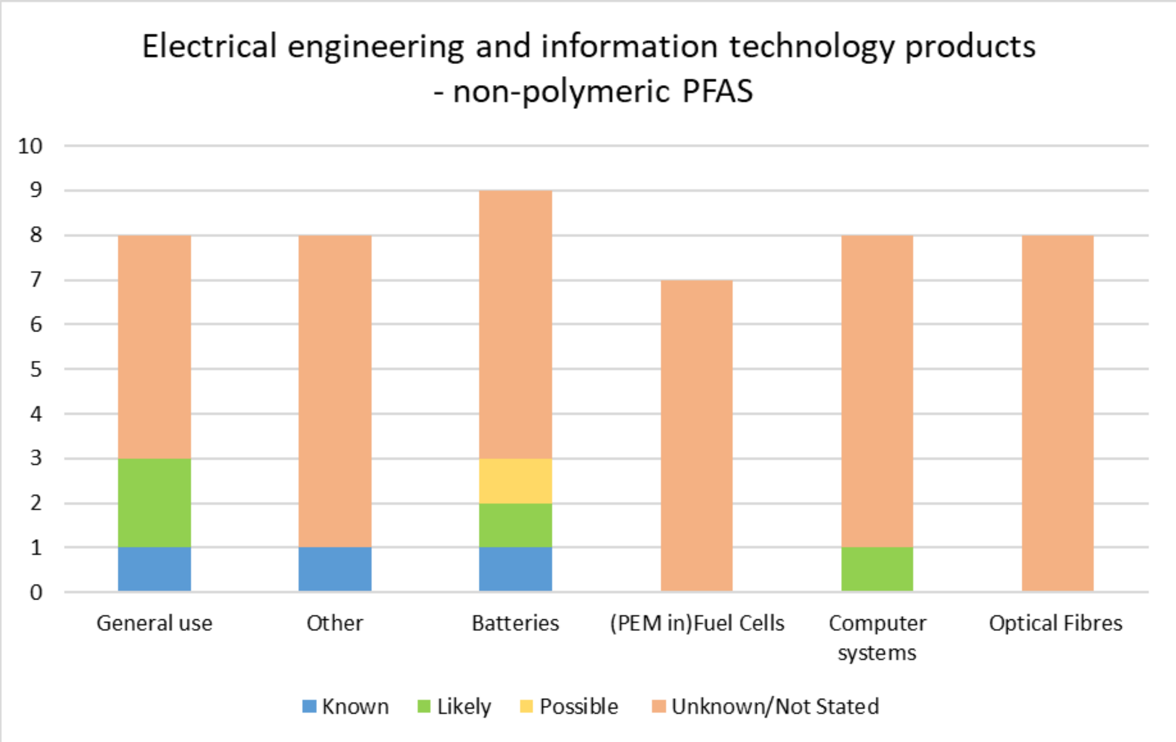
(Insulated) wires/cables (insulated)	High	Medium	Low	Unknown/Not Stated
General use	4	0	0	4
Other	3	0	0	4
Wire	8	0	0	3
Cables	7	0	0	3



B.5 Electrical engineering and information technology products

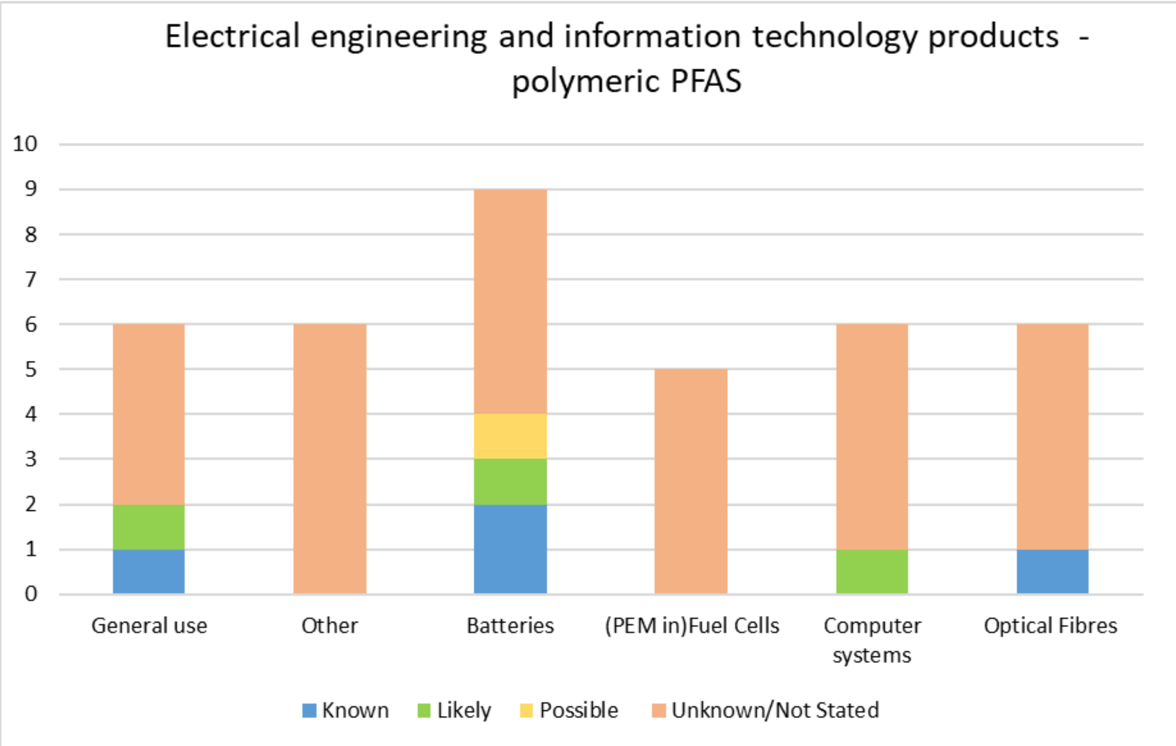
Presence of non-polymeric PFAS

Electrical engineering and information technology products	Known	Likely	Possible	Unknown/Not Stated
General use	1	2	0	5
Other	1	0	0	7
Batteries	1	1	1	6
PEM in Fuel Cells	0	0	0	7
Computer systems	0	1	0	7
Optical Fibres	0	0	0	8



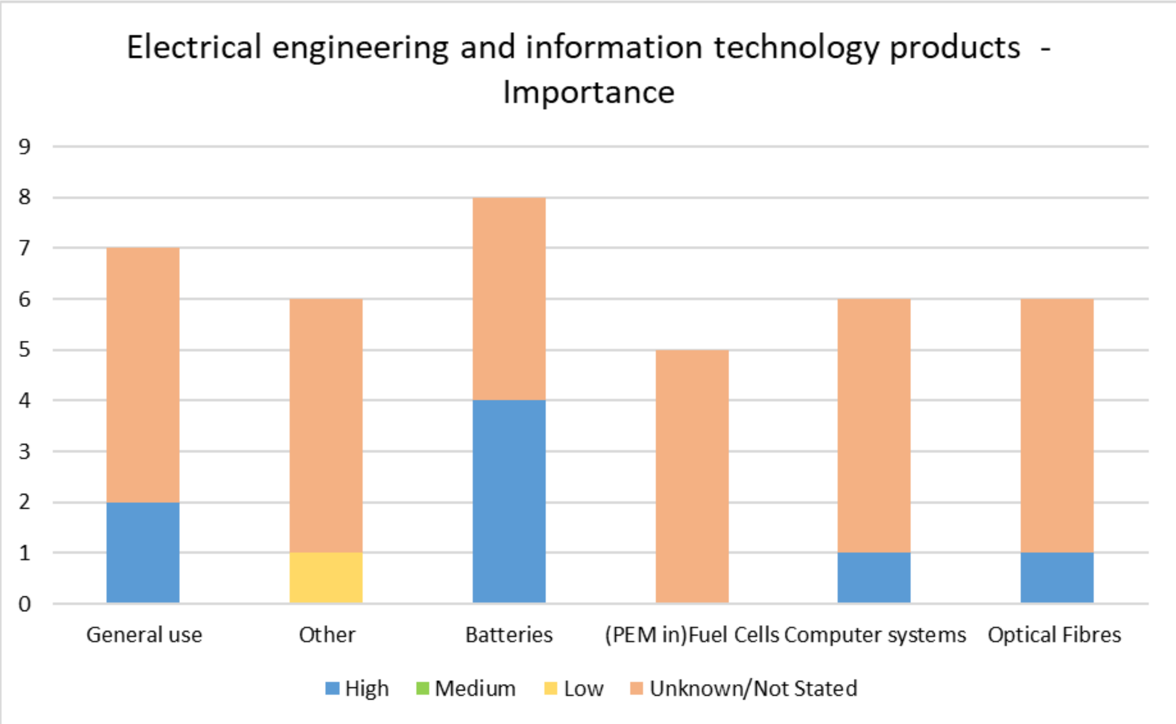
Presence of polymeric PFAS

Electrical engineering and information technology products	Known	Likely	Possible	Unknown/ Not Stated
General use	1	1	0	4
Other	0	0	0	6
Batteries	2	1	1	5
PEM in Fuel Cells	0	0	0	5
Computer systems	0	1	0	5
Optical Fibers	1	0	0	5



Importance of use

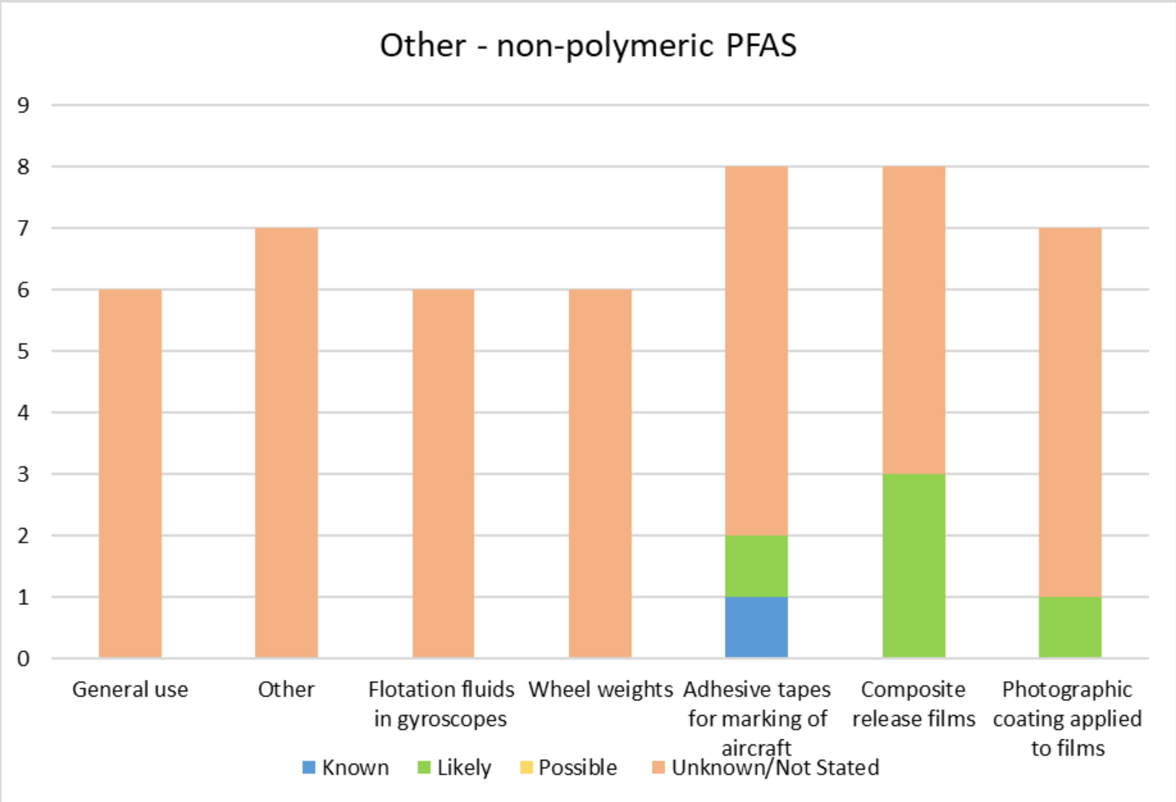
Electrical engineering and information technology products	High	Medium	Low	Unknown/ Not Stated
General use	2	0	0	5
Other	0	0	1	5
Batteries	4	0	0	4
PEM in Fuel Cells	0	0	0	5
Computer systems	1	0	0	5
Optical Fibres	1	0	0	5



B.6 Others

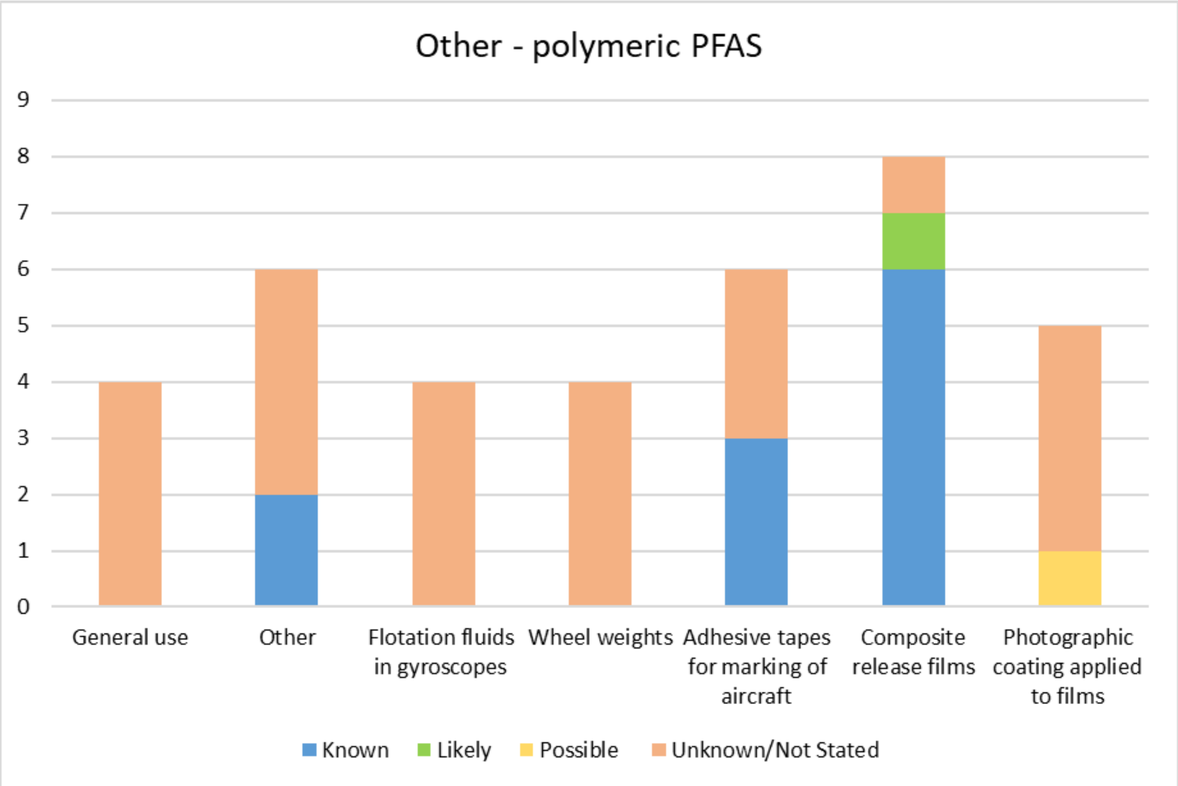
Presence of non-polymeric PFAS

Other	Known	Likely	Possible	Unknown/Not Stated
General use	0	0	0	6
Other	0	0	0	7
Flotation fluids in gyroscopes	0	0	0	6
Wheel weights	0	0	0	6
Adhesive tapes for marking of aircraft	1	1	0	6
Composite release films	0	3	0	5
Photographic coating applied to films	0	1	0	6



Presence of polymeric PFAS

Other	Known	Likely	Possible	Unknown/Not Stated
General use	0	0	0	4
Other	2	0	0	4
Flotation fluids in gyroscopes	0	0	0	4
Wheel weights	0	0	0	4
Adhesive tapes for marking of aircraft	3	0	0	3
Composite release films	6	1	0	1
Photographic coating applied to films	0	0	1	4



Importance of use

Other	High	Medium	Low	Unknown/ Not Stated
General use	0	0	0	4
Other	2	0	0	4
Flotation fluids in gyroscopes	0	0	0	4
Wheel weights	0	0	0	4
Adhesive tapes for marking of aircraft	1	0	1	4
Composite release films	6	0	0	2
Photographic coating applied to films	1	0	0	4