STUDY

Requested by the ITRE Committee

The Per- and polyfluoroalkyl substances (PFAS) and their role as enablers in the competitiveness of European industry

Policy Department for Transformation, Innovation and Health
Directorate-General for Economy, Transformation and Industry
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Abstract

This study examines how PFAS support European industrial competitiveness and the potential impact of a full or partial restriction. Focusing on six key fluoropolymers and F-gases used in aerospace, defence, green energy, and semiconductor sectors, it finds that substitution is often unfeasible, particularly in aerospace, defence and semiconductors. Substantial economic losses and job impacts are predicted under both above restriction options, with risks to Europe's global competitiveness. The study recommends permanent or long-term derogations for critical sectors, extending transition periods for green technologies, and excluding F-gases from the restriction. Further research and an innovation fund to develop alternatives are recommended. Overall, a balanced approach that protects the environment while preserving industrial and technological strength is proposed.

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It should be noted that this study is limited to examining the industrial implications of possible bans or restrictions on the use of a limited number of PFASs in specific strategic applications. A comprehensive assessment of PFAS as such, including environmental implications, is beyond the scope of this study. The results and conclusions should be interpreted within the context of these limitations.

The opinions expressed in this document are the sole responsibility of the authors and do not necessarily represent the official position of the European Parliament.

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CONTENTS

LIST OF ABBREVIATIONS

AoA	Analysis of Alternatives
AFFF	Aqueous Film-Forming Foam
AICIS	Australian Industrial Chemicals Introduction Scheme
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CEPA	Canadian Environmental Protection Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (US)
CSCL	Chemical Substances Control Law (Japan)
ETFE	Ethylene tetrafluoroethylene
EC	European Commission
EEA	European Economic Area
EPA	Environmental Protection Agency (US)
EPDM	Ethylene Propylene Diene Monomer
EU	European Union
EV	Electric Vehicle
F-gas	Fluorinated greenhouse gas
FEP	Fluorinated ethylene propylene
FFF	Fire Fighting Foams
FKM/FFKM	Fluorine Kautschuk Material, fluorocarbon-based elastomers

GDP	Gross Domestic Product
GPSR	General Product Safety Regulations (UK)
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
HFCV	Hydrogen Fuel Cell Vehicle
HNBR	Hydrogenated Nitrile Butadiene Rubber
HSE	Health and Safety Executive (UK)
ICT	Information and Communication Technology
ITRE	Committee on Industry, Research and Energy
K-REACH	Korean regulation for the Registration Evaluation Authorisation and restriction of Chemicals
Li-ion	Lithium-ion
MEE	Ministry of Ecology and Environment (China)
METI	Ministry of Economy, Trade and Industry (Japan)
MRO	Maintenance, Repair and Operation
MSDS	Material Safety Data Sheet
NACE	"Nomenclature statistique des Activités économiques dans la Communauté Européenne" in English: statistical classification of economic activities.
NITE	National Institute of Technology and Evaluation (Japan)
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
PEEK	Polyether Ether Ketone

PEM	Proton Exchange Membrane
PFA	Perfluoroalkoxy alkanes
PFAS	Per- and polyfluoroalkyl substances
PFCs	Perfluorocarbons
PFCAs	Perfluorocarboxylic acids
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PFHxS	Perfluorohexanesulfonic acid
PFCAs	Perfluoroalkyl carboxylic acids
PLC	Polymer of Low Concern
PMMA	Polymethyl Methacrylate
POP	Persistent Organic Pollutant
POSF	Perfluorooctanesulfonyl fluoride
PRODCOM	"Production Communautaire" in English: Community Production
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
R&D	Research and Development
REACH	Registration Evaluation Authorisation and restriction of Chemicals (EU regulation)
RMOA	Regulatory Management Options Analysis
RO	Regulatory Option (assessed in this study)

SBR	Styrene-Butadiene Rubber
SDS	Safety Data Sheet
SEA	Socio-economic analysis
SME	Small or Medium sized Enterprise
TSCA	Toxic Substances Control Act (US)
UHMWPE	Ultra-High-Molecular-Weight Polyethylene
UK	United Kingdom
US	United States
vPvB	Very Persistent and very Bioaccumulative

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EXECUTIVE SUMMARY

Per-and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals and materials which have received particular attention in recent years. The European Chemicals Agency (ECHA) has acted to limit PFAS by developing a restriction on their use in firefighting foams. A universal restriction dossier was also submitted by Germany, Norway, Sweden, Denmark, and the Netherlands covering over 10,000 substances and excluding only a few fully degradable PFAS subgroups. During consultation for the restriction dossier, two options were assessed: a full ban with an 18-month transition (Regulatory Option 1, RO1), and a ban with specific time-limited derogations (RO2).

The Committee on Industry, Research and Energy (ITRE) is now seeking an independent third-party analysis on the role PFAS plays in European industry competitiveness and possible consequences of a full or partial restriction. The study "Per-and polyfluoroalkyl substances (PFAS) and their role as enablers in the competitiveness of European industry" focuses on assessing the importance of six key fluoropolymers (PTFE, PVDF, ETFE, FEP, PFA, FFKM/FKM) which are believed to constitute 93% of all fluoropolymers used within Europe. The study also considers F-gases used as refrigerants. The importance of these materials is assessed in the context of markets of strategic relevance, namely, the aerospace, defence, green energy and clean technology, and semiconductor sectors. This study has assessed the importance of PFAS materials by conducting an analysis of alternatives (AoA), a socio-economic analysis (SEA), and an international competitiveness assessment.

Findings from the AoA: Substitution in some specific applications may be possible. However, many wider applications across all strategic sectors may face challenges to substitute PFAS solutions which are often 'best in class'. The aerospace and semiconductor sectors have low substitution potential due to limited to no alternatives being readily available and the long development and testing times of these industries. An AoA for the defence sector is limited by a lack of publicly available data (as manufacturing data are often confidential for national security reasons). The green energy and clean technology sector represent many wide ranging PFAS applications, with the substitution potential varying within this sector on an application-by-application basis.

Findings from the SEA: The indicative SEA estimates that there will be significant damage and cost to the European economy under both restriction scenarios. A full ban (RO1) is the most costly option and could result in costs of €562.8 billion euros in the first year with annual costs of €72.8 billion after. A time-limited derogation (RO2) could be less slightly less costly. RO2 has a first-year minimum economic cost of €561.7 billion with annual recurring costs of €71.7 billion. The SEA estimates that a minimum of approximately 39,000 enterprises and over 2.9 million employees, with SMEs making up 90% of this, could be impacted by such ROs.

Findings from the international competitiveness assessment: The regulatory trend is towards tighter controls, with global chemical companies being advised by investors to voluntarily phase out PFAS from their production. PFAS such as PFOA, PFOS, PFHxS, and PFCAs are regulated under the Stockholm Convention on Persistent Organic Pollutants, implemented by 190 signatories through national legislation.

However, depending upon which derogations are enacted, the EU UPFAS restriction could become one of the strictest regimes which could be detrimental to the competitiveness of European industry due to the lack of alternatives in key industries.

Conclusions and recommendations: Overall, the study underscores the complex trade-offs between environmental regulation, industrial competitiveness, and technological innovation. The recommendations emphasise the need for nuanced, sector-specific approaches rather than blanket restrictions, recognising both the essential role PFAS play in critical European industries and the ongoing efforts to identify and develop viable alternatives. The sector-specific recommendations are:

- A time unlimited derogation for PFAS in aerospace applications, due to the lack of available alternatives and the essentiality of ensuring the safety of aircraft for passengers. A time unlimited derogation to be reviewed every 10-15 years is proposed over a total exemption. Innovation funding should be made available to help facilitate the development and testing of alternative materials and systems. Commissioning studies to better understand the end-of-life process for aircraft and possible emissions is also recommended;
- A time unlimited derogation for the defence sector, due to growing global geopolitical insecurity and possibility for substantial disruption to supply chains. A large-scale defence sector chemical supply chain study is also suggested to identify more specifically which PFAS are used and where throughout the defence sector. Following from the study, more collaborative initiatives between European authorities and the defence sector are recommended to gradually and carefully substitute unwanted substances and materials in a way that ensures European security;
- To exclude F-gases from the scope of the UPFAS restriction and instead focus all regulatory control of F-gases into the existing F-gas Regulation. This will allow fostering the development of alternatives where possible in a more gradual way while still ensuring Europe retains the capacity to innovate in green technologies;
- A more detailed review of the proposed (and unproposed) time-limited derogations for green energy and clean technology uses of PFAS. There is evidence of alternatives being researched and developed, but more time may be needed for these to come to market than ECHA has allowed. As many green technologies are developed by SMEs, it is also recommended that a task force (possibly within ITRE or ECHA) is established to monitor and commission studies on alternatives which would further bolster European innovation and competitiveness. Finally, given that green and clean technologies are being transitioned to at an accelerating pace and for the foreseen future many of these technologies may rely on fluoropolymers, it is recommended that stringent emission control and remediation requirements (for example at end of life) are placed on companies in this sector.;
- A permanent derogation for PFAS for the semiconductor sector. Modern technologies, digital services, and AI depend entirely on semiconductors. Without semiconductors, Europe's digital economy will come to a standstill. The study suggests the investigation of a dedicated semiconductor chemical policy framework within the European Chips Act, following a detailed analysis of the industry and evidence-based risk assessment.

Broadening the Chips for Europe Initiative, research into alternative manufacturing technologies in semiconductor and quantum fields is recommended. In addition to the research to eventually eliminate PFAS from semiconductor manufacturing under the European Genesis Programme, in the meantime a new funding stream under the Chips Act could enable the adoption of the latest abatement technologies to ensure strict emissions control of PFAS.

Two further recommendations apply across all sectors. First, to develop stronger evidence on the human health and environmental effects of these fluoropolymers. Second, to consider creating an innovation and investment fund to promote and support technological advances in abatement and remediation.

1. INTRODUCTION TO THE IN-DEPTH ANALYSIS

1.1. Background and objectives of the in-depth study

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals and materials which have received particular attention in recent years for chemical and environmental regulation.

The European Chemical Agency (ECHA) took early regulatory steps to reduce PFAS use by developing a Restriction on the use of PFAS in firefighting foams (FFF). This Restriction was first proposed on 1 October 2020 and will ban the placing on the market and formulation of FFF containing over 1 mg/L of total PFAS (ECHA, 2023a). This Restriction is currently awaiting the decision of the European Commission before being enacted into law.

In addition to this restriction, following the policy goals set out by the European Commission, ECHA began the process of preparing a universal restriction dossier. Such a dossier has been prepared and submitted by five authorities (Germany, Norway, Sweden, Denmark, and The Netherlands) to try and reduce the use and sale of PFAS to prevent further emissions. The initial restriction dossier was submitted in early 2023 (ECHA, 2023b) with the updated dossier being released in August 2025 (ECHA, 2025a). The proposed universal EU restriction, based on the OECD definition of PFAS, covers more than 10,000 substances, excluding only a few fully degradable PFAS subgroups that fall outside the scope of the restriction (ECHA, 2023c). The OECD defines PFAS as "*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 (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS*" (OECD, 2021). During the consultation on the proposed EU restriction two different restriction options were assessed by dossier submitters:

i. A full ban with an 18-month transition period after entry into force (Regulatory Option 1, or RO1); and

ii. A ban with use-specific (mainly) time limited derogations (RO2).

The time-limited derogations and the duration of derogations (either five or 12 years from the end of the general transition period of 18 months) are based on socio-economic considerations and the availability of alternatives. In addition, some time-unlimited derogations have been proposed for PFAS addressed under other regulations such as active substances in plant protection products, biocidal products and human and veterinary medicinal products.

Non-Governmental Organizations (**NGOs**) **have also been active in PFAS discussions**.

Organisations such as the CHEM Trust, European Environmental Bureau and Client Earth have focused on advocacy, public awareness, and legal action, aiming to achieve a universal, group-based restriction on PFAS use, with exceptions only for truly essential uses where no alternatives exist. At the time of writing, 114 organisations have signed a manifesto for an urgent end to 'forever chemicals' PFAS[1].

The Committee on Industry, Research and Energy (ITRE) is seeking independent third party verified information on the role PFAS plays in European industry competitiveness and possible consequences of a full or partial restriction. While the Risk Assessment Committee (RAC) and Socio-Economic Assessment Committees (SEAC) of ECHA draft opinions are being developed, ITRE has requested a comprehensive analysis entitled "Per- and polyfluoroalkyl substances (PFAS) and their role as enablers in the competitiveness of European industry". This study focuses on key sectors to the European economy and security.

1.2. Study research questions and overview of approach

For an assessment to coherently analyse PFAS and their uses in strategic sectors a set of clear research questions (RQ) have been defined for this analysis with these questions being:

1. "In what way are PFAS, in particular fluoropolymers (and the substances and molecules made with their assistance), indispensable in EU strategic sectors such as clean technologies, renewable energy, semiconductors, aerospace and defence?";
2. "Where do alternatives to the PFAS in question exist, what is their status in terms of market readiness and what risks are associated with their use in terms of supply chain dependencies, production costs and product quality?";
3. "What would be the impact of limiting or banning the substances in question on availability, costs and performance of the strategic applications in question, and therefore ultimately for the implementation of EU policies as well as global competitiveness of the EU strategic sectors?"

1.2.1. Research sub questions

The above broader research questions have also been further subdivided to add critical nuance to the in-depth analysis and allow a more targeted research and literature review. The table below presents the sub questions which derived from the larger research questions for this study, and where they are addressed in this report. These sub questions are also quoted in each section where they are addressed.

[1] Stop PFAS Manifesto. Available at: https://www.banpfasmanifesto.org/en/

Table 1-1: Research sub questions under each overall research question

Research question	Sub question number	Sub question	Section
1.	1.1	What sectors are fluoropolymers used in?	2.1
	1.2	How are fluoropolymers used in strategic sectors?	2.2, 3.3
	1.3	Which performance criteria drive the use of fluoropolymers by industry?	2.1, 3.2
	1.4	How critical is the use of fluoropolymers within the key strategic industries?	3.3
2.	2.1	For which strategic market sectors do alternatives to PFAS exist?	3.3
	2.2	What possible alternatives to PFAS exist?	3.2, 3.3
	2.3	What is the technical feasibility of these alternatives?	3.3
	2.4	What is the economic feasibility of alternatives?	3.3
	2.5	What is the market availability of alternatives?	3.3
	2.6	What is the risk profile of alternatives?	3.3
	2.7	What is the change in product quality from using alternatives?	3.3
	2.8	What is the price impact for consumers from using alternatives?	3.3
3.	3.1	What are the financial and social costs of limiting or banning PFAS?	4.2
	3.2	What are the financial and social benefits of limiting or banning PFAS?	4.2
	3.3	What other policy areas may be impacted by limiting or banning PFAS?	4.2, 5.4
	3.4	Will strategic sectors be able to continue operating if PFAS is limited or banned within Europe?	4.2, 5.4
	3.5	What would be the impact of competitiveness of European sectors from banning or limiting PFAS?	5.4

Source: Authors' own elaboration.

1.2.2. Overview of the methodology for the study

The study involved several steps:

1. **A review of the substances in scope and markets of strategic relevance** (Section 2): A literature review was undertaken to provide an overview of why PFAS (and fluoropolymers in particular) are used in the markets of strategic relevance.

2. **An analysis of alternatives (AoA)** (Section 3): An AoA has been conducted to identify potential alternatives and infer substitution potential for the six fluoropolymers in scope. Alternatives have been assessed against a set of key criteria: technical and economic feasibility, market availability and risk profiles. An AoA is a crucial step that precedes and informs the Socio-Economic Analysis.

3. **A Socio-Economic Analysis (SEA)** (Section 4): This enabled analysis of the value of PFAS to the economy and society; and an impact assessment of four policy scenarios for the regulation of PFAS.

4. **Competitiveness assessment** (Section 5): A regulatory review of selected countries and regions sets the context of the global regulatory landscape for PFAS, followed by a European competitiveness impact assessment which combines the key findings of the AoA, SEA and regulatory review to draw high level conclusions on European competitiveness under four different policy scenarios, for each of the four sectors of interest to this study.

The following table sets out the key sections where the RQ are addressed, the main approaches and data sources used for answering the questions. The table also shows how findings from one section were used in later sections as sources of data.

Table 1-2: Methodology approach and research question and sub-question mapping

Approach	Data sources	Question answered	Sub question answered
Literature review	• Literature review • Interviews with representatives from each strategic market sector	1,2,3	1.1, 1.2, 1.3, 2.1, 3.3, 3.5
AoA	• Literature review • Interviews with representatives from each strategic market sector	1,2	1.2, 1.3, 1.4, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8
SEA	• AoA findings • EUROSTAT data • Literature review • Interviews with representatives from each strategic market sector	3	1.4, 3.1, 3.2, 3.3
European competitiveness impact assessment	• Regulatory literature review • AoA findings • SEA findings • Interviews with representatives from each strategic market sector	3	3.3, 3.4, 3.5

Source: Authors' own elaboration.

1.3. Limitations of the study

This study is intended to provide a high-level overview of PFAS (particularly fluoropolymers and F-gases) and their uses in strategic sectors. A short timeframe was allocated for the study (13 weeks). Thus, the study's approach has focused on readily available literature, including illustrative examples of alternatives for specific applications, and limited consultation with each of the strategic sectors to address the main gaps. Certain PFAS, such as PFOS and PFOA, have been studied more than others in terms of their environmental and human health effects. There is very little published research into the environmental and human health effects of fluoropolymers. The results and conclusions of this study should be read in the context of these limitations. The specific limitations of each of the three components of the study are explained below.

Additional consultation and hypothesis testing is recommended to validate the conclusions.

However, it needs to be recognised than gathering primary data from industry on novel alternatives may be difficult, as they may see this information as confidential whilst seeking to gain a competitive advantage over competitors. Thus, industry may be unwilling to share this type of information. The Authors recommend that more analysis is needed to validate the conclusions of this study.

1.3.1. Limitations of the Analysis of Alternatives (AoA)

The AoA is conducted at a relatively high level, and the findings should not be viewed as definitive in terms of substitution potentials. The AoA is based on identifying the number of applications which may involve PFAS within a strategic sector.

It then provides examples to illustrate the main challenges with substitution. Whilst this approach can capture the breadth of the strategic sectors and the examples are based on published data, including technical, economic, market availability, hazard and risk data no data from industry has been used. This helps to provide an independent and unbiased analysis from industry but also lacks the required detail to conclude definitively on substitution potential. To address this shortcoming, contact would need to be made with industry which was not possible within the timeframe of this study.

The substitution potential identified in this study can vary within the strategic sector depending on the type of application. This is due to the broad scope of sub-sectors within strategic sectors and applications of PFAS within sub-sectors. To accurately conclude on substitution potential an assessment should be made at the application level, as each application has different performance requirements and acceptability criteria. This leads to significant variation in the substitution potential within strategic sectors and therefore concluding on substitution potential at this high sectoral level is not reliable.

This study provides illustrative examples for alternatives in specific applications. Due to time constraints of the project, it was not possible to conduct an in-depth analysis of all alternatives and therefore illustrative examples in specific critical applications are provided.

1.3.2. Limitations of the Socio-economic analysis

An SEA would usually include large scale and extensive industry consultation with a sufficiently representative selection of stakeholders to gather robust and representative industry data on each in scope sector and their fluoropolymer uses, but this was not possible due to time and budget constraints. Public data from the NACE and PRODCOM databases was utilised by the study team to supply economic data for valuation and modelling. While this approach allowed the study team access to data regarding number of enterprises, employees, and profits generated from relevant products, **the portion, or market share, of these products and subsequent NACE sectors attributable to fluoropolymer usage is not known**. To mitigate this and permit a socio-economic analysis to be conducted, the study has employed the use of a low market share assumption model. The detail of this model approach is outlined in full in section 4.1.

While the produced SEA information can be useful indicative evidence as to the possible scale of impact of a fluoropolymer restriction, the SEA is limited in that it does not actually estimate the true level of impact the European economy would face.

The uncertainties with the assessment are therefore considerably high and require substantial contextual information for appropriate use of the presented indicative estimates.

The resulting output is an indication of potential scale, not a precise cost. The economic input data relies on a conservative assumption (the "low market share assumption model") rather than newly gathered industry-specific numbers. The full detail and explanation of this modelling approach is provided in section 4.1.

1.3.3. Limitations of the European competitiveness impact assessment

The study focused on selected countries and regions for the competitiveness assessment, namely Australia, Canada, China, Japan, South Korea, the UK and the US. These countries represent some of the largest and fastest growing chemical industries to compare with the regulatory regime in the EU/EEA and includes the major PFAS manufacturers. Other regions and countries which were not reviewed may have fewer restrictions on PFAS.

Other countries are excluded from the scope of the study and monitoring of their regulatory status is recommended to ensure that their lack of regulation does not pose a potential threat to European competitiveness. For example, according to Koulini *et al* (2024), PFAS use, and disposal was in general unregulated in India in 2024. Regulation may be limited in other low-middle income countries with chemical manufacturing industries (such as Argentina, Bangladesh, Egypt and Zambia). The lack of regulation may make these countries more attractive to companies wishing to continue manufacturing using fluoropolymers. Manufacturing has moved to regions or countries with cheaper labour and less regulation such as China, in effect 'offshoring' pollution from production (Saussay and Zugravu-Soilita, 2023; Li and Zhou, 2017). Moreover, as wages and regulation increase in China (see Annex 3) manufacturing may move to India or other countries with fewer regulatory constraints and lower wages.

The competitiveness analysis excludes full analysis of the regulation of polymers of low concern (PLC). These polymers (which include fluoropolymers) are exempted from regulation in various countries, but the criteria (properties) for this definition and extensive guidance on this varies between countries. There is currently no international agreement (for example by the OECD), on the definition of PLC. To inform the regulation of fluoropolymers in Europe, we recommend a thorough assessment of the properties used to define them in different countries, to identify commonalities in criteria. These common criteria could be considered in the PFAS restriction, and/or used to undertake a more detailed competitiveness impact assessment.

The competitiveness analysis is largely informed from feedback from the stakeholder consultation. The competitiveness analysis aims to present the impacts on industry under different policy scenarios across different dimensions such as impacts on costs and price, the capacity to innovate and international competitiveness. Consultation with industry is a reliable source for a competitiveness analysis, as they are aware of market competition and dependencies.

Stakeholder engagement included consultation with one industry association from each sector, from aerospace, defence, and semiconductors; and two organisations from the green energy and clean technology sector.

This was a small sample of stakeholders, but the consultation has been effectively used in this study to provide additional data for the AoA and SEA to strengthen the robustness of findings. Stakeholder consultation helped to identify and confirm the main factors and issues the sectors face which are important considerations for policy recommendations.

2. SCOPE OF THE IN-DEPTH ANALYSIS

The scope of the in-depth analysis is broken down into two thematic areas: substances and markets of strategic relevance. Both the substance and market scope of this study was agreed between the study team and ITRE committee:

- **Six fluoropolymers, and F-gas refrigerants are the focus of the study**;
- **The industrial sectors assessed represent markets of strategic importance to Europe.** The sectors assessed are aerospace, defence, green energy and clean technology, and semiconductors.

2.1. Substances in scope

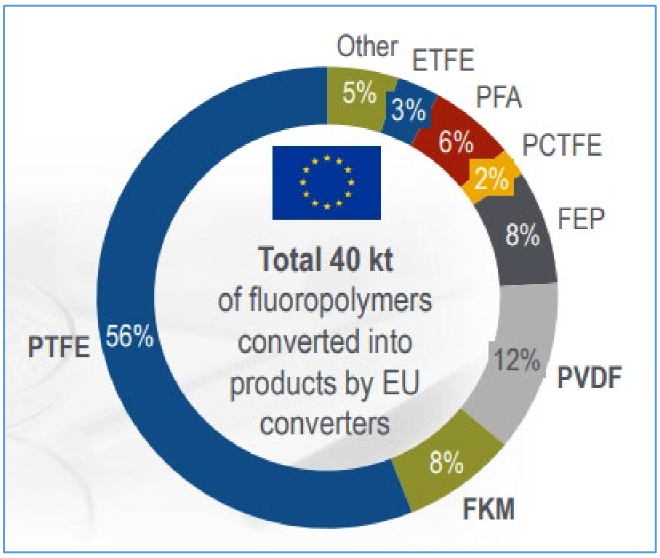
Box 1: Research questions addressed in section 2.1

The following section of the report addresses two research sub questions:

- RQ 1.1: What sectors are fluoropolymers used in?
- RQ 1.3: Which performance criteria drive the use of fluoropolymers by industry?

PFAS are defined by strong carbon–fluorine bonds, making them highly stable and resistant to heat, chemical, and biological degradation (Klingelhofer et al, 2024), and repellent to both water and oil. These properties make PFAS highly durable in harsh environments. While many PFAS exist, this assessment prioritises fluoropolymers, and a single use of fluorinated gases. The six fluoropolymers with the highest use rates in Europe (Conversio, 2023) have been selected specifically for assessment because of their use in strategic sectors, as confirmed by the Fluoropolymer Products Group of Cefic (Fluoropolymer Products Group, 2023). These fluoropolymers were also repeatedly found in literature sources to be used in specific applications within strategic sectors (see listed applications of selected fluoropolymers in sections 3.3.1, 3.3.2, 3.3.3 and 3.3.4).

Figure 1: European conversion of fluoropolymers to products in 2020



Source: Lindner, Beylage and Hein, 2023.

The chemical structure of the substances discussed below are available in Annex 1 of this report.

2.1.1. PTFE – polytetrafluoroethylene (CAS: 9002-82-0)

Polytetrafluoroethylene (PTFE) is the most 'typical' fluoropolymer, composed of fully fluorinated linear carbon chains formed by polymerisation of tetrafluoroethylene monomers. It has higher crystallinity than branched fluoropolymers and combines thermal and chemical resistance with very low friction due to its inert, ordered structure (ScienceDirect, 2025a). These properties make PTFE widely useful in industrial sectors, the construction sector, electrical and electronics manufacture, and consumer goods (Emerson, 2017; ScienceDirect, 2025a; Omnexus, 2025). Sections 3.2 and 0 expand on PTFE's properties and applications in strategic sectors further.

2.1.2. PVDF – polyvinylidene fluoride (CAS: 24937-79-9)

Polyvinylidene Fluoride (PVDF) is an unbranched fluoropolymer, polymerised from 1,1-difluoroethylene monomer units. Unlike PTFE, which is fully fluorinated, it consists of alternating fluorinated carbons (-CF_2-) in the polymer chains. It shows typical fluoropolymer properties such as thermal, chemical, and fire resistance, and mechanical strength (ScienceDirect, 2025b). Its applications include industrial, transport, nuclear, and health and food (Dallaev et al, 2022). Sections 3.2 and 0 expand on PVDF's properties and applications in strategic sectors further.

2.1.3. ETFE – ethylene tetrafluoroethylene (CAS: 25038-71-5)

Ethylene tetrafluoroethylene (ETFE) is a fluoropolymer formed from repeating ethylene and tetrafluoroethylene units. It combines resistance to weathering, temperature, and chemical degradation with good mechanical strength (Lamnatou et al, 2018; Hu et al, 2017). ETFE is transparent, with light transmission comparable to glass, and is valued as an architectural glass alternative offering improved fire resistance (Hu et al, 2017). In addition to its use in architecture ETFE is utilised in automotive, electrical, industrial, medical, and packaging applications (Omnexus, 2025; AFT Fluorotec, 2025). Sections 3.2 and 0 expand on ETFE's properties and applications in strategic sectors further.

2.1.4. FEP – fluorinated ethylene propylene (CAS: 25067-11-2)

Fluorinated ethylene propylene (FEP) is a copolymer of tetrafluoroethylene and hexafluoropropylene, where the additional CF_3 group disrupts the polymer backbone, lowering the melting point and crystallinity but improving processability compared with linear fluoropolymers like PTFE (ScienceDirect, 2025c). FEP has high chemical and temperature resistance, electrical insulation, and mechanical strength. FEP is widely used where PTFE-like properties are needed with easier processing such as electrical wiring (Holscot, 2019; Adtech, 2025). Its melt processability also enables food hygiene, industrial, aerospace, construction, chemical processing, packaging, electronic, and medical equipment applications (Holscot, 2019). Sections 3.2 and 0 expand on FEP's properties and applications in strategic sectors further.

2.1.5. PFA – perfluoroalkoxy alkane (CAS: 26655-00-5)

Perfluoro alkoxy's (PFA) structure is like FEP and PTFE, with alkoxy groups altering the tertiary structure, lowering melt temperature, and improving processability (Process Technology, 2017).

It provides key properties like thermal, flame, and chemical resistance, while offering greater flexibility than PTFE.

PFA is widely used in consumer coatings, laboratory equipment, chemical processing, and semiconductor manufacturing, where high purity and low contamination are critical (Emerson, 2017; Polyflon, n.d.). Sections 3.2 and 0 expand on PFA's properties and applications in strategic sectors further.

2.1.6. FFKM/FKM – perfluoroelastomer (CAS: 26425-79-6, 9011-17-0)

Fluorine Kautschuk Material (FKM) refers to fluorocarbon-based elastomers, often called FKM rubber (ERIKS, 2024). Unlike non-fluorinated elastomers, FKM maintains performance in harsh conditions. Its key properties are high chemical and temperature resistance combined with elasticity and compression set resistance (Klingender, 2008).

Due to these properties, FKM is widely used in sealing applications (Klingender, 2008; ScienceDirect, 2025c), critical to the aerospace, automotive, oil and gas, chemical processing, and pharmaceutical/food processing sectors (TRP Polymer Solutions, 2024). Sections 3.2 and 0 expand on FKM's properties and applications in strategic sectors further.

FFKM is also included in the scope of this substance. FFKM is a higher-grade variant of FKM and presents a more costly but more chemically and thermally resistant form of fluoroelastomer.

2.1.7. F-gases

Fluorinated gases (F-gases) are short-chain PFAS, mainly hydrofluorocarbons (HFCs), hydrofluoroolefin (HFOs), and perfluorocarbons (PFCs). Other gases such as sulphur hexafluoride and nitrogen trifluoride are also F-gases, but only PFAS-classified F-gases are assessed in this study. Their strong carbon–fluorine bonds give them stability and high energy transfer capacity, making them effective heat transfer fluids. They are non-flammable and non-toxic but pose higher global warming potential if released (Area Cooling Systems, 2025). F-gases are widely used in HVACR (heating, ventilation, air conditioning, refrigeration) but their application also extends to automotive, military, food, medical, electronics, and green technology sectors. Section 0 expands on F-gas applications in strategic sectors further.

2.2. Markets of strategic relevance

Box 2: Research questions addressed in section 2.2

> The following section of the report addresses the research sub question:
>
> - *RQ 1.2: How are fluoropolymers used in strategic sectors?*

This study focuses on the use of fluoropolymers in four interlinking sectors (aerospace, defence, green energy and green technology, and semiconductors), and the use in of F-gases in one (green energy and green technology). All these sectors are of strategic importance to Europe, which have been identified as essential to the future of European industrial competitiveness (Draghi, 2025).

Box 3: Strategic relevance of sectors within scope

Under the 2021 update to the EU Industrial Strategy, strategic industrial ecosystems will follow 'transition pathways' to manage the green and digital transitions, with cross-cutting alignment across the policy themes of climate, digital, trade, R&D and procurement (EC, 2021).

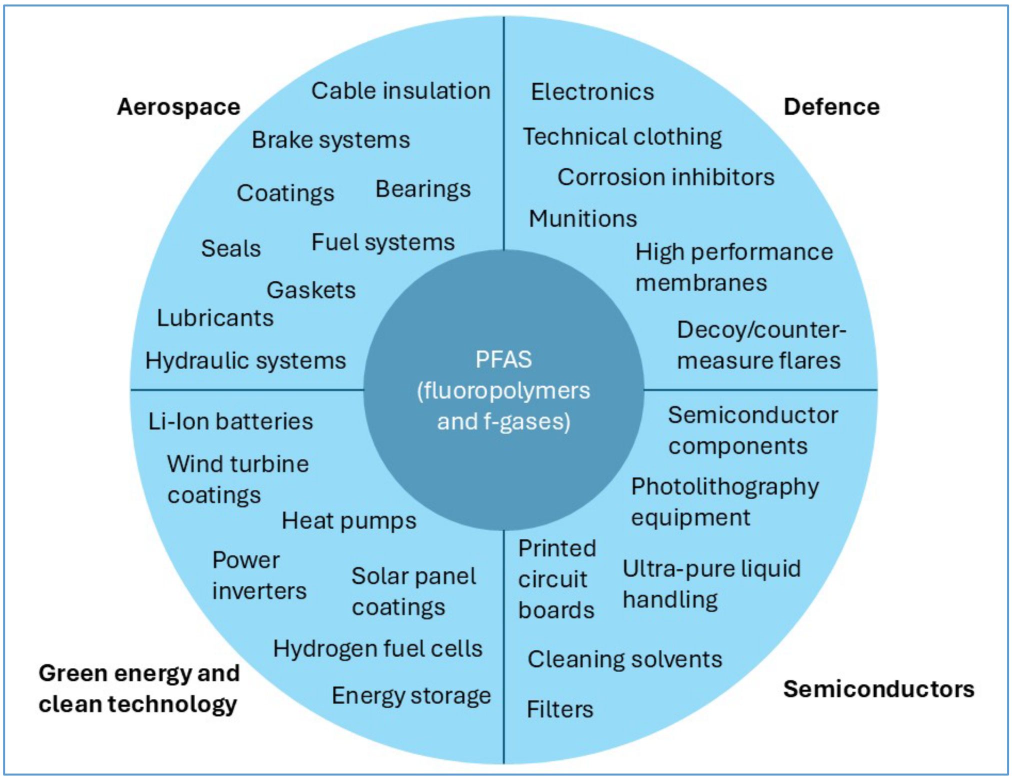
Under the European Green Deal, the EU climate change and defence roadmap sets out actions for the defence sector to address climate change risks and become more sustainable.

The green energy and clean technology sector are critical to developing and delivering a sustainable green transition within Europe and delivering the European Green Deal.

Semiconductors are critical for the digital, defence and clean technology sectors, and permit the EU's digital and energy transition. The EU Chips Act (Regulation (EU) 2023/1781) aims to reduce reliance on Asia and the US by strengthening production of semiconductors in Europe.

The markets of strategic interest have been screened for use of PFAS and the following PFAS applications have been identified for each sector (Figure 2), confirming relevance and potential implications as a result of the EU UPFAS Restriction. This is a non-exhaustive list based on the literature review conducted as a part of this study. Further applications are noted under each sector heading in section 3 of this report.

Figure 2: Screening of PFAS applications in strategic sectors



Source: Authors' own elaboration.

2.2.1. Aerospace

The aerospace industry is key for international transport, economic development, and national security. It encompasses the design, manufacture, maintenance and operation of aircraft and spacecraft used for both civil and defence purposes. In 2019 civil aeronautics provided 405,000 jobs in the EU with research and development estimated at €8 billion in 2019, although aircraft production rates declined after the COVID 19 pandemic (EC, n.d. a). More recently, it was estimated that the civil aerospace aeronautics sector had a turnover of €118.9 billion in 2023 (ASD, 2024). The aerospace sector is notably being driven by the Transition Pathway for the Aerospace Ecosystem (EU, 2024), with the Clean Sky 2 R&D programme developing cleaner, quieter, lower-emission aircraft technologies (Clean Aviation, 2025).

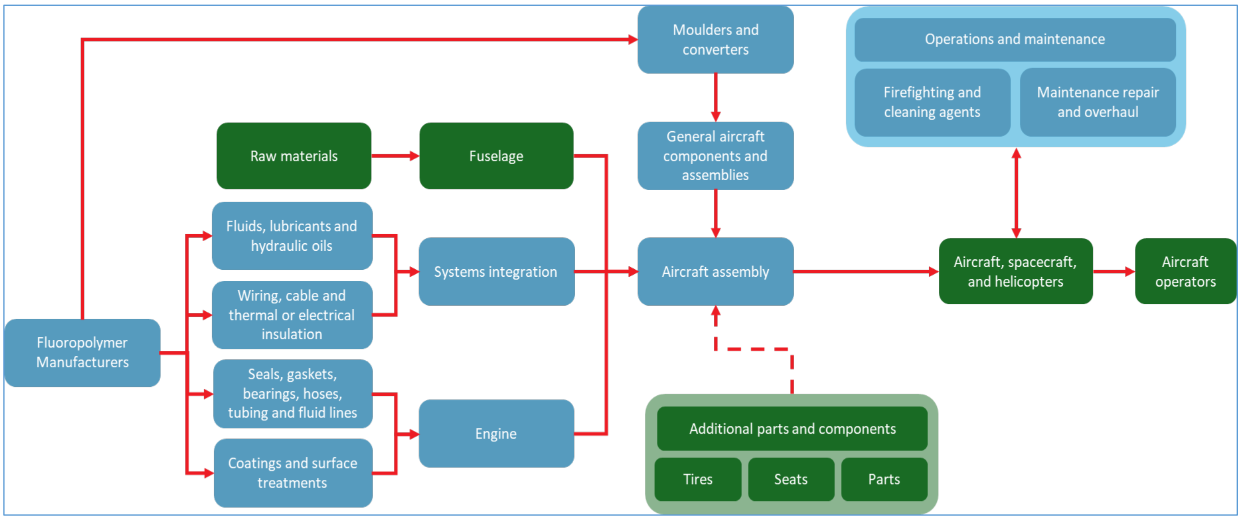
The sector has complex engineering requirements, due to the requirements of robust safety and regulatory standards. Component failures can have catastrophic and fatal consequences meaning development cycles in the industry are very long and resource (time, labour and capital) intensive. Due to the cost of developing and manufacturing them, aircraft have long service lives requiring components which perform over long periods.

Research efforts in the industry typically focus on safety, reliability, and fuel efficiency to drive the development of safe and economically viable craft to operate. Consistent safety performance of components in extreme conditions, and long service life demanding durable materials has driven this markets use of fluoropolymers.

Fluoropolymers are used in a wide range of components within the aerospace sector. While some final products may not contain fluoropolymers, they may have been manufactured using fluoropolymers or are reliant on parts which are made from fluoropolymers. Specific fluoropolymer applications in the aerospace sector are discussed in more detail in section 3.3.1.

The European aerospace supply chain is a highly complex and multi-tiered structure and characterised by deep integration across EU Member States. The aerospace industry supply chain is presented below (Figure 3).

Figure 3: Supply chain of the aerospace sector utilising PFAS



Source: Authors' own elaboration.
Note: Green boxes indicate non fluoropolymer products.

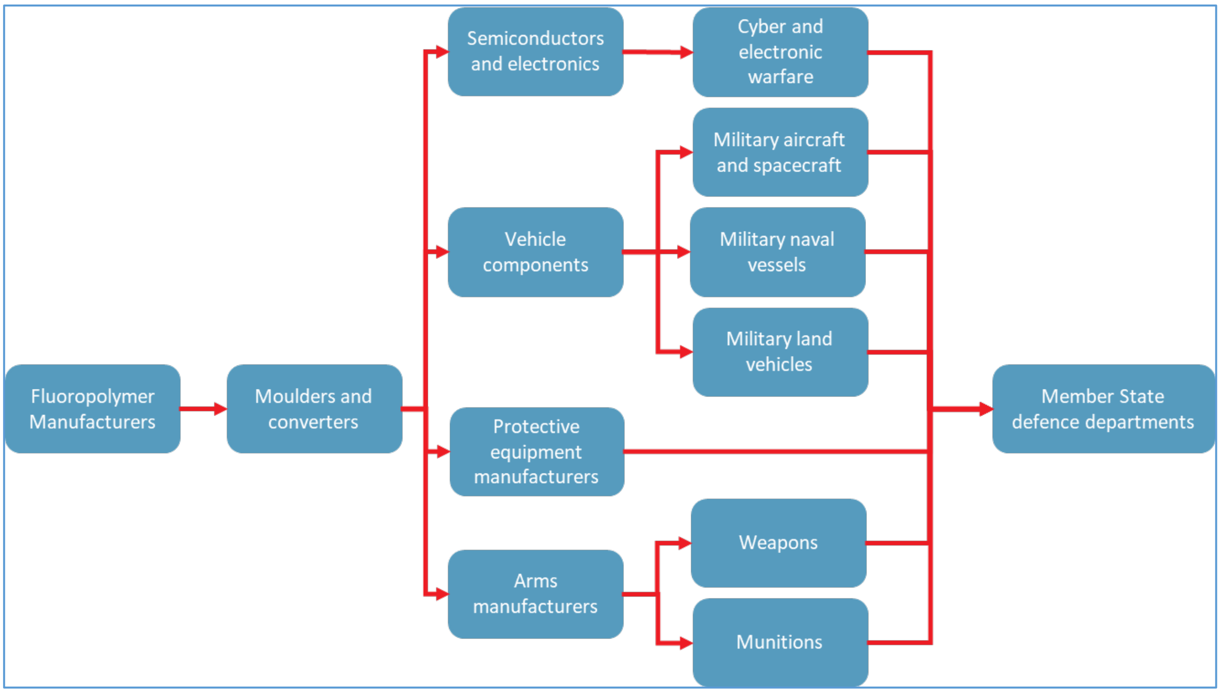
2.2.2. Defence

The defence sector comprises of a range of industries and Member State governments committed to developing, manufacturing, purchasing, and deploying military hardware. This includes developing and manufacturing weaponry, munitions, vehicles, aircraft, protective equipment, and electronic warfare. A strong self-sufficient European defence sector strengthens European security and reduces reliance on external suppliers. Since 2014, when combined EU Member State expenditure on defence was €189 billion, spending on defence has increased year on year. In 10 years, this figure has almost doubled to €343 billion in 2024 (Consilium, 2025).

Fluoropolymers are used in weaponry, ammunition, personal protective equipment and military electrical systems. There are also fluoropolymer applications aircraft, overlapping with the Aerospace strategic sector.

Defence applications are highly complex with thousands to millions of components reliant on one another within and across applications. All applications with their own development cycles but also all with the absolute requirement of working when required without fail. Specific fluoropolymer applications in the defence sector are discussed in more detail in section 3.3.2. A representation of defence industries supply chain is presented below (Figure 4).

Figure 4: Supply chain of the defence sector utilising PFAS



Source: Authors' own elaboration.

2.2.3. Green energy and clean technology

This sector encapsulates technologies and products aimed at decarbonising the European industry and consumer activities whilst maintaining energy security. Green energy encompasses the development of wind, solar and other renewable energy sources, increasing energy security.

Clean technology covers technologies such as efficient hydrogen fuel cells used for either energy production or motor vehicles (hydrogen fuel cell vehicles or HFCVs), lithium-ion batteries used in electric vehicles (EVs) or heat pumps for domestic heating and cooling. The bespoke and broad definition of this sector was agreed with the EP for this study, and is not directly comparable to 'green energy' or 'clean technology' sectors in other studies without checking first what is covered.

There is no single authoritative figure for the value of this sector as a whole to the EU economy. This is due to fragmented technologies, overlapping sectors, and different definitions. It is however estimated that the global clean technology market had a market size of $916.2 billion in 2024 (Grand View Research, n.d.). In 2023 the EU renewable energy industry outperformed the overall economy in 2023 in terms of turnover and gross value added.

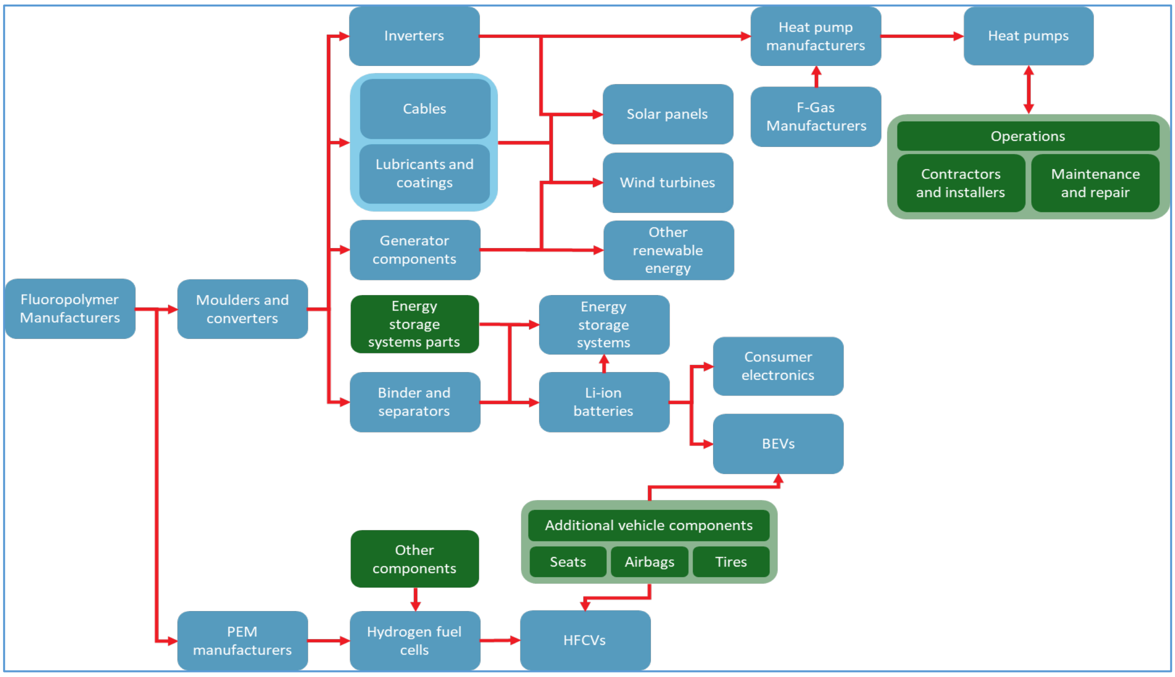
The manufacturing production value of clean energy technologies in Europe was approximately €80 billion in 2023, with significant growth in the production of batteries, heat pumps and fuel cells (Georgakaki *et al*, 2025). There was an overall trade deficit in 2023, due to high imports of solar PV and batteries, but a positive trade balance for wind and district heating. In 2022 the renewable energy sector employed 1.7 million people across Europe.

Fluoropolymers and F-gases have become critical materials in many developing green technologies.

For example, fluoropolymers can be found in solar panels, wind turbines, and every lithium-ion battery on the market. Furthermore, fluoropolymer proton exchange membranes (PEM) have been essential in the development of economically viable hydrogen fuel cells vital for green hydrogen production. Specific fluoropolymer applications in the green energy and clean technologies sector are discussed in more detail in section 3.3.3.

The green energy and clean technology industry supply chain is presented below (Figure 5).

Figure 5: Supply chain of the green energy and clean technologies sector utilising PFAS



Source: Authors' own elaboration.

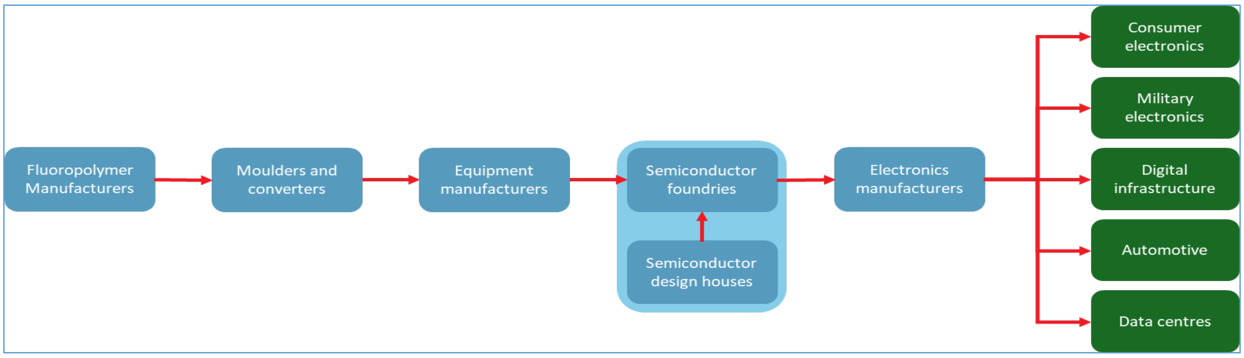
Notes: Green boxes indicate non fluoropolymer products which would also face disruption in the event of restriction. Inverters are also an essential component in energy storage systems.

2.2.4. Semiconductors

The semiconductor sector underpins all modern electronics, and the tech industry. It was estimated that the value of European sales in 2022 was around €50 billion with strong demand and growth expected in the medium and long term (ERM, 2023). **The exact value of this sector is hard to estimate due to global supply chains and overlapping industries.** The sector encompasses the design, fabrication, and packaging of semiconductors and integrated circuits. The EU Chips Act (Regulation (EU) 2023/1781) aims to reduce reliance on Asia and the US by strengthening domestic production of semiconductors. The semiconductor industry supply chain is presented below (Figure 6).

Fluoropolymers are required to ensure no contamination occurs throughout the entire manufacture process. The industries manufacturing process is highly complex, needing perfectly sterile conditions which is an extreme requirement supporting the use of Fluoropolymers. Fluoropolymer applications in the semiconductor sector are discussed more in section 3.3.4.

Figure 6: Supply chain of the semiconductor sector utilising PFAS



Source: Authors' own elaboration.

Note: Green boxes indicate non fluoropolymer products which would also face disruption in the event of restriction.

3. ANALYSIS OF ALTERNATIVES ASSESSMENT

3.1. Overview of approach

The AoA is focused on alternatives readily available on the market and not on novel alternatives. This section presents an Analysis of Alternatives (AoA) for each strategic sector of commonly cited alternatives. The alternatives list is drawn from the authors' experience of PFAS AoAs since the start of the EU UPFAS Restriction process. The alternatives identified via the authors' experience have been frequently investigated by industry in previous works and are therefore solutions which are currently available on the EU market. It is possible wider alternatives are in development that have not yet made it to market. Industry can often treat these with confidentiality. Due to the basis of industry investigations, these novel alternatives are not considered in the current study although may be available in as alternatives in future years.

The method applies a high-level AoA and relies on a literature review to compare alternatives, using key metrics. These metrics include physiochemical properties, economic feasibility, market availability, and risk profile of materials (Annex 5). These comparisons are contextualised against sector performance requirements to infer substitution potential. This approach allows broad coverage of multiple applications but lacks the nuance of application-specific AoAs. Some critical application-specific use examples are given, assessing technical feasibility then, if relevant, economic, market, and risk factors. All sources were screened through a credibility matrix (Annex 4). Due to the high-level nature of this AoA and the grounding in literature data alone, the substitution potential of this AoA should be seen as indicative and not considered a definitive conclusion.

Future additional consultation will be beneficial to gather data on alternatives. Confirmation of substitution potential requires test data from industry R&D which would require extensive consultation with industry. Stakeholder consultation conducted in the scope of this study was used to support the analysis of substitution potential to the best degree possible and has highlighted some key challenges and opportunities for substituting fluoropolymers and F-gases in the strategic sectors of interest.

3.2. Identification and review of possible alternatives

Box 4: Research questions addressed in section 3.2

The following section of the report addresses two research sub questions:

- *RQ 1.3: Which performance criteria drive the use of fluoropolymers by industry?*
- *RQ 3.2: What possible alternatives to PFAS exist?*

Although there are alternatives that replicate some fluoropolymer functionality, few provide all required properties. A direct comparison of fluoropolymer performance and identified possible alternatives is presented in Table **3-1** below.

As previously noted, this assessment is based solely on literature findings and only discusses possible alternatives defined by the Authors as regularly considered alternatives informed by previous experience working with PFAS data gathering/evaluation.

Substitution poses challenges and alternatives must be assessed case by case with full knowledge of application requirements. In most cases, alternatives replicate some fluoropolymer functionality, but few provide all the beneficial properties. A few critical selected applications are examined further in section 3.3. Throughout these sections data from the tables in Annex 5 is used to indicate whether alternatives perform comparably, better, or worse than fluoropolymers for each of the performance criteria listed. This is contextualised in the requirements of the specific end use to understand the inferred substitution potential.

Conclusions on substitution potential should be treated as indicative, not representative of all applications within a strategic sector.

Table 3-1: Generalised comparison of possible alternatives to fluoropolymers in scope of this analysis

Possible alternative	Comparison		
	Improved	Comparable	Lacking
PEEK	Mechanical properties (for solid sheet/extruded materials)	Thermal resistance	UV and some specific chemical resistance
Polyethylene (multiple grades)	Elasticity	Processability	High temperature resistance and flammability
UHMWPE		Mechanical properties (inflexible materials)	High temperature and chemical resistance
Polyamide		Low temperature resistance	High temperature, chemical and UV resistance
PVC		Flammability and processability	High temperature and chemical resistance
PMMA		Optical and mechanical properties (for solid sheet/extruded materials)	High temperature and chemical resistance
Polyester (Little available data)		Mechanical properties (for solid sheet/extruded materials)	
Polycarbonate (Little available data)		Low temperature resistance	High temperature resistance
Polypropylene		Elasticity	Temperature resistance and flammability
Stainless steel (Solid fluoropolymer parts only – little available data)	Mechanical properties		
HNBR		Low temperature resistance and elasticity	High temperature resistance

Possible alternative	Comparison		
	Improved	Comparable	Lacking
(FFKM/FKM only)			
SBR (FFKM/FKM only)	Elasticity	Low temperature resistance	High temperature and chemical resistance
Silicone	Elasticity	Temperature and UV resistance	Flammability
EPDM (FFKM/FKM only)	Elasticity		Thermal and fire resistance

Source: Authors' own elaboration.

Note: Where FFKM/FKM only is indicated in the possible alternative column, the comparison relates to fluoroelastomer uses only.

3.3. AoA findings and results

Box 5: Research questions addressed in section 3.3

The following section of the report addresses the research sub questions:

- *RQ 1.2: How are fluoropolymers used in strategic sectors?*
- *RQ 1.4: How critical is the use of fluoropolymers within the key strategic industries?*
- *RQ 2.1: For which strategic market sectors do alternatives to PFAS exist?*
- *RQ 2.2: What possible alternatives to PFAS exist?*
- *RQ 2.3: What is the technical feasibility of these alternatives?*
- *RQ 2.4: What is the economic feasibility of alternatives?*
- *RQ 2.5: What is the market availability of alternatives?*
- *RQ 2.6: What is the risk profile of alternatives?*
- *RQ 2.7: What is the change in product quality from using alternatives?*
- *RQ 2.7: What is the price impact for consumers from using alternatives?*

This section provides an overview of the findings of the high level AoA. Information in this section is sub-divided by strategic sector to indicate the range of fluoropolymer applications in the sector, the drivers of fluoropolymer use, and specific examples of substitution potential. Key conclusions are presented based on the information provided and uncertainties associated with the high-level analysis approach.

3.3.1. Aerospace

a. Overview of substances and applications

PFAS are used in many applications within the aerospace sector. The literature review and consultation have identified the following aerospace specific applications which utilise fluoropolymers:

- General components – PTFE (Polyfluor, n.d.);
- Anti-icing coatings on turbine blades – general (PW Consulting Chemical & Energy Research Center, 2025; Rekuviene et al., 2024);
- Bearings – general (Conversio, 2023);
- Brake systems – general (Consultation);
- Cable insulation – PTFE, FEP, ETFE, PVDF (Conversio, 2023; Dallaev et al., 2022; IAEG, 2024);
- Cleaning solvents – F-gases (Glüge et al., 2020; NetRegs, n.d.);
- Closed cell foams – PVDF (Dallaev et al., 2022);
- Coatings – general (IAEG, 2024);
- Electronic systems – general (IAEG, 2024)
- Engine seals – FKM/FFKM (Advanced EMC Technologies, 2024; Eastern Seals, 2024);
- Fire-fighting foams – general (Cheney, 2023);

- Fuel systems – PTFE, FKM/FFKM (consultation) (Advanced EMC Technologies, 2024; Conversio, 2023; Eastern Seals, 2024);
- Gaskets – general (consultation);
- Hydraulic systems – PTFE, FKM/FFKM (Conversio, 2023; Eastern Seals, 2024; OECD, 2025);
- Landing gear – general (consultation); and
- Lubricants – general (IAEG, 2024)

PFA is also noted as being used in unspecified aerospace applications. It is possible that applications which did not specify a substance may be using PFA. Several sources also identified use of PTFE, ETFE, PFA and FFKM in general in the sector meaning there are potentially more fluoropolymer applications than those listed above. Therefore, the above list should not be seen as an exhaustive list as it is estimated that over 1 million individual components may contain fluoropolymers in a large aircraft (ECHA public consultation comment ID 7624). In the consultation under this study with the European aerospace industry, it was confirmed that thousands of components containing fluoropolymers are integrated within systems, subsystems and assemblies in this sector.

b. Substitution potential

Consultation for this study has revealed that fluoropolymers are used at every level of the aerospace supply chain meaning the substitution potential may be highly variable within the sector and cannot be assessed for the sector as whole. This consultation also revealed all components involved in the manufacture of an aircraft are considered critical as failure of any single component may compromise reliability and safety. Industry notes that fluoropolymers are relied upon for high specification, safe and reliable products and often there are no suitable alternatives available that fulfil the challenging performance requirements. Even when alternatives are available substitution can take time due to stringent safety, testing and certification requirements (EC, 2012; ECHA public consultation comment ID 8661). Consultation with stakeholders under this study identified in some cases, a redesign of equipment entails additional time associated with substitution.

As the substitution potential of all applications of fluoropolymers within the aerospace sector cannot be assessed within this report, two critical applications have been selected. These applications were selected based on the findings of IAEG (2024) and relate to the use of fluoropolymers as engine seals and electrical insulation coatings. This report identified several critical applications for fluoropolymers, but engine seals and electrical insulation coatings were the most widely confirmed critical applications by respondents to an internal consultation. Coatings were equally reported as a widely used critical application however this application was not selected as coatings may have greater variability in the performance requirements depending on where the coating is applied in the aircraft and would therefore be more challenging to conclude on the substitution potential.

Table 3-2: Substitution potential examples in the aerospace industry

Application	Substance	Performance criteria	Substitution potential
Engine sealings	FFKM	Chemical resistance: (aviation fuel and oil); Wide operating temperature range: (<0°C to >200°C); Mechanical stability in extreme environments; Water (hydrophobic) and oil repellent (oleophobic); Low frictional co-efficient (IAEG, 2024)	**Inferred substitution potential: Low.** As shown in the Annex 5 tables, none of the alternatives meet the technical requirements for this application. Polyethylene, UHMWPE, Polyamide, PVC, PC, PP, HNBR, and EPDM have operating temperature limits below the 200 °C required, with polyethylene's limit inferred from its melt temperature. PMMA and SBR lack resistance to aromatics and hydrocarbons, making them unsuitable for exposure to aircraft fuels and oils. PEEK shows promising traits but is not viable as an elastomer due to low elongation at break compared with compounds such as FFKM, SBR, and EPDM. Silicone appears more promising, but further data on chemical resistance is needed to confirm its substitution potential. Polyester and stainless steel lack sufficient data to assess suitability. The risk profile of silicone, particularly potential human and environmental exposure to siloxanes, may represent a regrettable substitution compared with FFKM, reducing its overall substitution potential.
Wiring coatings (thermal barrier)	PTFE, FEP, ETFE, PVDF	Flexibility; Thermal resistance: (-55°C to 150°C); Chemical resistance (biological contaminants, acids, alkalis, fuels, hydrocarbons and solvents); Mechanical stability in extreme environments; Low moisture absorption; Uniform electrical properties; Hydrophobic and oleophobic; Low co-efficient of friction; Dimensional stability; High dielectric strength (IAEG, 2024)	**Inferred substitution potential: Moderate.** Based on the Annex 5 tables, most alternatives lack the technical performance needed to replace fluoropolymers. Polyethylene, UHMWPE, EPDM, and SBR cannot meet the 150°C upper temperature requirement, and SBR, EPDM, polycarbonate, HNBR, and polypropylene also fail at lower temperatures. Polyamide shows poor resistance to strong acids and bases, while UHMWPE and PEEK have low resistance to some acids. PEEK's semi-crystalline structure also limits flexibility, excluding it as an option. Stainless steel is unsuitable due to high conductivity and inflexibility. Some materials show partial potential: PVC, PMMA, and silicone could be feasible, but further data are needed on PVC's operating range, PMMA's low-temperature limit, and silicone's chemical resistance. There is insufficient data on polyester to infer its substitution potential. Based on the Annex 5 tables, the authors consider PMMA and PVC as commodity polymers with good availability, low costs (PMMA confirmed), and low inherent hazard, making them possible substitutes. Silicone, however, raises concern due to potential siloxane exposure, which increases risk relative to fluoropolymers and may represent a regrettable substitution.

Source: Authors' own elaboration.

c. Key conclusions

There are thousands of individual aerospace fluoropolymer applications. Based on the volume of individual components using PFAS and the range of applications, substitution potential may vary within the sector. For the example of engine seals, no alternatives investigated in this report are expected to meet the technical performance requirements. Lower technical performing alternatives may lead to failures during engine operation posing an intolerable safety risk.

Due to the integrated nature of fluoropolymers within the supply chain there is likely to be significant disruption across the industry should fluoropolymers be restricted, resulting in an inability to manufacture aircraft components and systems (i.e. aircraft engines).

Whilst wiring coating alternatives were found to be theoretically feasible, further case by case analysis would be required to confirm the exact extent of substitution potential to avoid making an inaccurate sector wide conclusion for this application.

It is likely that the aerospace industry would not be able to substitute fluoropolymers to alternatives in the thousands of required applications to continue the manufacture of complex aircraft and therefore may have an inferred low substitution potential.

Figure 7: Key conclusions of the AoA for priority aerospace applications

	Technically feasible	Economically feasible	Hazard and risks	Market availability
Engine seals	Silicone? – more data needed	Silicone? – more data needed	**No feasible alternatives**	Silicone? – more data needed
Wiring coatings	PVC? PMMA? Silicone? – more data needed	PVC PMMA Silicone? – more data needed	PVC PMMA	PVC PMMA Silicone? – more data needed

Source: Authors' own elaboration.

Note: A substance must be listed under all criteria to be deemed a potentially feasible alternative

3.3.2. Defence

The Authors were unable to gather consultation data for the defence sector, due to confidentiality, and therefore the information provided below is based on published literature only.

a. Overview of substances and applications

The extent of PFAS use in the defence sector is relatively uncertain due to the confidential nature of the industry. Several aerospace applications of fluoropolymers and F-gases are also likely applicable to defence, especially those relating to military aircraft. The following defence applications have been identified as utilising fluoropolymers:

- Countermeasure flares – PTFE, FKM (Orzechowski et al, 2021; Gaines, 2023);
- Corrosion inhibitors - general (IAEG, 2024);
- Firefighting foams - general (Conflict and environment observatory, 2025; Gaines, 2023);
- High performance membranes - general (IAEG, 2024);
- Military electronics (Conflict and environment observatory, 2025)
- Military technical clothing (PPE) (Henry *et al*, 2018); and
- Munitions - general (Conflict and environment observatory, 2025; Gaines, 2023).

PVDF, ETFE, and FEP, are also being used in unspecified defence sector applications (EMR CLAIGHT, 2025a; EMR CLAIGHT, 2025b; Invest Saudi, 2021; MarketsandMarkets, n.d.), meaning there are potentially more fluoropolymer applications than those listed above. Therefore, the above list should not be seen as an exhaustive list.

b. Substitution potential

Substitution potential has been investigated for munitions and decoy flares showing variable results. These selected priority applications could not be informed by literature. As an alternative, the authors have selected two specific applications from previous experience known to relate to the protection of life and prevention of injury: decoy flares and munitions (Table **3**-**3**). Both of these applications relate to the protection of human health/life and are therefore justifiably considered by the authors as critical applications of PFAS. In munitions PFAS are used as binders present in the explosive component to provide stability and prevent the occurrence of misfiring (even after storage for years). In decoy/countermeasure flares PFAS are used in the explosive composition of the flare to recreate the exact heat signal of the aircraft to misdirect heat seeking missiles and protect the aircraft operator. Other applications are less known to the authors and would pose additional challenges for assessing substitution potential due to the confidentiality of information in the defence sector.

Table 3-3 Substitution potential examples in the defence sector

Application	Substance	Performance criteria	Substitution potential
Munitions	Fluoropolymers in general	Shock absorbance; Long-term stability (ageing resistance) (Glüge et al., 2020).	**Inferred substitution potential: Low/Moderate.** As fluoropolymer applications in munitions require shock absorbance, this requires an elastomeric compound to be used. As such all possible alternatives except for HNBR, SBR, Silicone and EPDM are not technically feasible. To be a technically feasible alternative these substances would need to indicate longevity in situ as munitions may be stored for many years before use. Degradation of the polymer binder may cause accidental misfiring potentially leading to loss of life or injury. Longevity is a product of resistance to various factors and so comparisons are made for thermal, chemical and UV resistance to infer longevity. In comparison to fluoropolymers HNBR, SBR and EPDM have lower thermal resistance whilst EPDM and Silicone also have relatively low fire resistance. SBR indicates low compatibility with hydrocarbons, acids, bases and organic solvents and is therefore likely to be incompatible with chemicals in munitions. For other alternatives the chemical resistance has not been identified. Both Silicone and EPDM indicate strong UV resistance. Based on this information it is likely SBR would not be a suitable alternative for fluoropolymers in munition, whilst more information on chemical resistance is required to confirm the suitability of HNBR, Silicone or EPDM. The lack of flammability resistance for Silicone and EPDM may also provide challenges should a fire occur in a munition's storage area. Considering economic and availability factors no data was identified however hazards and risks are considered. For HNBR degradation of the polymer under ageing may cause corrosive residues which may damage the munitions and as such this may not be seen as a suitable alternative. For

Application	Substance	Performance criteria	Substitution potential
			silicone materials, exposure to siloxanes because of increased use would increase the risk profile over that of fluoropolymers, making Silicone a regrettable substitution. For EPDM no additional considerations are raised and the risk is considered comparable to fluoropolymers. EPDM may therefore represent a possible substitution for fluoropolymers in munitions; however additional nuance should be considered before confirming this conclusion.
Decoy flares	PTFE, FKM	Correct heat signature to act as a decoy for heat seeking missiles (Orzechowski et al, 2021; Gaines, 2023)	**Inferred substitution potential: Low.** Decoy flares represent a relatively unique use of PFAS within the defence industry. Flares are comprised of Magnesium, Teflon®, Viton® (MTV) pyrotechnics and are designed to mimic the heat signature of aircraft. Without Teflon® PTFE or Viton® FKM, these countermeasure flares cannot be manufactured as these Fluoropolymers are essential in the pyrotechnic composition. As a result, the substitution of PFAS within MTV countermeasure flares is not possible as alternatives cannot recreate the same reaction as occurs in MTV based pyrotechnics.

Source: Authors' own elaboration.

c. Key conclusions

Substitution in the defence sector can be varied, based on the examples presented within this report. From the Authors' experience, sectors involving high specification equipment, such as defence, typically have extensive use of fluoropolymers due to their wide offering of technical performance. This includes aircrafts and aerospace applications, where substitution potential can be regarded as low.

For the defence sector, only a few fluoropolymer applications are identified in literature. It is expected that a larger number of applications exist than those stated in this report and so this may limit the understanding of criticality.

In munitions some alternatives are inferred as potentially feasible based on a high-level comparison of technical qualities of possible alternatives. In other applications such as decoy flares, the chemistry required is designed around the current fluoropolymers being used and therefore substitution is likely to be impossible.

This illustrates the range of different scenarios the defence sector may face when considering a full PFAS Restriction. The conclusions of this study should be viewed considering the limitations outlines in section 2.3.

It is likely that substitution in the defence sector is variable based on the examples presented within this report. The extent to which market effects may occur because of restriction will be determined by the number of critical applications of PFAS within the sector and the performance requirements.

Figure 8: Key conclusions of the AoA for priority defence applications

	Technically feasible	Economically feasible	Hazard and risks	Market availability
Munitions	HNBR? EPDM? Silicone? - more data needed	HNBR? EPDM? Silicone? – more data needed	EPDM	HNBR? EPDM? Silicone? – more data needed
Decoy flares	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**

Source: Authors' own elaboration.

Note: A substance must be listed under all criteria to be deemed a potentially feasible alternative

3.3.3. Green energy and clean technology

a. Overview of substances and applications

The green energy and clean technology sector cover a vast range of different technologies containing a range of applications which are expected/known to utilise fluoropolymers and f-gases.

The following green energy and clean technology applications have been identified as utilising fluoropolymers and F-gases:

- General renewable energy – PVDF (Merchant Research and Consulting Ltd (2025);
- Battery binder – general (CONVERSIO, 2023);
- Electrolysers in hydrogen fuel cells – general (Kilgore, 2025);
- Energy storage systems – PVDF (Merchant Research and Consulting Ltd, 2025);
- Heat pumps – PTFE, PFA, FFKM/FKM, FEP, F-gases (R32, R410A, R407C), (Ehpa, 2025; Mitsubushi, 2025; EIA, 2025; Chemours ,n.d.; Issa et al., 2025; Fluorotherm, 2018; Kintek, 2025);
- HVACR applications – general (Glüge et al., 2024; EPEE, 2024; ATMO, 2022; NetRegs, n.d; EU Commision, n.d.);
- Power inverters – general (Consultation);
- Li-ion battery binder – PVDF (Merchant Research and Consulting Ltd, 2025; Dallaev et al., 2022);
- Li-ion separators – PVDF (Dallaev et al., 2022);
- Refrigeration – F-gases (Sovacool et al., 2021);
- Solar panel coatings – general (The Danish Environmental Protection Agency, 2024);
- Solar Panel manufacturing – ETFE (Smartech, n.d; MarketsandMarkets, 2022; EMR CLAIGHT, 2025a; The Danish Environmental Protection Agency, 2024); and
- Wind turbine coatings – general (The Danish Environmental Protection Agency, 2024)

It is possible that applications which did not specify a substance (recorded as general above) may be using any of the PFAS mentioned or those outside of the scope of this study. This is due to the wide range of applications which are noted in this strategic sector and the potential for extensive numbers of specific applications, each with its own set of unique performance requirements.

b. Substitution potential

Substitution potential is variable and challenging to assess due to the range of independent applications of fluoropolymers and f-gases within the green energy and clean technologies sector. Examples of substitution potential within the green energy and clean technology strategic sector have been suggested based on the authors experience of working with PFAS and consultation with industry on critical applications. The resulting examples discussed are coatings for photovoltaic panel front and back sheets (essential for durability of photovoltaic panels), cathode binders in lithium-ion batteries (essential for the development of electric vehicles) and F-gas refrigerants used in heat pumps (essential for the efficient operation of heat pump systems).

Whilst a wide range of applications could have been selected to represent this sector these applications were identified by the authors as being critical in the functioning of the equipment. The three examples have been selected to represent different divisions of the sector. Lithium-ion batteries are important in transitioning to green transportation and in the energy (storage) sector, heat pumps are currently important in transitioning to green infrastructure, and PV panels represent a major investment area in green energy generation. By assessing these applications, the report provides insights into how PFAS are used to support energy efficient infrastructure, low carbon energy generation and decarbonisation of transport.

Table 3-4 Substitution potential examples in the green energy and clean technology sector

Application	Substances	Performance criteria	Substitution potential
Coating of front and back sheets for photovoltaic panels	ETFE	UV resistance; weathering resistance; high chemical resistance; easily processed; non-flammable; Broad operational temperature range; High Light transmission (Cornwall Solar Company, n.d.)	**Inferred substitution potential**: **Moderate**. Based on the Annex 5 tables, most alternatives fall short of ETFE's technical performance. PEEK and polyamide show low UV resistance, while polyethylene, silicone, and EPDM have higher flammability and reduced fire resistance. UHMWPE and SBR lack the chemical and weathering resistance needed for long-life external use. Data gaps prevent conclusions for polycarbonate, polypropylene, and polyester. PVC appears broadly suitable, though more data on UV resistance are needed. PMMA may meet all requirements, but confirmation would require more detailed information. Stainless steel is excluded as it cannot be used as a coating. Industry consultation indicates PFAS-free back sheets exist but are more costly, less durable, and not yet produced at sufficient scale. Data from the Global Growth Insights (2025) market report contradict industry on costs, highlighting PFAS free back sheets as a more cost-effective and rapidly growing solution. The market report does corroborate issues with alternatives durability as fluorinated solutions are preferred for applications in harsh climatic conditions. Substitution potential therefore exists but with uncertain costs and durability in the specific application as a driver of the substitution potential.
F-gas refrigerants in heat pump systems	F-gases (R32, R410A, R407C)	Low boiling point; high latent heat vaporisation; low flammability; cost-effective and readily available (Adams, 2025)	**Inferred substitution potential**: **Low**. Industry consultation suggests low substitution potential for F-gases in heat pumps. The revision of the F-Gas Regulation (EU-2024/573) identified natural refrigerants for systems under 12 kW, but substitution is limited. Alternatives such as ammonia, propane, or CO_2 require higher operating pressures, reducing efficiency (Konghuayrob and Khositkullaporn, 2016), and necessitating redesigns that increase size and cost. Heat pumps are 3–5 times more expensive than boilers, and added costs reduce

Application	Substances	Performance criteria	Substitution potential
			viability. Propane also raises safety concerns due to flammability. Overall, substitution is not currently feasible given economic, technical, and safety constraints.
Cathode battery binder in Li-Ion batteries	PVDF	High chemical resistance; High purity; High electrochemical stability; High thermal resistance (AEM, n.d.); Tensile strength; Elasticity (Qin et al, 2024); Strong adhesion (Chemsec, n.d.)	**Inferred substitution potential**: **Low**. Cathode binders require elasticity to accommodate mass changes during charge cycles. Alternatives such as PEEK, PMMA, polyethylene, and polyamide show insufficient elongation and tensile strength; polyamide also lacks chemical resistance and polyethylene thermal resistance. Polypropylene, UHMWPE, PVC, and EPDM have lower thermal resistance, while SBR lacks resistance to strong acids, limiting compatibility. For polycarbonate, silicone, HNBR, and polyester, data gaps on dielectric strength and chemical resistance prevent conclusions. Stainless steel is unsuitable due to poor adhesion and lack of elastomeric properties. Overall, no alternatives assessed are technically feasible substitutes for PVDF in lithium-ion battery binders. This application has significant investment in R&D and a number of companies such as Leclanche are trialling li-ion batteries using alternatives (Leclanche, 2024). These technologies are however not currently used at scale and would take time to upscale to the required market capacity. Due to the scope of this study, novel alternatives are not considered in this assessment (see section 3.1).

Source: Authors' own elaboration.

c. Key conclusions

For green energy and clean technology, it is expected that substitution potential will be highly variable. The green energy and clean technology strategic sector represent a significant number of applications of fluoropolymers, as identified in the literature review. These applications range from protective coatings to refrigerant gases and present a wide range of functional requirements for alternative substances to meet. Given the range of applications noted, the strategic sector also covers many subsectors including HVACR, energy generation, electronics, automotive and the hydrogen economy. Substitution within the green energy and clean technology strategic sector is likely to be highly varied as each sector and application poses different performance requirements.

In the illustrative examples given none of the investigated alternatives may be suitable to replace PVDF as a cathode binder in lithium-ion batteries whilst PMMA may be considered as a possible technical alternative to ETFE in solar panel front and back sheet coatings. This illustrates that whilst some applications may be feasible for substitution, concluding on substitution potential for the entire strategic sector is not possible and a more nuanced approach is required.

The illustrative example of F-gases used in heat pumps as refrigerants indicates the level of nuance required to consider full substitution potential. Consultation with industry undertaken for this study identified nuances in the impacts of substitution such as increased costs due to the need for higher pressure systems in an already unfavourable market situation. This poses a different conclusion to that reached under the previous impact assessment for the revision of the F-gas regulation (European Commission, 2022) and indicates the need for careful consideration when concluding on substitution potential for an application, sector or strategic sector entirely.

For green energy and clean technology, it is expected that substitution potential will be highly varied, and impacts may be significant for interconnected supply chains within the strategic sector. **Further research is needed on specific applications due to divergent findings, such as F-gases used in heat pumps as refrigerants**.

Figure 9: Key conclusions of the AoA for priority green energy and clean technology applications

	Technically feasible	Economically feasible	Hazard and risks	Market availability
Coating of front and backsheets for photo-voltaic panels	PFAS free backsheets - from consultation - more data needed	PFAS free backsheets - from consultation - more data needed	PFAS free backsheets - from consultation - more data needed	PFAS free backsheets - from consultation - more data needed
F-gas refrigerants in heat pumps	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**
Cathode binder in Li-Ion batteries	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**

Source: Authors' own elaboration.

Note: A substance must be listed under all criteria to be deemed a potentially feasible alternative

3.3.4. Semiconductors

a. Overview of substances and applications

Consultation with a key industry stakeholder estimated that 100% of products in the semiconductor industry contain or are reliant upon fluoropolymers. It was noted that every semiconductor is manufactured with fluoropolymers in either the chip itself, packaging, manufacturing equipment or another complimentary component. Additionally, consultation with stakeholders also revealed applications not found within the literature review. These include containers such as baths (PTFE), wafer carrier systems, injection moulding equipment (PFA), ultra-pure water piping (PVDF and FEP), rubbers in the ceiling of plasma chambers (FKM and FFKM), topcoats and lithography equipment (general PFAS) and plasma etching deposition (PFAS containing gases).

The following semiconductor applications have been identified as utilising fluoropolymers:

- Circuit boards/ printed circuit boards– PTFE; general (Smartech, n.d.; Polyfluor, n.d.);
- Cleaning solvents- F-gases (NetRegs, n.d.);
- Filters for etching and cleaning process – general (consultation);
- Lithography machines– FFKM (Plackovic and Walker, 2024);
- Equipment to produce semiconductor manufacture equipment (consultation);
- Photolithography equipment- general (MacGillivray, 2024);
- Plasma processing- general (Ophek, 2025)
- Pumps – general (CONVERSIO, 2023)
- Thermal insulation for wet solution – general (consultation)
- Semiconductor baskets– PFA (Polyflon, n.d.)
- Semiconductor parts – PTFE (Smartech, n.d.)
- Ultra-pure liquid handling – general (CONVERSIO, 2023)
- Wafer handling machines– FFKM (Plackovic and Walker, 2024)
- Water fabrication– FFKM (Plackovic and Walker, 2024; Barnwell, n.d.);
- Water surface treatment machines– FFKM (Plackovic and Walker, 2024); and
- Vacuum pumps – general (consultation)

PVDF and F-gases are also being used in unspecified semiconductor sector applications (MarketsandMarkets, 2024; Maerchant Research and Consulting ltd, 2025; Mordor Intelligence, n.d.; Sharma, R., Chandola, V., Bhat, S, 2025; Marco Rubber, 2021; and Sovacool et al 2021). No sources were found which mentioned the use of ETFE or FEP in the Semiconductor sector however these were noted as being used by the industry during consultation.

b. Substitution potential

Substitution potential is application specific but all applications are involved in the successful production of semiconductors, making all applications 'critical'. Based on the consultation held with industry many applications for PFAS (both fluoropolymers and f-gases) were identified.

Of these applications a large number were discussed as being essential to the manufacture of semiconductors and therefore several critical applications are considered. The examples presented in the following table relate to ultrapure water piping systems and photoresists and were selected based on the previous experience of the Authors' work in this sector. This was substantiated by discussions with key stakeholders as a part of the consultation conducted under this study and provided justification for the selection of these two applications for further investigation

Table 3-5 Key performance criteria of PFAS used in semiconductor applications.

Application	Substances	Performance criteria	Substitution potential
Ultra-pure water piping	PVDF, FEP	High temperature resistance; High purity; Mechanical strength; Low flammability; Ease of processing (Semi, n.d.)	**Inferred substitution potential**: **Low/Moderate**. Based on the Annex 5 tables, it is expected that PMMA and stainless steel may be potential technically feasible alternatives, due to properties of temperature resistance, mechanical strength and low flammability. To confirm substitution potential, more information is required on the purity of material and (for PMMA and stainless steel) the ease of processing. Purity is critical as contamination of ultrapure water at the lowest level may cause failure of the chip during the manufacturing process. PEEK provides the beneficial properties whilst also stating high purity and therefore may be a potential alternative. PVC, UHMWPE, polypropylene and polyamide are not considered to be suitable based on their comparably low operating temperature. Polyethylene is unsuitable due to its relatively high flammability rating. For polycarbonate and polyester too little information is available to infer substitution potential. For HNBR, SBR, Silicone and EPDM, these potential alternatives are not suitable for rigid polymer component applications. For PEEK no additional data is available to discuss the economic feasibility, market availability or hazard and risk. The Authors note PEEK and fluoropolymers are both considered speciality polymers and would likely present high prices and relatively low market volume.
Topcoats in photoresists during lithography	General	High purity; High chemical resistance; High thermal resistance; etching resistance (due to highly cross-linked molecules) (Cheersonic, n.d.)	**Inferred substitution potential**: **Low**. Based on the Annex 5 tables UHMWPE, polyamide, PVC, polypropylene and SBR present limitations in their technical performance to replace PFAS as photoresist topcoats. For UHMWPE and polyamide both thermal and chemical resistance would likely be insufficient to replace PFAS. Additionally, PVC and polypropylene would likely not have sufficient thermal resistance to present a suitable alternative. SBR has limited chemical resistance to strong acids and bases used in the etching process and therefore may also not present a suitable alternative. Stainless steel cannot be used as a coating and therefore is not suitable as an alternative in this application. For all other alternatives more information is needed before substitution potential can be inferred, mainly because of purity requirements to ensure minimal contamination of chips and wafers during the lithography process. For PEEK purity is given as high, however some chemical resistance provides limitations depending on which chemicals are used in the lithography process. Based on the above no alternatives can be suggested as a potential replacement for topcoats applied in the lithography process.

Source: Authors' own elaboration.

c. Key conclusions

The semiconductor industry uses PFAS significantly throughout the iterative process of manufacturing semiconductors. Despite producing 'one' product, semiconductors are highly specialised to the application in which they are used creating high variation in the design and manufacturing equipment required by the industry. PFAS are used in semiconductors in addition to the processing equipment required to manufacture semiconductors. This is largely due to the extreme conditions required to manufacture current semiconductors capable of delivering the expected performance for modern technology.

The illustrative examples presented for ultrapure water systems and topcoats for photoresists in the lithography process represent two critical applications in the manufacture of semiconductors. In the first example PEEK is theoretically demonstrated to provide the desired properties for substitution into ultrapure water systems. However, as no suitable alternatives for top coating of photoresists were found, semiconductor manufacturing would not be possible, despite potential alternatives for ultra-pure water systems. This is due to the dependence of semiconductor manufacturing on multiple applications of PFAS and so potentially feasible substitution in one application does not mean avoided impacts for the semiconductor industry.

The AoA indicates that the semiconductor industry would likely not be able to substitute PFAS to alternatives in all the required applications and therefore may have an inferred low substitution potential.

Figure 10: Key conclusions of the AoA for priority semiconductor applications

	Technically feasible	Economically feasible	Hazard and risks	Market availability
Ultra-pure water piping	PEEK	PEEK? - more data needed	PEEK? - more data needed	PEEK? - more data needed
Topcoats in photoresists during lithography	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**	**No feasible alternatives**

Source: Authors' own elaboration.

Note: A substance must be listed under all criteria to be deemed a potentially feasible alternative

4. SOCIO-ECONOMIC ANALYSIS

4.1. Overview of approach

A socio-economic analysis (SEA) can help to identify the level of cost and disruption (financially and socially) to the European economy from regulatory action in strategic sectors. In doing this the SEA serves two functions. Firstly, it allows for a product, or market sector to be evaluated in terms of its value to the economy and society. Secondly, it can also be used to determine if a certain action is worth taking by applying use scenarios and analysing the impacts under each one. The SEA process is also refined by combining information identified in the AoA process. If there are very few or no viable alternatives to PFAS for a sector or group of industrial uses, costs will be expected to be higher compared to a situation when more viable alternatives are available.

To generate robust SEA cost benefit values or ratios, five distinct areas of assessment are quantified (where possible) during the SEA process. These are:

- A sectoral supply chain assessment;
- A social cost assessment;
- A human health impact quantification;
- An environmental damage quantification; and
- Qualitative arguments pertaining to wider impacts on other regulatory agendas

The sectoral supply chain value assessment comprises assessing the volume and value of products manufactured and sold at each stage (or node) within a sector's supply chain(s). The supply chains for the strategic sectors assessed by this SEA are presented above in section 2.2. **Typically for each supply chain segment an SEA would seek to quantify the number of enterprises operating, the volume of products manufactured, imported, exported, and placed on the market, the revenue and profits from sales of products, the growth profile of the industry, annual R&D spending and any CAPEX commitments**. As a result of the limitations outlined in Section 1.3, only the number of enterprises operating, the profits generated, and possible (un)employment impacts per sector can be estimated. Therefore, all the values presented in this section are in relation to the profits of companies or employment impacts.

Social costs are defined as costs arising from changes in employment. Employees losing their jobs can spread costs across society. Individuals suffer from a loss of income, enterprises suffer productivity losses, and national governments will receive less income from employers and social security, and welfare costs will increase. **Quantified damaged to human health and the environment are the typical elements that the previous two cost factors are compared against**.

Exposure to some groups of PFAS substances such as PFOA (perfluorooctanoic acid), PFOS (perfluorooctanesulfonic acid), PFHpA (perfluoroheptanoic acid), and PFHxS (perfluorohexansulfonic acid) is believed to potentially result in health effects such as testicular and prostate cancer and possible endocrine disruption as well (Boyd, Ahmad, Singh, Fazal, Prins, Madak Erdogan, Irudayaraj, Spinella, 2022). **However, to date little research has been conducted into possible health effects arising from exposure to the in-scope fluoropolymers, therefore at present there are no known human health effects arising from exposure to these fluoropolymers**.

Likewise, while fluoropolymers are very persistent in the environment, a specific quantifiable environmental damage which occurs from their presence is yet to be identified from research. Therefore, like human health effects due to a lack of specific research investigating these most common fluoropolymers there are currently no known environmental damages identified from fluoropolymer emissions. **This unfortunately means that neither a human health nor environmental damage quantification can take place**.

As outlined below **the study team have been able to conduct an indicative SEA by using a low market share assumption model**. This economic assessment methodology was first developed by the study team to assist the Restriction Dossier Submitters update the Restriction Dossier (specifically Annex E of the updated restriction dossier).

The low market share assumption model methodology involves identifying relevant PRODCOM (Production Communautaire (Community Production)) codes in Eurostat which relate to fluoropolymer products and applications identified by the AoA. The public PRODCOM data allows for statistics on EU wide production, importation and exporting of products to be extracted. Similarly, the identification of relevant PRODCOM codes jointly allows for relevant sectoral NACE (Nomenclature of Economic Activities) codes to be identified which allow for public statistics on number of enterprises, employees, turnovers, SME distributions, average salaries, and average operating margins to be extracted. However, these codes are inclusive of companies and products which are unrelated to fluoropolymers therefore market share assumptions must be made to derive value estimates.

Because of the large array of applications associated with fluoropolymers in these critical industries it has not been possible to identify a fluoropolymer market share for every application or product. **Therefore, this assessment has assumed a very low market share value for fluoropolymers to derive an indicative socio-economic impact estimate. For this analysis where a more specific market share could not be identified, deduced, or reasoned a market share value of 1% has been applied. This is assumptive for the purpose of estimating indicative economic impacts, and the value of 1% has been used as it demonstrates a low market share, but this also allows for a level of conformity between this assessment and the Dossier Submitters assessments which also used a 1% market share assumption as default in their updated dossier**. Similarly, due to fluoropolymers typically being specialty products used for specific properties (as identified in the AoA) the study team believe low market share of 1% is justified. This market share has not been applied to all identified NACE and PRODCOM codes in each sector however with some codes having market shares as high as 100% being applied. This is explained in more detail in each sectors results discussion below. It should be noted that due to the use of the NACE[2] and PRODCOM[3] databases all the data used for this assessment has been sourced from Eurostat.

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2 Enterprise statistics (NACE) database. Available at: https://ec.europa.eu/eurostat/databrowser/view/sbs_sc_ovw__custom_18461513/default/table; https://ec.europa.eu/eurostat/databrowser/view/sbs_ovw_act__custom_18461505/default/table.

3 Sold production, exports and imports (PRODCOM) database. Available at: https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_18461343/default/table.

The principle of this approach is if economic impacts, based on known and assumed low market shares, for a regulatory scenario are already high this serves as indicative evidence as to what the true impact of a restriction on fluoropolymers could mean for these sectors and the wider European economy. Therefore, again it should be noted that the presented results are indicative of how large impacts could be but are not conclusive.

4.1.1. Regulatory options

The economic impacts of fluoropolymer use are assessed under the following **four scenarios**:

1. A continued use scenario (no regulatory change is implemented);
2. A full ban on PFAS with an 18-month transition period (Regulatory Option 1, RO1);
3. A ban with use-specific (mainly) time limited (12-years plus an 18-month transition period) derogations (Regulatory Option 2, RO2);
4. Time unlimited derogations (Regulatory Option 3, RO3)

Under the continued use scenario, the main socio-economic benefits will be the profits from businesses operating and selling products, employment will also continue under the continued use scenario however the value of continued employment has not been quantified. The main socio-economic costs under this scenario would be the quantified environmental and human health condition costs.

For the non-use scenario these costs and benefits are largely reversed with costs being profit losses, and unemployment costs, with benefits being human health savings, environmental savings. Again, however because no human health or environmental assessment can be conducted due to the unknown effects of fluoropolymers the benefits under the non-use scenarios will also be zero.

It should be noted that for this analysis, economic impacts under RO3 have been set equal to those under the continued use scenario. This is because a time unlimited derogation effectively equals a scenario where regulation has not been implemented as enterprises can continue to operate unaffected. **Similarly, because of the low substitutability of the in scope critical sectors, this analysis has assumed that all sectors would not be able to sufficiently substitute fluoropolymers within a 13.5-year period (12-year derogation plus the 18-month transition period) meaning the impacts under RO2 are set equal to the impacts estimated under RO1**. There are some exceptions to this which are contextually explained below.

It should be noted that some applications identified under the green energy and clean technology sector (such as batteries) have been recommended a shorter 6.5-year derogation period (6-year derogation plus the 18-month transition period). However, there is still uncertainty around the true viability and scalability of proposed alternatives for some of these technologies. Additionally, the green energy and clean technology sector discussed in this study is a very broad sector description which encompasses lot of applications and technologies with various derogation recommendations, therefore despite this for the purpose of this study the green energy and clean technology sector and all other in scope sectors have been assessed under the assumption of RO2 impacts being equal to RO1 impacts (with some exceptions).

4.2. Socio-economic assessment findings and results

Box 6: Research questions addressed in section 4.2.

The following section of the report addresses the research sub questions:

- *RQ 3.1: What are the financial and social costs of limiting or banning PFAS?*
- *RQ 3.2: What are the financial and social benefits of limiting or banning PFAS?*

4.2.1. Aerospace

It should be noted the indicative estimates produced for the aerospace industry do not account for impacts to airline and air freight operators, only component and craft manufacturers. As demonstrated in Figure 3, the aerospace supply chain is highly complex and consists of many different suppliers and manufacturers culminating in the manufacture and then operation of civil aircraft. **A total of 71 PRODCOM codes and 21 NACE codes (more could exist however) were identified by the study team with the list of these codes presented in Annex 2**. The identified codes cover a total of 10 different supply chain segments including products which are made from or using fluoropolymers, to products which do not contain nor are made from fluoropolymers but are dependent on fluoropolymers via the wider supply chain (for example aircraft seats contain no fluoropolymers, but without the rest of the supply chain there is no demand for aircraft seats within Europe. Products of this nature are marked in green boxes throughout the supply chain figures in section 2.2).

For most component related supply chain segments (such as seals and wiring), their associated codes contain many other non-related products in the PRODCOM data, therefore the low market share of 1% has been applied to these codes.

However, from the AoA and other prior experience of the study team it is understood that 100% of downstream products such as aircraft engines and complete aircraft contain, and are reliant upon, fluoropolymers therefore for NACE and PRODCOM codes relating downstream products like engines and aircraft manufacturing a 100% market share has been applied instead of the 1% value. The results of the indicative economic impact analysis by regulatory option and supply chain segment are presented below. A positive value indicates a benefit to the European economy with a negative value indicating a cost.

Table 4-1: Indicative socio-economic impacts to the aerospace sector by regulatory option

Supply chain segment	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
Seals, gaskets, bearings, hoses, tubing and fluid lines	+44	-1,930	-1,930	+44
Wiring, cable, and thermal/electrical insulation	+26	-865	-865	+26
Coatings and surface treatment	+2	-334	-334	+2
Fluids, lubricants and hydraulic oils	+12	-328	-328	+12
Systems integration	+146	-1,550	-1,550	+146
Engine manufacturing	+3,680	-46,500	-46,500	+3,680
General aircraft components	+66	-1,900	-1,900	+66
Aircraft assembly	+7,860	-50,700	-50,700	+7,860
Operations and maintenance	+6	-952	-952	+6
Additional aircraft parts	+630	-1,870	-1,780	+630
Total	**+12,500**	**-99,800**	**-99,700**	**+12,500**

Source: Authors' own elaboration.
Notes: + indicates gains; - indicates costs.

Under a continued use scenario and a time-unlimited derogation (RO3), the indicative value assessment estimates that the benefits from PFAS to the aerospace industry would be €12.5 billion per year. However, it should be noted that after accounting for the use of industry average profit margins, not all applications being captured in PRODCOM codes. Possible true market shares and including the value of airline and airfreight operators, this value could be underestimated by potentially a factor of 10 or more. Given that RO3 would grant time unlimited use derogations this effectively constitutes the continued use scenario making the benefits to the economy under this RO to also be a minimum positive contribution of €12.5 billion.

The total cost under RO1 (a full PFAS ban) and RO2 (a ban with 12-year derogation) of unemployment is estimated to be a minimum of €87.4 billion for the social cost of unemployment and €7.1 billion for the social security cost of unemployment. Due to the low substitutability of fluoropolymers across the aerospace industry RO1 and RO2 effectively result in the cessation of the market. In the event this happens, an estimated minimum of nearly **4,500 business would close** with 97% of these being micro, small, and medium businesses and 71% being micro alone.

Furthermore, the SEA indicative model estimates a **minimum of nearly 440,000 people being employed within industries connected to the aerospace sector**.

Due to the understood low substitutability (under both and RO1 and RO2 respectively) of fluoropolymers within this sector as outlined in the AoA findings it is subsequently believed that business closure is the most likely industry response to RO1 and RO2. Therefore, it is also assumed that 100% of the estimated employees in this sector will be made unemployed under RO1 and RO2.

These unemployment costs will only be experienced by Europe within the first year after entry into force of the restriction option. The only socio-economic cost that will be experienced in the first year and subsequent years would be the value of lost industry profits valued at €12.5 billion.

Therefore, the first-year economic costs of RO1 are estimated to be €99.8 billion with subsequent annual costs of €12.5 billion. The first-year economic costs of RO2 are estimated to be €99.7 billion with subsequent annual costs of €12.4 billion.

The lower annual recuring cost value for RO2 assumes that a longer transition period would allow non-PFAS related component manufacturers to secure their export businesses meaning these sales would continue under RO2, it is assumed this will not occur under RO1.

4.2.2. Defence

Unfortunately, due to the confidentiality of the defence sector even an indictive cost assessment cannot be conducted. It should be noted however that in 2024 European defence spending reached €343 billion equivalent to 1.9% of EU Member States GDP, and this is expected to rise to 2.1% GDP equivalent spend in 2025 (Consilium, 2025). The defence industry itself in 2023 was estimated to have generated turnover of €158.8 billion with large growth trends (between 15% and 18%) in land, sea, and aeronautic military areas. Similarly in 2023 the sector was estimated to employ over 581,000 jobs with over 2,500 SMEs in the European defence industry.

Given the interconnectivity of the aerospace and semiconductor sectors with the defence sector, it could be reasonably assumed that the defence sector would be significantly affected with major loss of employment in the event of a fluoropolymer restriction. Therefore, the costs to Europe in economic terms arising from a restriction to the defence sector could be very substantial. In times of growing geopolitical tensions, it is of paramount importance to minimise any risks to the supply chain in the defence sector.

4.2.3. Green energy and clean technology

The green energy and clean technology sector is a very broad sector encompassing many different technologies and products. **A total of 60 PRODCOM codes and 8 NACE codes across 13 supply chain segments were identified**. For most products in this sector the 1% market share has been applied however for all fuel cell, solar panel, and battery related applications a 100% market share has been applied (see rationale in 4.2). Similarly for fuel cells and lithium-ion batteries their subsequent downstream applications in the automotive sector have had 100% market shares applied.

The results of the indicative economic impact analysis by regulatory option and supply chain segment are presented below. A positive value indicates a benefit to the European economy with a negative value indicating a cost.

Table 4-2: Indicative socio-economic impacts to the green energy and clean technology sector by regulatory option

Supply chain segment	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
Solar panels	+10	-381	-381	+10
Inverters	+411	-751	-751	+411
Binders and separators	+267	-320	-320	+267
Li-ion batteries	+5,600	-8,230	-8,230	+5,600
Battery Electric Vehicles	+6,230	-123,000	-123,000	+6,230
Energy storage	+537	-3,510	-3,510	+537
Fuel cells	+20	-360	-360	+20
HFCVs	+242	-116,000	-116,000	+242
Additional vehicle parts	+6,920	-130,000	-129,000	+6,920
Wind turbines	+1,170	-1,680	-1,680	+1,170
Generators	+5	-888	-888	+5
Other renewable technology	+1	-372	-372	+1
Heat pumps	+934	-1,290	-1,290	+934
Total	**+22,300**	**-354,000**	**-353,000**	**+22,300**

Source: Authors' own elaboration.
Notes: + indicates gains; - indicates costs.

As seen from the above table under the continued use scenario and RO3 the green energy and clean technology sector are estimated to produce annual contributions of €22.3 billion. It should be noted however that many green technologies are still novel and are developing markets and the automotive industry is still transitioning towards electric vehicles meaning the real economic benefits per annum in the long run are likely to be substantially higher.

As with aerospace and the defence sectors the currently understood low substitutability of fluoropolymers means a fluoropolymer restriction under RO1 or RO2 would likely lead to heavy economic damages as businesses close and withdraw from the market without sufficient government incentives and support.

The impacts to the European economy on an indicative basis are estimated to be over 12,500 businesses closing again with the vast majority being SMEs, and nearly 2 million people being made unemployed. This results in indicative first year cost estimates to the European economy of €354 billion and €353 billion for RO1 and RO2 respectively.

The RO2 value is again lower based on assuming exporters would have time under RO2 to secure their export business and make it viable, it is assumed this will not occur under RO1.

The total cost of this unemployment is estimated to be a minimum of €332 billion for the social cost of unemployment and €32.1 billion for the social security cost of unemployment under both ROs.

These unemployment costs will only be experienced by Europe within the first year after entry into force of the restriction option. The only socio-economic cost that will be experienced in the first year and subsequent years would be the value of lost industry profits valued at €22.3 billion. **Therefore, the first-year economic costs of RO1 are estimated to be €354 billion with subsequent annual costs of €22.3 billion. The first-year economic costs of RO2 are estimated to be €353 billion with subsequent annual costs of €21.3 billion**.

Beyond these economic damages the level of lost potential within the green energy and clean technology sector resulting from a fluoropolymer ban would also be substantial as for example fluoropolymers have been a key enabler in the green hydrogen economy meaning a restriction on fluoropolymers would also completely close new markets and prevent new green technologies from developing putting Europe at a global disadvantage in green tech, while also jeopardising the commendable ambitions of a green industrial transition under legislative agendas such as the Green Deal.

4.2.4. Semiconductors

As previously mentioned, **semiconductors are an essential component to every piece of modern-day technology from consumer electronics to data centres. A total of 42 PRODCOM codes and 11 NACE codes across 3 supply chain segments were identified** focusing on the manufacture of semiconductor equipment, semiconductors themselves and subsequent electronic items using semiconductors. Due to the vast nature of semiconductor use a full-scale impact assessment of semiconductors would require substantially more time and methodology approaches as there is the need to value not only electronic products but also digital services, data centres, and AI which are powered by chips and data centres.

The results of the indicative economic impact analysis by regulatory option and supply chain segment are presented below. A positive value indicates a benefit to the European economy with a negative value indicating a cost.

Table 4-3: Indicative socio-economic impacts to the semiconductor sector by regulatory option

Supply chain segment	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
Equipment manufacturers	+9,200	-10,900	-10,900	+9,200
Semiconductor foundries	+12,300	-29,000	-29,000	+12,300
Electronics manufacturers	+16,500	-68,600	-68,600	+16,500
Total	**+38,000**	**-109,000**	**-109,000**	**+38,000**

Source: Authors' own elaboration.

Notes: + indicates gains; - indicates costs

The semiconductor sector and subsequent electronics manufacturing under a continued use scenario is estimated to generate at minimum annual benefits for the economy of €38 billion.

Again, it should be noted these are the benefits arising from just the manufacture and sale of electronic devices and semiconductors and does not account for digital services and productivity semiconductors have enabled.

In the event of a fluoropolymer restriction the semiconductor industry would cease to operate in Europe and semiconductors, and electronic devices could not be imported into Europe either, which based on the identified codes and assumptions of this indicative model would produce first year economic costs of at least €109 billion. However, it has been estimated that once accounting for the digital world and services semiconductors have unlocked a ban on fluoropolymers and the subsequent loss of semiconductors could reduce the size of the European economy by 50% (SEMI, 2020) which based on the 2024 GDP value would result in economic costs of potentially nearly €9 trillion.

An estimated minimum of nearly 22,000 enterprises would close, 98% of these being SMEs, along with 500,000 employees losing their jobs. This results in indicative first year cost estimates to the European economy of €109 billion for both RO1 and RO2. The values here are the same as it is assumed that under RO2 there will still not be enough time for the semiconductor industry to transition away from PFAS. The total cost of this unemployment is estimated to be a minimum of €62.5 billion for the social cost of unemployment and €8.1 billion for the social security cost of unemployment under both ROs.

These unemployment costs will only be experienced by Europe within the first year after entry into force of the restriction option. **The only socio-economic cost that will be experienced in the first year and subsequent years would be the value of lost industry profits valued at €38 billion**.

4.3. Summary of findings

The socio-economic assessment conducted as part of this study has employed a low market share assumptive model, utilising publicly available statistics to generate indicative economic impact estimates for each in-scope industrial sector under various regulatory options. The regulatory options covered a variety of scenarios from no regulation being introduced (the continued use scenario, RO1) to a full ban on PFAS (RO1) while also considering various derogation periods (12 years under RO2 and time unlimited under RO3).

Using supply chain maps (presented in section 2.2) for each in-scope sector, a variety of PRODCOM and subsequent NACE codes for each supply chain node were identified. These codes were used to obtain public statistics on domestic production, earnings, profitability, number of enterprises, number of employees, average salaries, and SME distribution to be extracted and used for modelling. By use of this data and applying a 1% low market share assumption to products and supply chains (in some instances where it was known that more of a market was reliant upon fluoropolymers higher percentages were applied), indicative impact estimates for each regulatory option could be derived. The results of the SEA for each of the in-scope sectors is presented below in Table 4-4.

Table 4-4: Indicative socio-economic impacts to in-scope sectors by regulatory option

Sector in-scope	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
Aerospace	+12,500	-99,800	-99,700	+12,500
Defence	n/a	n/a	n/a	n/a
Green energy and clean technology	+22,300	-354,000	-353,000	+22,300
Semiconductors	+38,000	-109,000	-109,000	+38,000
Total	**+72,800**	**-562,800 (year 1)** **-72,800 (recuring)**	**-561,700 (year 1)** **-71,700 (recuring)**	**+72,800**

Source: Authors' own elaboration.
Notes: + indicates gains; - indicates costs.

Of the regulatory options assessed during this study, RO3 (time unlimited derogations being granted for these critical sectors) is the least damaging to the economy and society. This is because RO3 is in the short term effectively equivalent to a continued use scenario with strategic sectors seeing little to no disruption to their access to PFAS which, as highlighted in the AoA, is often essential and critical for applications in these sectors. **Under RO3 the European economy would benefit from a minimum annual contribution of €72.8 billion**.

On the contrary however, the European economy and society are significantly impacted under both RO1 (a full PFAS ban) and RO2 (a full PFAS ban with a 12-year derogation) with **RO1 being the most damaging regulatory option for the European economy incurring first year minimum costs of €562.8 billion with recuring annual costs of €72.8 billion. Under RO2 these costs are only marginally reduced with first year costs equating to €561.7 billion with recurring annual costs of €71.7 billion.** Costs to the European economy under RO2 compared to RO1 due to the assumption that manufacturers and exporters of non-fluoropolymer products within certain supply chains will have time to stabilise and secure their export business.

For example, an aircraft seat manufacturer will still be permitted to manufacture their seats as they do not contain PFAS or fluoropolymers. However there will be no domestic demand under an RO2 scenario as manufacturing aircraft will become impossible, but the seat manufacturer would still be able to manufacture and export their seats globally. The costs to Europe under RO2 are very similar to those of RO1 due to the generally believed low substitutability of fluoropolymers from these supply chains due to the complexities as outlined in the AoA of this assessment.

In addition to the above quantified economic damages arising from lost output and social costs of unemployment, the SEA conducted under this study has also sought to indicatively quantify the possible scale of business closures and unemployment that each regulatory option may incur. This indicative results by in-scope sector are presented in Table 4-5 below.

Table 4-5: Additional indicative socio-economic impacts to in-scope sectors by regulatory option

Sector in-scope	RO1		RO2		RO3	
	Business closures	Job losses	Business closures	Job losses	Business closures	Job losses
Aerospace	4,487	439,680	<4,487	<439,680	0*	0*
Defence	n/a	n/a	n/a	n/a	n/a	n/a
Green energy and clean technology	12,554	1,998,157	<12,554	<1,998,157	0*	0*
Semiconductors	21,978	501,263	21,978	501,263	0*	0*
Total	**39,019**	**2,939,100**	**<39,019**	**<2,939,100**	**0***	**0***

Source: Authors' own elaboration.

Notes: Under an RO2 scenario within the aerospace and green energy and clean technology sectors there is the possibility that some businesses may be able to keep operating after securing their export businesses for non-fluoropolymer products, however due to public data constraints it cannot be accurately or reasonably determine what scale of job loss or business closure reduction this may have, therefore the results for RO2 are marked with a less than symbol to represent that impacts will be lower but by an unknown amount, this impact reduction is not expected to be significant however.

Results under RO3 are marked with an asterisk to represent the possibility that while a time unlimited derogation on these in-scope sectors should not result in business closure or job losses directly it cannot be guaranteed that some might still occur. There remains a possibility that disruption to other sectors in Europe which use fluoropolymers could have knock on effects or negative multiplier effects which could consequently cause some unintentional job loses or business closures in the in-scope sectors.

As shown in the above table **under RO1 over 39,000 European companies under a low market share impact estimate are expected to likely close because of a full PFAS ban affecting over 2.9 million jobs**. Under RO2 due to the prospect of some businesses continuing to operate from exports the impact on jobs and business closures will be low but given available data the scale of this reduction cannot be accurately or indicatively estimated. The reduction is not expected to be substantial, however. **On the contrary however given that RO3 is effectively a business as normal scenario very little to no business closures or job losses are indicatively estimated to occur**. It cannot be ruled out however that under an RO3 scenario however some loses may occur from wider or other supply chain disruptions.

5. EUROPEAN COMPETITIVENESS IMPACT ASSESSMENT

5.1. Overview of approach

The current regulatory framework for PFAS in Australia, Canada, China, Japan, South Korea, the UK and the US were reviewed for the competitiveness assessment. These countries were chosen to represent some of the largest and fastest growing chemical industries to compare with the regulatory regime in the EU/EEA (BRC, 2025). There is no official global ranking for PFAS manufacture by country, but ChemSec identified the top 12 PFAS manufacturers in the world (ChemSec, 2023), and their headquarters are in the US, Japan, the EU and China.

Initially, a literature review was undertaken. The literature included existing published summaries on the global regulation of PFAS by legal experts and the Chemical Watch to gain an overview. These summaries were used to identify national PFAS legislation which was then reviewed directly and is summarised in Annex 3.

Searches were also undertaken on the Yordas Helix product risk and regulatory intelligence management system using key words to check for regulations in the countries and regions of interest. The search results were then screened for relevance, with Member State and US State regulations being excluded as well as voluntary restricted substances and defunct regulations. The remaining results were then mapped to applications for each of the strategic sectors as identified in the AoA, to provide a summary of the current regulatory restrictions for each sector (Table 5-3 to Table 5-6).

Key findings from the AoA were fed into the competitiveness impact assessment. This includes examples of critical fluoropolymer applications, whether suitable alternatives are already available, respective costs of fluoropolymers and alternatives, and transition times.

Qualitative descriptions of the impacts on small and medium sized enterprises (SMEs) have been drawn from the indicative findings of the SEA. Data specifically on R&D investment into fluoropolymers and alternatives is lacking.

Findings from interviews with representatives of the strategic sectors were particularly important to the competitiveness analysis. These interviews were used to gather stakeholders' opinions about the impact of the three different regulatory options on the competitiveness of their sector and gather comments on the regulation of PFAS. The results of the competitiveness impact assessment for each strategic sector are summarised in section 5.3 in Table 5-7 to Table 5-10.

5.2. Identified legislative landscape of PFAS in selected third countries

The full results of the regulatory review for PFAS in select third countries is presented in Annex 3. Below is a summary of the PFAS regulatory landscape (Section 5.2.1), regulation of F-gases in Europe (Section 5.2.2), the potential impact of the proposed EU PFAS restriction on competitiveness in the context of existing regulatory frameworks (Section 5.2.3) and future restrictions on PFAS (5.2.4). The regulatory landscape has then been mapped across to each sector in Section 5.2.5.

5.2.1. PFAS regulatory landscape

Internationally, PFAS substances such as PFOA, PFOS, PFHxS, and PFCAs are controlled under the Stockholm Convention on Persistent Organic Pollutants, which is implemented through national laws by 190 signatories.

Broader regulation of PFAS takes place through national chemical management frameworks, including AICIS in Australia, the "new pollutants" regulatory system in China, CSCL in Japan, REACH in the European Union, K-REACH in South Korea, UK REACH, and TSCA in the United States. In China, PFAS regulation currently applies only to those substances covered by the Stockholm Convention, and oversight is inconsistent across provinces and sectors, making it weaker than in the other regions examined. Canada operates a phased risk management plan for PFAS, though fluoropolymers are excluded. In the United States, regulatory measures are fragmented, with individual states setting their own rules while, at the federal level, PFOA and PFOS are classified as hazardous under the Superfund law. Japan has restricted 138 PFOA-related compounds, which has increased production costs but does not directly regulate fluoropolymers. Production of long-chain PFAS is declining globally, although it continues to expand among new producers in continental Asia (Wee and Aris, 2023).

Exemptions commonly found in legislation include allowances for unintentional trace contaminants (Stockholm Convention, Australia, South Korea). **Certain uses remain permitted**, such as firefighting foams (China, Japan, and US airports), and activities related to research, development, and testing (Australia, China, South Korea).

The six fluoropolymers in scope are rarely addressed explicitly. Under the Stockholm Convention, PFOS restrictions do not apply to certain medical devices such as ETFE layers and radio-opaque ETFE, while PFOA restrictions do not apply to PTFE and PVDF membranes, FEP used in high-voltage cables, and fluoroelastomers used in automotive applications.

The general regulatory direction is towards tighter controls, although exemptions for fluoropolymers exist. For example, in Canada fluoropolymers are excluded from PFAS regulation, while in Australia, Japan, South Korea, and the United States, "polymers of low concern" (PLCs), which include fluoropolymers, are exempt from certain regulatory requirements, with the precise definition of PLCs varying by jurisdiction. In the European Union, polymers are currently exempt from registration and evaluation under REACH, but may still be subject to authorisation or restriction. **The proposed EU PFAS restriction represents the most comprehensive and stringent regime to date**, the extent of which will depend on the final derogations adopted.

Annex 3 contains a summary of the current regulatory approach for Europe, Australia, China, Japan, South Korea, the UK and the US.

a) A note on the Stockholm Convention

The Stockholm Convention on POPs has been included in this regulatory review, since it covers the regulation of some PFAS. Although it is not aimed specifically at regulating the fluoropolymers in scope, PFOA and PFOS which it covers are or were used in the manufacture of some of the fluoropolymers (PTFE, PVDF, FKM, FFKM) as polymerisation aids, emulsion stabilisers and surfactants.

The scope of the Convention is also expanding over time: PFHxS, its salts and PFHxS-related compounds were added to Annex A in 2022 (UNEP, 2025a); and more recently in May 2025, the Conference of the Parties to this Convention adopted a decision to list long-chain perfluorocarboxylic acids (PFCAs), their salts and related compounds in Annex A (UNEP, 2022). The ammonium salt of C9 PFCA was identified as being used in the production of fluoropolymers, however the draft indicative list of long-chain PFCAs does not explicitly include any of the six fluoropolymers in scope of this project (UNEP, 2024).

The Stockholm Convention therefore has a potential regulatory impact on the feasibility and/or cost of manufacture of the fluoropolymers in scope.

5.2.2. Regulation of F-gases in Europe

The Fluorinated Greenhouse Gases Regulation (or F-gases Regulation (EU) 2024/573) is a cornerstone of the EU's climate strategy. Effective from March 2024, it replaced an earlier 2014 F-gases Regulation (Regulation (EU) No 517/2014). It supports the EU's goal of climate neutrality by 2050 and aligns with the European Climate Law (Regulation (EU) 2021/1119) and the Kigali Amendment to the Montreal Protocol aiming to phase out hydrofluorocarbons (HFCs) (UNEP, 2016).

The regulation targets sharp reductions in F-gas emissions, particularly hydrofluorocarbons (HFCs), which have very high global warming potentials. Its scope covers all listed F-gases, including HFCs, perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and other fluorinated substances, as well as products and equipment containing them, such as refrigeration, air conditioning, heat pumps, fire protection systems, aerosols, electrical switchgear, and cleaning solvents.

A central measure is the phasedown of HFCs. Quotas fall to 60% of baseline levels in 2025, 45% in 2027, 24% in 2030, and 15% from 2036, with a full phaseout by 2050. Annex IV sets deadlines for shifting to low global warming potential (low-GWP) refrigerants in equipment, starting in 2027, with stricter limits through the 2030s. From 2025, exports of equipment containing high-GWP gases (≥1000 GWP) will also be prohibited.

It introduced market restrictions, product bans, leak checks, and a revised quota system, while strengthening requirements for containment, handling, and end-of-life disposal. Supporting provisions include tighter leak detection, certification and training requirements for technicians, and seven-year validity for certificates to ensure ongoing competence. Labelling rules will also change in 2025 to provide clearer information on refrigerants and their climate impact.

5.2.3. Potential impact of the proposed EU PFAS restriction on competitiveness in the context of other existing regulatory frameworks

The proposed European restriction on PFAS is more comprehensive compared to other regions, although some derogations have been proposed (see Table 5-3 to Table 5-6). That said, PFAS in general are regulated to some extent in all regions and countries reviewed. The most notable differences are explained below.

Relocating to China or Canada could become more attractive to companies wishing to continue to manufacture or use fluoropolymers following a PFAS restriction in Europe. China currently only regulates the PFAS substances required under the Stockholm Convention rather than PFAS in general. China is also developing a framework for managing chemicals ("new pollutants") but this is not yet fully implemented. Canada excludes fluoropolymers from their risk management approach to PFAS. Based on the regulatory review undertaken, other regions which regulate PFAS do not seem to make this distinction.

Another significant point of note is how 'polymers of low concern' (PLCs) to the environment and human health (including fluoropolymers) are defined and exempted from regulation in different jurisdictions. **The OECD discussed PLCs in the 1990s and 2000s but never reached agreement on the criteria for PLCs** (Oziel, 2024), so **countries have developed their own criteria for PLCs in the absence of internationally harmonised criteria** to take a risk-based approach to regulation. **In Australia, Japan, South Korea and the US, PLCs are exempted from certain regulatory requirements** (Table **5-1**), but there is currently no exemption for PLC fluoropolymers, under the proposed EU universal PFAS restriction. **Therefore, these countries could also be more attractive to companies wishing to continue to manufacture or use fluoropolymers following a PFAS restriction in Europe.** (Although under EU REACH, there is currently an exemption for polymers from registration and evaluation, some are still subject to authorisation and restriction (ECHA, 2023d)).

Table 5-1: Summary of exemptions from regulation for polymers by country or region

Regulatory action	Exemption	Geographical scale of restriction
Introduction to the Australian market	Exemption for PLCs according to Australian criteria	Australia
Fluoropolymers	**Excluded** from phased risk management approach	Canada
Import and manufacture of PLCs under CSCL	Exemption can be obtained for the import or manufacture of PLCs	Japan
Registration of the manufacture or import of polymers (including fluoropolymers)	Registration is required for the manufacture or import of polymers at volumes greater than one tonne per year under K-REACH, apart from certain polymers which meet the criteria for 'polymer of low concern' (PLC), for R&D substances, or for export-only uses.	South Korea
Manufacture and distribution of new chemicals (PLCs)	Exemption from the regulatory requirements for new chemicals if they meet the US criteria for PLCs.	US

Source: Authors' own elaboration.

5.2.4. Future restrictions on PFAS

Some reviews of potential restrictions and implementation of future restrictions on PFAS are scheduled globally but there is not an exact timeline. The timeline for other restrictions was still to be confirmed at the time of writing (Table **5-2**). This summary highlights how various regulatory agencies across the world are in the process of reviewing PFAS further and tightening regulatory regimes further.

Table 5-2: Timeframe of selected reviews and future restrictions on PFAS across different global regions from 2025 onwards

Date	PFAS restriction under review / regulatory restriction coming into force	Geographical scale of restriction
2025	Finalisation of an Annex 15 dossier on PFAS in fire-fighting foams, could lead to future restriction. Evidence for an Annex 15 dossier on the use of PFAS in coatings and cleaning agents, could lead to future restriction. Evidence for an Annex 15 dossier on PFAS use in applications most likely to release PFAS emissions or expose humans, including textiles, coatings and cleaning products; could lead to future restrictions.	UK
Currently	POPs Control Act (Act No 15841/2018) is currently under review	South Korea
Mid 2026	Final proposal on universal PFAS restrictions. Consolidated opinions are expected to be drafted mid-2026.	Europe
2026	Future decision under CERCLA on whether to designate all PFAS as hazardous substances, the releases of which would then require remediation	US
January 2027	Expected date that the UK Carbon Border Adjustment Mechanism (CBAM)[4] will come into effect. For the aluminium sector, PFCs (which are also F gases) such as tetrafluoromethane and hexafluoroethane are included in the emissions covered.	UK
Spring 2027	Proposed Regulation on PFAS: prohibition of any use in firefighting foams	Canada
Summer/ autumn 2027	Consultation on regulation of PFAS in consumables (with available alternatives)	Canada
By 2030 TBC	The EU CBAM could be expanded to cover all product groups covered by EU ETS or to product groups with a risk of carbon leakage (which include inorganic basic chemicals, industrial gases, synthetic rubber amongst others, and therefore could cover PFAS, F gases and fluoropolymers respectively)	Europe
TBC	Long chain PFCAs will be added to Annex A of the Stockholm Convention	International
TBC	Testing of all PFAS for toxicity to human health by the EPA could lead to future restrictions	US

[4] Which regulates greenhouse gas emissions embedded in certain imported goods.

Date	PFAS restriction under review / regulatory restriction coming into force	Geographical scale of restriction
TBC	Consultation on regulation of other PFAS uses	Canada
TBC	Future assessment of fluoropolymers, as possible candidates to the Watch List under section 75.1 of CEPA	Canada
TBC	Some use exemptions for the PFAS Action Act 2021 have been proposed but not yet decided upon (they remain as bills in committee at the time of writing): • Agricultural operations • Airports • Entities using AFFF fire-suppression (aqueous film-forming foam) • Solid waste facilities • Public and private drinking water systems and treatment facilities	US
TBC	UK REACH Annex XVII Restrictions proposed – use of PFAS in firefighting foams	UK
TBC	General Product Safety Regulations (GPSR) 2005: Placing an unsafe product on the market is a criminal offence under the GPSR. As the evidence base increases, in the future a product containing PFAS could be considered an unsafe product.	UK

Sources: Chemical Watch (2025); Environment and Climate Change Canada and Health Canada (2025); PWC (2023); UK Government (2024); UNEP (2025b).

The results of keyword searches in Yordas Helix Substance Inventory by the study team.

Note: Chemical Watch authors note that dates were correct as at the 22 April 2025.

5.2.5. Regulatory restrictions on PFAS by sector

The below tables summarise the regulatory restrictions, exemptions and 'acceptable uses' mapped to applications by sector.

Table 5-3: Summary of PFAS regulatory restrictions for aerospace sector applications

Applications	Regulatory restriction	Geographical scale
Aviation hydraulic fluids	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, currently active	International
Metal plating (hard metal plating) only in closed-loop systems	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, currently active	International
Fire fighting foam	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, currently active	International
Textiles (PPE) for oil and water repellency to protect workers	Exemption (for PFOA, its salts and PFOA-related compounds) in the Stockholm Convention, currently active	International
Fire-fighting foam for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems, including both mobile and fixed systems	Exemption (for PFOA, its salts and PFOA-related compounds) in the Stockholm Convention, currently active	International
Use of fluoropolymers or perfluoropolythers for aerospace safety applications	ECHA has recommended a 12-year derogation plus 18-month transition period	EU/EEA
Releases of PFOA and PFOS and related substances into the environment (may be extended to all PFAS in future)	Remediation of these releases is required under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as the 'Superfund', with exemptions for the use of fire fighting foam at airports.	US

Source: Regulatory review by the study team, details provided in Annex 3.

Table 5-4: Summary of PFAS regulatory restrictions for defence sector applications

Application	Regulatory restriction	Geographical scale
Textiles (PPE) for oil and water repellency to protect workers	Exemption (for PFOA, its salts and PFOA-related compounds) in the Stockholm Convention, **currently active**	International
Fire-fighting foam for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems Table 5-5	Exemption (for PFOA, its salts and PFOA-related compounds) in the Stockholm Convention, **currently active**	International
Fire fighting foam	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention**, currently active**	International
Defence sector as a whole	ECHA recommends a 12-year derogation plus 18-month transition period under REACH restriction	EU/EEA
Use of fluoropolymers (fluoroelastomers) for defence (military) applications	ECHA recommends a 12-year derogation under REACH restriction	EU/EEA
Use of PFAS for explosives in military applications	ECHA recommends a 12-year derogation plus 18-month transition period under REACH restriction	EU/EEA
PPE for the armed forces	ECHA recommends a 12-year derogation under REACH restriction	EU/EEA
Releases of PFOA and PFOS and related substances into the environment (may be extended to all PFAS in future)	Remediation of these releases is required under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as 'Superfund'.	US

Source: Regulatory review by the study team, details provided in Annex 3.

Table 5-5: Summary of PFAS regulatory restrictions for green energy and clean technology sector applications

Application	Regulatory restriction	Geographical scale
Metal plating (hard plating) only in closed-loop systems	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, **currently active**	International
Manufacture of PTFE and PVDF for the production of: FEP for the production of high-voltage electrical wire and cables for power transmission	Exemption (for PFOA, its salts and PFOA-related compounds) in the Stockholm Convention, **currently active**	International
Li-ion batteries (binders and electrolytes)	ECHA recommends a 12-year derogation plus 18-month transition period under REACH restriction.	EU/EEA
Li-ion batteries (separator coatings)	ECHA recommends a 5-year derogation plus 18-month transition period under REACH restriction	EU/EEA
Fuel cells and electrolysis technology	ECHA recommends a 12-year derogation plus 18-month transition period under REACH restriction	EU/EEA
Separator coatings for batteries and PTFE nozzles in high voltage (>145 kV) switchgears and circuit breakers	ECHA recommends a 5-year derogation plus 18-month transition period under REACH restriction	EU/EEA
Front- and backsheets in photovoltaic cells	ECHA recommends a 5-year derogation plus 18-month transition period under REACH restriction	EU/EEA
Heat pumps	Ban on PFAS used in domestic, commercial and industrial applications (no derogation proposed) under REACH restriction.	EU/EEA
Releases of PFOA and PFOS and related substances into the environment (may be extended to all PFAS in future)	Remediation of these releases is required under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as 'Superfund'.	US

Source: Regulatory review by the study team, details provided in Annex 3.

Table 5-6: Summary of PFAS regulatory restrictions for semiconductor sector applications

Applications	Regulatory restriction	Geographical scale
Photo resist and anti-reflective coatings for semi-conductors	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, currently active	International
Etching agent for compound semi-conductors and ceramic filters	Acceptable use (of PFOS, its salts and POSF) in the Stockholm Convention, currently active	International
Photoresists and anti-reflective coatings for semiconductor manufacture	Acceptable use (of PFOS, its salts and POSF) under the Stockholm Convention	China
Etching agents for compound semiconductors and ceramic filters	Acceptable use (of PFOS, its salts and POSF) under the Stockholm Convention	China
Semiconductor manufacturing	12-year derogation plus 18-month transition period under the EU REACH restriction	EU/EEA
Releases of PFOA and PFOS and related substances into the environment (may be extended to all PFAS in future)	Remediation of these releases is required under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as 'Superfund'.	US

Source: Regulatory review by the study team, details provided in Annex 3.

5.3. European PFAS restriction competitiveness impacts

Box 7: Research questions addressed in section 5.3

The following section of the report addresses the research sub questions:

- RQ 3.3: What other policy areas may be impacted by limiting or banning PFAS?
- RQ 3.4: Will strategic sectors be able to continue operating if PFAS is limited or banned within Europe?
- RQ 3.5: What would be the impact of competitiveness of European sectors from banning or limiting PFAS?

The competitiveness assessment synthesises the results from the AoA, SEA, regulatory review and stakeholder interviews. As the assessment aims to present the estimated impacts on industry of different policy options, the results of stakeholder consultation are particularly important but where possible they have been triangulated with the results of the other analyses. A qualitative analysis of the impacts on SMEs has been drawn from the SEA. The findings from the competitiveness assessment are presented in a table for each strategic sector (Table 5-7 to Table 5-10 below). For ease of reading, the estimated impact data is shown in tables. The policy scenarios are on the X axis:

0. Continued use scenario (no regulatory change is implemented);
1. Regulatory option 1 (RO1) a full ban on PFAS;
2. Regulatory option 2 (RO2) a ban with use-specific (mainly) time limited derogations; and
3. Regulatory option 3 (RO3) time unlimited derogations.

The criteria for the competitiveness assessment are on the Y axis:

- Scale of impact;
- Stakeholder consultation inputs (unique insights);
- SME competitiveness;
- Cost competitiveness;
- Capacity to innovate; and
- International competitiveness.

Please note that the **findings of this competitiveness impact analysis are only indicative**, since the qualitative and quantitative data it relies upon are limited (as explained in Section 1.3). Due to gaps in data, there are some gaps in the tables below. In the below write up, the term 'industry' is often used to describe feedback from the stakeholder consultation.

A general note on competitiveness impacts: for all of the strategic sectors, **the chemicals industry often represents the top of the supply chain and may be impacted directly by any loss of PFAS manufacturing** but also via other chemical products dependent on supply chains using PFAS.

5.3.1. Aerospace

Table 5-7: Competitiveness impacts to the aerospace sector from a European PFAS restriction

	Continued use	RO1	RO2	RO3
Scale of impact	**The AoA identified a wide range of PFAS applications** including general components, turbine blade anti-icing coatings, bearings, brakes, cable insulation, cleaning solvents, foams, coatings, engine seals, fire-fighting foams, fuel systems, gaskets, hydraulics, landing gear and lubricants. Industry confirms this and estimates that **a large aircraft may contain over one million PFAS-based components**, each critical since **the failure of any one could compromise safety**.	The AoA and stakeholder consultation indicate **major impacts since PFAS are widely used in aerospace and few alternatives currently meet safety and reliability standards**. The SEA estimates the impact to **cost approximately €99.8 billion**. Fluoropolymers are also essential for hydrogen, electric aircraft and sustainable aviation fuel, so there would be **impacts on developments for the green transition**. The aerospace supply chain is very large and dependent on manufacture of complex components and sub-systems. **Without alternatives to PFAS and no transition period the**	ECHA has recommended a 12-year derogation plus 18-month transition period for the use of fluoropolymers or perfluoropolythers for aerospace safety applications. Although the SEA indicates that the **impacts of RO2 are slightly less severe than RO1 (an estimated €100 million less in monetary terms), industry estimates it would take decades to phase out PFAS in aerospace due to strict safety testing and certification**. If time-limited derogations are applied, **the sector calls for review clauses**.	The SEA estimates that this option is **equivalent to RO1**, continued use. The **aerospace sector argues for exclusion from PFAS restrictions, citing their essential role in safety- and performance-critical applications**. It also **calls for fluoropolymers and their precursors to be exempt, as no alternatives meet required safety and reliability standards**.

	Continued use	RO1	RO2	RO3
		entire supply chain may lose part or all of their manufacturing portfolio.		
Stakeholder consultation inputs	See above.	The aerospace sector warns that without PFAS, manufacture and servicing in the EU would be impossible. It calls for regulatory predictability, a balanced risk-based approach, international coordination, and certainty to operate competitively.	See above.	Industry wants aerospace applications to be exempted from the PFAS restriction, including precursor chemicals needed for their manufacture.
SME competitivene ss	No impact.	Combining the results of the AoA and SEA: With low substitution potential, many aerospace SMEs would close under RO1, as alternatives are lacking and competition cannot offset losses.	The SEA finds SME competitiveness under RO2 would be preserved only for exporters of non-fluoropolymer parts, while most others would likely close with no alternatives available.	No impact.
Cost competitivene ss	The AoA identified that some alternatives to fluoropolymers, such as PMMA for wiring, are low-cost and readily available. Others, like silicone for engine seals, pose risk concerns that	The aerospace industry predicts that the economic impacts would be significant and detrimental to the functioning of the EEA in terms of aviation.		

	Continued use	RO1	RO2	RO3
	could lead to regrettable substitution.			
Capacity to innovate	Combined expenditure on R&D in the aeronautics and defence sectors was an estimated 23.4 billion Euros in 2023 (ASD, 2023). According to industry there has been some investment into the development of PFAS alternatives.			
International competitiveness	No impact Various acceptable uses of PFAS (PFOS and PFOA) exist under the Stockholm Convention for this sector for aviation hydraulic fluids, metal plating, textiles and fire-fighting foam (see Table 5-3).	The aerospace industry warns a PFAS ban would disrupt trade, trigger closures or relocation, and halt MRO, endangering civil aviation. It urges the EU to follow other regions in targeting only uses with available alternatives.	The aerospace industry says competitiveness hinges on the scope and duration of derogations, warning that without them impacts could mirror RO1 across firms, supply chains, MRO, and end users.	The aerospace industry says international competitiveness requires full PFAS derogations for production and MRO, given the widespread use of PFAS.

Source: Authors' own elaboration.

5.3.2. Defence

Table 5-8: Competitiveness impacts to the defence sector from a European PFAS restriction

	Continued use	RO1	RO2	RO3
Scale of impact	**Applications in the defence sector overlap with those in the aerospace sector**, especially for military aircraft. **Published data is limited on PFAS applications in the defence sector**, but known applications identified by the AoA (besides similar applications to aerospace) include: **countermeasure flares; corrosion inhibitors; firefighting foams; high performance membranes; military electronics; military technical clothing (PPE); and munitions**.	Due to inaccessible (confidential) data, it was **not possible to conduct an SEA for the defence sector**. The defence sector says RO1 would have a **significant impact as PFAS are widely used throughout the defence sector and there are currently only a limited number of potential suitable alternatives available that fulfil the safety and reliability performance requirements. The AoA, albeit based on limited publicly available data, supports this**. The supply chain impacts of RO1 are largely unknown based on the confidentiality in the defence sector.	ECHA has recommended various derogations for this sector as a whole, for defence applications, for explosives and for military PPE (Table 5-4). **Less impact than RO1 (depending upon the extent of derogations), but worth noting that industry estimates that it would take decades to fully phase out use of PFAS in the defence sector, on an unprecedented scale**.	The **defence sector stresses the need for their sector to be excluded from the scope of the PFAS restriction**. They also believe that **fluoropolymers (and the precursor chemicals used for their manufacture) should be excluded from the PFAS restriction** due to their **widespread use in defence** products and **absence of alternatives which meet the performance requirements for safety and reliability**.

	Continued use	RO1	RO2	RO3
		It is however expected supply chains may be similar in scale to those for aerospace. Not all supply chains are expected to be impacted however based on the range of products and variable substitution potential.		
Stakeholder consultation inputs		Significant disruptions could result, leading to production ceasing for critical applications and a lack of MRO for defence products in service, with knock-on effects for their continued operation.		
SME competitivenes s	No impact.	Unknown.	Unknown.	No impact.
Cost competitivenes s	Unknown as very limited data available.	According to industry the economic impacts would be severe and damaging to the functioning of the EEA for national and European defence and security.		

	Continued use	RO1	RO2	RO3
Capacity to innovate	Expenditure on R&D in the aeronautics and defence sectors combined was an estimated 23.4 billion Euros in 2023 (ASD, 2023). There has been some investment into the development of PFAS alternatives.			
International competitivenes s	Defence supply chains are globally integrated and highly interdependent.	If PFAS were banned, the defence sector would not be able to continue making and servicing products in the EEA. The defence sector needs regulatory certainty to maintain competitiveness and to continue to operate.	The defence sector says that the impact would depend on the extent of the derogation for PFAS used in the production, operation and MRO of defence products. Without a full derogation for defence, the impact could be as significant as RO1 for defence companies, supply chains, third-party MRO facilities, defence agencies and customers of defence products and services.	The impact would depend on the extent of the derogation, according to the defence sector. Industry says a complete derogation from the PFAS restriction is needed as PFAS are widely used in their sector for critical applications.

Source: Authors' own elaboration.

5.3.3. Green energy and clean technology

Table 5-9: Competitiveness impacts to the green energy and clean technology sector from a European PFAS restriction

	Continued use	RO1	RO2	RO3
Scale of impact	**This sector uses PFAS widely**, as identified by the AoA. Solar PV and batteries rely on inverters (which contain fluoropolymers), often paired with storage to support energy saving, grid stability, security and decarbonisation. Heat pumps reduce gas dependency but require PFAS-based seals and F-gas refrigerants.	The AoA indicates that substitution potential varies widely across applications with different performance needs in this sector. **Industry says no suitable alternatives exist for PFAS in inverters, batteries or heat pumps**. Without suitable alternatives, PV deployment would stop, heat pumps could not replace gas boilers, and redesigns would be needed. **The SEA estimates the impact would be approximately €354 billion**. As PV, batteries and heat pumps are vital for decarbonising, **a PFAS ban would severely affect Europe's energy transition,**	ECHA has recommended various derogations for this sector, for certain applications in Lithium-ion batteries, fuel cells and electrolysis, separator coatings, front- and backsheets in photovoltaic cells (Table 5-5). **The SEA estimates that RO2 would be one billion Euros less than RO1.** According to industry, 5–12-year derogations for PFAS substitution at PV module level could work provided there are policy incentives to increase production. However, there is a trade-off in terms of the durability of PFAS-free PV modules according to industry.	Time unlimited derogations would be better for inverters, batteries and heat pumps for which it will take time to develop technically and financially viable alternatives according to industry. This conclusion is based upon the results of the stakeholder consultation which are substantiated by the AoA.

	Continued use	RO1	RO2	RO3
		security and competitiveness. With PV panels lasting over 30 years, a ban on PFAS in end-of-life recycling would also threaten circular economy targets. Like defence, **this sector relies on multiple supply chains, with impacts varying by substitution potential and upstream dependencies**.	The necessary redesign for heat pumps to use alternatives would take an unknown amount of time, so even if they had been recommended, time limited derogations would not be enough.	
Stakeholder consultation inputs		The solar industry recommends that a ban should focus on new Solar PV products and allow small trace amounts of PFAS for future end-of-life recycling purposes.		Industry argues that controlling PFAS emissions and recovering refrigerants is preferable to a ban, noting their use in small amounts within closed-loop systems in heat pumps where most are recovered and reused.
SME competitiveness	No impact	Based upon the SEA: Many green technology ideas develop from SMEs meaning they would be disproportionately impacted and less competitive.	According to the SEA, only if alternatives were readily available and sufficient policy incentives were in place could SMEs remain competitive.	No impact

	Continued use	RO1	RO2	RO3
Cost competitiveness		Industry warns this would devastate the EU inverter sector. Heat pumps, already 3-5 times costlier than gas boilers, would become unaffordable with alternatives which are not market ready. PFAS-free solar panels are more expensive, less durable, and lack sufficient production capacity.	According to industry the recommended 5-year derogation for PV modules should be a 12 year derogation to allow for development of alternatives and incentives for PFAS-free alternatives.	Industry says time unlimited derogations are needed for hard-to-substitute PFAS components in inverters, batteries and heat pumps. Policy certainty is vital to allow adaptation and stimulate R&D investment.
Capacity to innovate		Green energy representatives had no market data but noted EU manufacturers are increasing research and hope for more funding to become available. Alternatives to F-gases, such as propane, are under study but are uncertified, costlier, less safe, less efficient, and require redesigns.		Industry favours an approach which incentivises PFAS-free products rather than strict bans.
International competitiveness	At least 80% of the upstream production of PV is currently	Industry warns EU PV production would be at risk if PFAS rules are stricter than	Industry says a derogation is needed for PFAS used in PV module production to avoid	

	Continued use	RO1	RO2	RO3
	concentrated in China, according to industry. Industry notes that many components in batteries (such as cathodes, anodes and cells) are also produced in China currently, although there are efforts to diversify raw material sourcing.	abroad. The impact depends on enforcement, such as tolerance for trace PFAS and where responsibility lies. A product-level ban would be less disruptive than one on production processes. With the EU accounting for only 15% of global PV demand, manufacturers may withdraw from its market. Heat pump production in Europe would also stop or move abroad, as alternatives like propane remain unsafe and impractical.	undermining this strategic sector in Europe. They say that derogations are also needed for inverters and semiconductors.	

Source: Authors' own elaboration.

Note: Policy incentives to stimulate the PV market could look like a public procurement requirement for solar PV with PFAS-free polymer layers could be introduced to stimulate the market and increase production capacity, under the Net Zero Industry Act (EC, 2023).

5.3.4. Semiconductors

Table 5-10: Competitiveness impacts to the semiconductor sector from a European PFAS restriction

	Continued use	RO1	RO2	RO3
Scale of impact	According to the AoA and industry a large number of PFAS applications are essential to the manufacture of semiconductors. Significant disruption to the EU chemicals industry would be avoided.	The SEA is less comprehensive than for the other sectors, but indicates that this would cost €109 billion. The AoA and industry warn that a PFAS ban would hit this sector hard, as many uses, such as photoresist topcoats, lack alternatives. Manufacturing would not be possible in Europe without a significant transition period. All supply chains for the industry would lose European business or would need to relocate. Wider impacts may be felt in the EU chemicals industry as complex supply chains dependent on PFAS solutions may close, reducing	The SEA estimates RO2 to have an impact equivalent to RO1 due to an inability to substitute within the derogation timeframes offered. ECHA has recommended a derogation for semiconductor manufacturing (Table 5-6), but depending upon the extent of this derogation, in reality this policy option is likely to still have very significant impacts (see below). Industry recommends reporting on alternatives' development every five years but notes that many alternatives are not	More feasible, see below.

	Continued use	RO1	RO2	RO3
		demand for other associated chemical products.	technically feasible and little will change in this timeframe.	
Stakeholder consultation inputs	According to the semiconductor industry, every sector of the economy depends on semiconductors; any systems containing a battery and industry in the broadest sense use semiconductors.	Industry says removing PFAS from semiconductors would set the economy back to the 1970s. PFAS are used in about 60% of semiconductor manufacturing processes, underpinning lithography, coatings and filters, with global supply chains reliant on EU capacity. Emission controls across hundreds of processes are deemed unfeasible, and many applications still lack alternatives.	The impact remains significant as few alternatives exist and development takes time, for example heat transfer fluids may need 5–8 years according to industry. For semiconductors, many applications lack substitutes and some may take over 50 years to replace.	This option is more feasible, but some alternatives may take over 50 years to develop according to industry. Alternatives must be qualified and adapted to high-precision, high-volume semiconductor production, which takes time.
SME competitivenes s	No impact	Combining the results of the AoA and SEA: With no alternatives, semiconductor firms risk closure, including SMEs. A loss of semiconductor access would reduce	Due to the lack of alternatives identified by the AoA and development time of the semiconductor industry, the SME impacts under RO2 are believed to be the same as RO1.	No impact

	Continued use	RO1	RO2	RO3
		productivity and competitiveness for SMEs across nearly all industries.	The SEA indicates that business closure will occur; losing access to semiconductors and electronics would overwhelmingly reduce the competitiveness of European industry against international competitors.	
Cost competitivenes s		The semiconductor sector notes that although PFAS are costlier than possible alternatives, **technical feasibility is the priority**, and many applications still lack suitable alternatives.		
Capacity to innovate	The European Genesis programme is developing alternatives to PFAS used in semiconductors, but this will take time (budget requested).			

	Continued use	RO1	RO2	RO3
International competitivenes s	No impact.	The sector warns that EU manufacturing would shut and move abroad, disadvantaging EU firms. Asia and the US could absorb capacity, but global output would slow since key processes still rely on Europe.	As in RO1, loss of semiconductor access under RO2 would weaken not only this sector but all European industries reliant on advanced technologies.	No impact.

Source: Authors' own elaboration.

6. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions derived from this study should be read in the context of the limitations outlined in Section 1.3. These conclusions are based on indicative evidence collected across the analysis of alternatives and socio-economic analysis, meaning that true costs or impacts discussed in these conclusions could be significantly higher due to the conservative and higher levels assessments conducted during this study.

6.1. AoA conclusions

In this report the substitution potential of specific examples is inferred based upon the properties and economic data of possible alternatives.

The study finds there are **thousands of applications of PFAS in the aerospace sector**. The high level AoA undertaken, based solely on the properties of a possible alternative, indicates **a low substitution potential for this sector**. This is caused by a lack of suitable alternatives for some applications and lengthy transition times due to stringent safety, testing and certification requirements. PFAS use is commonly present throughout supply chains. There is a lack of suitable alternatives for certain applications such as engine seals; a ban on PFAS would mean that aircraft engines and all the associated components, containing or reliant upon upstream PFAS use, can no longer be manufactured in the EU.

The AoA for the **defence sector** is limited by **a lack of publicly available data**; the design, constituents and performance of components in the defence sector are often confidential for national security reasons. Some theoretically possible alternatives were identified (such as for use in munitions binders), but in many cases, it is unlikely that PFAS could be substituted in high specification applications (such as decoy flares). The Authors conclude that **substitution potential may be highly variable within this sector**. **More in-depth analysis is needed** including direct communication with manufacturers **before overarching conclusions can be drawn for this sector**.

The **green energy and clean technology sector represent many wide ranging PFAS applications,** spanning applications in HVACR (such as refrigerant gases), renewable power generation, energy storage, electronics, automotive (such as Electric Vehicles) and the hydrogen economy. The AoA indicates that **substitution potential varies within this sector and impacts of a PFAS ban could be significant** for interconnected supply chains. PFAS-free alternatives are available for solar panels, but according to industry **PFAS cannot yet be fully substituted in batteries or inverters. Without inverters solar panels and battery storage systems cannot operate.** Similarly, suitable alternatives and the necessary redesigns to safely replace F-gases as refrigerants in heat pumps are not yet feasible. Specifically, **cost and performance implications for potential alternatives in solar panels and heat pumps may limit substitution potential**.

Industry notes that **100% of products in the complex semiconductor industry contain PFAS**, either in chips, packaging, manufacturing equipment or another component.

Due to the range of applications of PFAS in the sector, the impact on the upstream supply chain of this industry is expected to be significant.

Since substitution is not yet possible in all applications of PFAS in this sector, **the AoA infers that this sector has a low substitution potential**. Semiconductors are themselves used in various electronics, aerospace, defence and green energy and clean technology applications, so if semiconductors were not available due to a PFAS restriction this impact would be significant on all strategic sectors of this report alongside progress towards the green and digital transitions.

Based on the strategic sectors in scope, this high-level AoA indicates that substitution in some specific applications may be possible but many wider applications across all strategic sectors may face challenges to substitute the often 'best in class' performing PFAS solutions.

6.2. SEA conclusions

Through the SEA assessment, **the three sectors the authors were able to examine in more detail (aerospace; green energy and clean technology; and semiconductors) consists of approximately 39,000 enterprises and over 2.9 million employees, with SMEs making up 90% of all sectors. The combined continued use benefits across the three sectors are estimated to be €72.8 billion per year**. This figure refers to only the estimated profits of only some parts of each sector so is likely to be an underestimate of the total benefits. **RO3 (a ban on PFAS with a time unlimited derogation) is equivalent to the continued use scenario and therefore the benefits of the continued use are also the economic benefits of RO3**.

RO1 (a full ban of PFAS with an 18-month transition period) is the most detrimental option to the European economy resulting in estimated first year costs of €562.8 billion euros and estimated recurring annual costs of €72.8 billion. The RO2 (a ban on PFAS with an 18-month transition period and 12-year derogation) option slightly mitigates these costs but not by a substantial amount. **RO2 has an estimated first-year economic cost of €561.7 billion with estimated annual recurring costs of €71.7 billion**.

RO3 has the lowest impact on the European economy and is the least disruptive option for critical and strategically important European industries using fluoropolymers. RO3 would still permit authorities and industry to lower and eventually phase out fluoropolymer use over time, but this RO allows this to be done in a more controlled and collaborative manner, bringing the eventual benefits of lower fluoropolymer emissions with significantly lower economic and social costs.

For the defence sector, the SEA is limited by a lack of publicly available data for national security reasons. However, there is considerable overlap between the uses of PFAS in the defence sector and many non- military specific applications, e.g. semiconductors for computers and engine manufacture for aircraft. **This SEA has also not been able to quantify the environmental or human health impacts and therefore the costs of these have not been considered under the continued use and the benefits have not been considered under the ROs**. This is due to a lack of published studies on the human health or environmental damages arising from exposure to or releases of the six in-scope fluoropolymers.

It has not been established whether the health and environmental risks from exposure to PFAS substances which have been studied, such as PFOS and PFOA, apply to the PFAS subgroup of fluoropolymers – further research is needed.

6.3. Conclusions from the PFAS regulatory review

Internationally, PFAS such as PFOA, PFOS, PFHxS, and PFCAs are regulated under the Stockholm Convention on Persistent Organic Pollutants, implemented by 190 signatories through national legislation. **Broader PFAS regulation occurs under national chemical registration and restriction regimes** including AICIS (Australia), "new pollutants" regulatory system (China), CSCL (Japan), REACH (EU), K-REACH (South Korea), UK REACH, and TSCA (US). **China currently only regulates the PFAS covered by the Stockholm Convention, and chemical regulation is piecemeal varying by province and industry; a weaker regulatory regime than the other regions and countries reviewed**. Canada has a phased risk management approach to PFAS, but this excludes fluoropolymers. In the US, regulation is fragmented: states have their own rules, while federally PFOA and PFOS are designated hazardous under the Superfund and require remediation. Japan has restricted 138 PFOA-related substances, affecting production costs but not directly regulating fluoropolymers. Production of long-chain PFAS is declining, except among new producers in continental Asia (Wee and Aris, 2023).

Common exemptions in regulations include unintentional trace contaminants (Stockholm Convention, Australia, South Korea). **Permitted uses often cover firefighting foams** (China, Japan, US airports) and **R&D or testing** (Australia, China, South Korea).

The six fluoropolymers in scope are rarely mentioned directly. Exemptions under the Stockholm Convention include:

- PFOS restrictions do not apply to certain medical devices (e.g. ETFE layers, radio-opaque ETFE); and
- PFOA restrictions do not apply to PTFE and PVDF for membranes, FEP for high-voltage cables, and fluoroelastomers for automotive uses.

The regulatory trend is towards tighter controls, with global chemical companies being advised by investors to voluntarily phase out PFAS from their production (Moorghen, 2025). **However, in certain cases fluoropolymers are excluded from PFAS regulation** (Canada), **and 'polymers of low concern' (PLCs, which include fluoropolymers) are exempted from specific regulatory requirements** (Australia, Japan, South Korea, US) **although the definition of PLCs varies by country**. In the EU, polymers are currently exempted from registration and evaluation under REACH, but not necessarily from authorisation or restriction. **The proposed EU universal PFAS restriction represents the strictest and broadest regulatory regime, depending upon which derogations are adopted**.

6.4. General recommendations

As identified within the SEA of this assessment, a key issue with the current assessment of fluoropolymers is the limited information regarding human health and environmental effects. Whilst some PFAS are known or suspected to be carcinogenic to humans (PFOA and PFOS respectively, IARC, 2025), this knowledge is not ubiquitous to all PFAS materials. In particular, there is a lack of scientific studies assessing fluoropolymers for human health and environmental effects.

Therefore, a wider non sector specific recommendation of this study would be for a high priority to be placed on commissioning studies to assess the six common fluoropolymers within scope of this assessment to better understand their ability to cause health and environmental effects. The results, if they show that fluoropolymers do not cause these effects, could then be used to justify an exemption or derogation under the EU PFAS restriction for the use of fluoropolymers.

Secondly this study has considered the impacts to certain strategic sectors within the European economy and competitiveness resulting from implementing a PFAS restriction. It must be considered however if there are alternative ways to achieve the commendable goals of a healthier European chemical sector without causing business uncertainty and long, complex and expensive regulatory processes for both public bodies and private industry. In addition to a rapid acceleration in research into PFAS free alternatives since the announcement of the UPFAS restriction there has also been an increase in research and development of technologies which can easily, effectively, and economically prevent PFAS emissions into the environment or remove them from the environment (remediation). Therefore, another wider, non-sector specific recommendation would be to consider establishing an innovation and investment fund, possibly to be overseen by ECHA, which would focus on promoting and encouraging technological advancements in abatement and remediation technologies. Development of such technologies could be supported at the European level and could be more strategically integrated into European chemical policy to improve human health and environmental conditions via prevention or removal of emissions whilst maintaining European industry and competitiveness. Therefore, it is recommended to explore creating a funding and innovation framework to better develop abatement and remediation technologies to alleviate PFAS emissions without the need for wide scale regulation such as restrictions. This recommendation would require careful consideration in the context of European environmental principle of rectification at source, prioritising pollution prevention over remediation to prevent transferring the pollution problem to the environment or society; in addition to the precautionary principle and polluter pays principle (Article 191(2), Treaty on the Functioning of the European Union, EU 2016/C 202/01).

6.5. Sector specific conclusions and recommendations

The conclusions and recommendations of this study, combining the findings from the AoA, SEA and competitiveness analysis are summarised below by sector.

6.5.1. Aerospace

a) Conclusions

PFAS are integral to over a million aircraft components, each of which is expected to be critical to safety. It remains to be seen whether the time-limited derogation recommended by ECHA for safety applications is adopted and the defined scope of 'safety applications'. **Alternatives to PFAS are scarce, substitution would take decades, and certification processes are lengthy in this sector**. **The indicative SEA estimates a PFAS ban would cost at minimum approximately €99.8 billion in first year costs with annual recurring costs of €12.5 billion, with time limited derogations being only slightly less severe**.

The aerospace industry calls for exemptions covering both aerospace products and precursor chemicals, stressing the importance of regulatory predictability, review clauses for derogations, and international coordination. Without PFAS, aerospace manufacturing and servicing in the EU would halt, causing major trade and competitiveness impacts. The aerospace supply chain is highly complex and involves many different manufacturers which may exacerbate the impacts of a restriction. Without PFAS alternatives for some applications the final aircraft cannot be produced and all European manufacture of all aircraft, subsystems and components would likely be impacted. Overall, this study finds that **the sector is highly dependent on PFAS, with no viable alternatives in many cases, making broad exemptions or derogations essential to minimise industry disruption**.

b) Recommendations

The aerospace sector is one of Europe's leading industries and is an example of the technology, innovation, quality, and competition Europe can provide to the world. However, the aerospace supply chain is global, highly complex, and easily vulnerable to changing or differing standards or access to goods in certain markets. Likewise, the industry is also safety focused with component or system failures potentially having fatal outcomes. The margin for error and risk of failure for aerospace components is very small and passenger safety cannot be compromised. This is why the industry has become reliant upon high performing fluoropolymers for many critical components. **Therefore, due to the very high standard needed to ensure passenger safety, the lengthy testing schedule for components and craft, and the current scarcity of alternatives it is recommended that PFAS use in aerospace applications be granted a time unlimited derogation**.

A time unlimited derogation is proposed over a total exemption as this would allow the parliament and European authorities to amend the derogation as and when they see fit or is necessary over the long run to incentivise innovation and move away from problematic substances. Therefore, two further recommendations are proposed based on the findings of this study.

First, given the long development times and testing schedules of components and aircraft it is recommended that the time unlimited derogation for PFAS in aerospace be reviewed and potentially revised every 10-15 years.

Such a mechanism would signal to the aerospace industry that the intention remains for fluoropolymers and PFAS to be substituted away from as much as possible, but that understanding is being shown on the complexity of achieving such a task, so sufficiently long review periods are granted for industry to innovate.

Secondly to help further facilitate the potential of substitution and development of safe alternatives and to help bolster European innovation and competitiveness, funding should be made available to support research and development of new technologies, components, or materials that could help reduce the sector's reliance on PFAS over the long term. Finally given the complexity involved with decommissioning an aircraft it could be pertinent to commission studies to better understand this process and better define how PFAS emissions might occur at the end of life with such a study also making recommendations on how these could be better monitored, controlled, prevented, or remediated.

6.5.2. Defence

a) Conclusions

PFAS uses in the defence sector overlap with those in aerospace but also extend to countermeasure flares, electronics, PPE, munitions and other applications. **Alternatives are limited, and any phase-out would take decades**. ECHA has recommended various time-limited derogations for this sector. Industry agrees but goes further, saying that defence should be excluded entirely from the PFAS restriction, including fluoropolymers and their precursors. **A ban would disrupt production, servicing and supply chains, with severe consequences for both EU and national defence**. An SEA was not possible due to inaccessible (confidential) data. In conclusion, **there is a strong case for a time-unlimited derogation or exemption, due to this sector's reliance on PFAS for operational readiness and security**.

b) Recommendations

Europe and the wider world are currently experiencing heightened geopolitical tensions across several regions, which makes a stable, reliable, and self-sufficient defence sector more important than ever. **This wider political and security context combined with this study's findings lead to this study recommending that a time unlimited derogation be granted for the defence sector**. It has been identified in this study that a PFAS ban would cause substantial defence supply chain disruption and due to alternatives currently being very limited and infeasible substitution would take a long time, potentially decades, meaning a 12-year derogation period is also insufficient.

A time unlimited derogation for defence uses of PFAS is recommended instead of exclusion from the restriction altogether because by introducing a time unlimited derogation the European Parliament and authorities would retain the ability to amend this derogation in the future with greater ease than initiating a new defence specific restriction. **Therefore, beyond implementing a time unlimited derogation it is also recommended that a large-scale defence sector chemical supply chain study be commissioned to identify more specifically and exactly which PFAS are used and where throughout the defence sector**. This study could be expanded in scope to study all the substances and materials used within the defence sector to enable transition and substitution planning of materials over the long term. **After this study has identified which PFAS are used and where they are found, it is recommended that more collaborative initiatives between European authorities and the defence sector be conducted. These initiatives could include innovation or substitution funding streams to gradually and carefully replace unwanted substances and materials in a way that does not disrupt the defence sector or jeopardise European security**.

6.5.3. Green energy and clean technology

a) Conclusions

PFAS are central to PV modules, batteries, inverters and heat pumps, all of which are essential to decarbonisation. **No alternatives exist for many of these uses, meaning that a ban would be highly disruptive to the energy transition, energy security and competitiveness**. Due to the broad number of uses in this sector many unique supply chains will be impacted, exacerbating the impacts of a restriction. **The indicative SEA estimates that a ban on PFAS across the green energy and clean technology sector would result in first year minimum costs of approximately €354 billion with estimated annual recurring costs of €22.3 billion**. Beyond these costs however, the AoA and SEA in this study have identified that the disruption a PFAS restriction would have on this industry would also have wider reaching implications on other EU agendas such as the Green Deal and Fit-for-55 plans. Furthermore, it is identified in the SEA that a PFAS restriction in this sector would have a disproportionate impact on new and upcoming technologies and industries, such as the green hydrogen industry, which would greatly damage European innovation and competitiveness.

ECHA has recommended time-limited derogations on certain applications in lithium-ion batteries, separator coatings, fuel cells and electrolysis technology and front- and backsheets in photovoltaic cells. Industry goes further than this requesting a longer derogation for PV modules, ideally lasting 12 years, and unlimited derogations for inverters, batteries and heat pumps. PFAS-free solar PV options are currently more expensive, less durable and lack production capacity. As a result, the sector favours emission controls and incentives over outright bans, while stressing the need for policy certainty and R&D support. In conclusion, this analysis indicates that **PFAS is indispensable for the green transition, requiring tailored derogations and pragmatic regulation to avoid jeopardising EU climate goals**.

b) Recommendations

The recommendations of this study for the green energy and clean technology sector are divided by recommendations pertaining to F-gases and those related for fluoropolymers.

F-gases are used in the sector in uses such as heat pumps which are emerging as a key green technology to achieve the ambitious targets set out in the Green Deal and Fit-for-55 programme. The findings of this studies AoA have indicated that while alternatives using non-fluorinated gases are available, they are still a developing technology and not a universal replacement solution at present.

Furthermore, there already exists a legislative framework for the control, and gradual phase down of F-gases in the form of the F-gas Regulation. The current F-gas Regulation covers many F-gases and many of their uses on an individual regulatory basis and there is already a mechanism built into this Regulation to ensure updates and revisions to reflect current technologies and alternatives within Europe. **It is therefore a recommendation of this study to exclude F-gases completely from the scope of the UPFAS restriction and instead focus all regulatory control of all F-gases into the existing F-gas Regulation**. This would allow for a more nuanced approach to regulating and phasing down the use of F-gases and fostering the development of alternatives where possible in a more gradual way that would be far less disruptive to European industry and reducing impacts to European competitiveness while still ensuring Europe retains the ability and capacity to innovate in green technologies. Data collected regarding the use of F-gases throughout the PFAS restriction process could also be utilised in the upcoming F-gas Regulation revision process and impact assessment.

With regards to fluoropolymers in this sector the picture is slightly more complex pertaining to alternatives. Some alternatives are available for certain uses however there is disagreement over their ubiquity as a complete replacement for PFAS in all uses and use conditions, while there are still many applications which are lacking available alternatives. Similarly, the green energy and clean technology sector overlaps with highly valuable and critical European industries such as the energy and automotive sectors. Given the importance and prevalence of these industries in Europe, it is critical to ensure that decisions are made with strong understanding of the ease of transitioning to alternatives. **At present due to conflicting evidence and the vast array of uses within this sector it is recommended that a more detailed review of the proposed (and unproposed) time-limited derogations for green energy and clean technology uses of PFAS be undertaken**. There is clear evidence of alternatives being researched and developed, but more time is needed to fully see if alternatives have wide-reaching potential. Therefore, time-limited, application specific derogations with regular reviews would be preferable as this allows the European Parliament and authorities the ability to amend and strengthen the restrictions for this industry over time as alternatives become feasible. This would help to prevent any regrettable impacts on the green transition. **In tandem with this, as many green technologies are developed by SMEs it is also recommended that some form of body or task force (possibly within ITRE or ECHA) be established**.

The purpose of this body would be to commission and oversee research on alternatives in the green energy and clean technology sectors, and to provide innovation funding to support the development of new technologies and materials that strengthen European innovation and competitiveness.

Indeed, **innovation funding should be prioritised for this sector** (containing many small players) over other sectors such as aerospace and defence. Finally, given that green and clean technologies are being transitioned to at an accelerating pace and for an unknown time period these technologies may rely on fluoropolymers, **it is recommended that in parallel with granting a time unlimited derogation stringent emission control and remediation technology implementation requirements be placed on companies in this sector**.

6.5.4. Semiconductors

a) Conclusions

PFAS are used in 100% of semiconductor products and around 60% of semiconductor processes, from lithography equipment to topcoats and filters. This assessment found that suitable alternatives are unavailable for many applications. The indicative SEA estimated that the cost of a PFAS ban both with and without a time limited derogation would result in the industry leaving Europe incurring first year costs of at least €109 billion with annual recurring costs of €38 billion. Other studies and research however have indicated that due to the integrated nature of modern technology, which is dependent on semiconductors, a loss of access to semiconductors and digital services could result in a 50% reduction in European GDP equal to nearly €9 trillion in 2024. **Eliminating PFAS is considered unfeasible in this sector and could set the economy back decades, as the development of alternative materials or alternative semiconductor manufacturing processes could take up to 50 years**. ECHA has recommended a time-limited derogation for semiconductor manufacturing.

The industry prioritises technical feasibility over cost of alternatives and highlights the long timescales required for certification in high-volume, high-precision manufacturing. Without sufficiently long derogations, EU production would cease, shifting capacity abroad and weakening competitiveness, while also disrupting global supply chains. Since the Stockholm Convention exemption for use of PFOS and its related substances in semiconductor manufacturing no longer applies in the EU, but still applies in China, so depending upon the final decision on semiconductor manufacturing derogations under the EU PFAS restriction, this sector could move to China (Annex 3). The supply chains for chip manufacturing are a global industry with different processes taking place for the same chip in different regions. **As a result of a proposed restriction in Europe, global semiconductor manufacture would therefore be compromised short term, whilst other global regions would move to replace the unique processes currently conducted in the EU. Furthermore, the goals under the EU Chips Act to strengthen semiconductor production in Europe and to reduce reliance on Asia and the US would become impossible**. Further to this, the semiconductor industry is concerned about the requirement to control emissions of PFAS at source, since their components span many production lines. They asked us for clarification on the definition of this requirement, as they currently see this as economically unfeasible. In conclusion, the **semiconductor sector is critically reliant on PFAS, with substitution infeasible in the long term, and time unlimited derogations are the most feasible policy option**.

b) Recommendations

In general, as little disruption as possible should be imposed onto the semiconductor industry. Modern technologies, digital services, and the development of AI are solely dependent on access to semiconductors. Without semiconductors the digital age ends in Europe. To continue decreasing semiconductor dye sizes and increasing the number of transistors per chip, to improve chip performance compute power, and energy efficiency, the need for sterile and reliable manufacturing conditions grows ever more important.

This precision requirement is why the entire chemistry, physics, and engineering of modern-day semiconductors is built upon a reliance on fluoropolymers and F-gases for some processes. Therefore, removing the semiconductor industry's access to fluoropolymers would necessitate redesigning the entire process of manufacturing a semiconductor chip. Now while this goal is in itself not impossible, it is certainly impossible to achieve in the short term. **Therefore, based on the findings of this studies' indicative AoA and SEA a time unlimited derogation on the use of PFAS within the semiconductor is strongly recommended**. In the short term this would prevent more of the semiconductor industry from viewing and selecting other nations such as the US, for new semiconductor manufacturing capacity. Without such a derogation for PFAS in the semiconductor industry three of the five strategic objectives of the European Chips Act will be completely impossible to achieve. A PFAS ban with any derogation short of time unlimited, will prevent strengthening research and technological leadership, building and reinforcing Europe's capacity to innovate in the design, manufacturing, and packaging of advanced chips, and prevent putting in place an adequate framework to increase production by 2030.

Furthermore, due to the overwhelming importance of semiconductors in the digital era it is recommended that over the medium term, uses of materials and substances associated with semiconductors should be automatically exempt from wider reaching chemical regulations such as REACH authorisations or restrictions. Instead, we recommend that over the medium to long term a framework for semiconductor chemical policy should be implemented through revisions to the European Chips Act. This framework would be underpinned by first performing in-depth analysis of the semiconductor industry to fully map and understand which materials and substances are used in Europe (or the world) within the semiconductor industry. Such an activity would fall within the already existing European Chips Act strategic objective of developing an in-depth understanding of the global semiconductor supply chain. After establishing such a chemical framework and identifying which substances are used globally and within Europe it would be important to establish an evidence-based risk assessment of the identified substances and materials, such health and environmental risk studies may also benefit from the one substance one assessment principle recently passed by the European Parliament.

Finally, the overarching long term recommendation arising from implementing such a framework into the European Chips Act and establishing this knowledge base would be to systematically draw up action plans with the semiconductor industry to collaboratively work towards reducing or transitioning away from using hazardous materials. In addition to the European Genesis Programme, this could be achieved by reallocating existing or introducing new funding streams beyond those already established under pillar one of the Chips Act.

This would expand and synergise the scope of the Chips for Europe Initiative to not only develop and deploy next generation semiconductor manufacturing technologies but also allow Europe to lead the way on alternative manufacturing technologies in the semiconductor and quantum fields.

Parallel to this it is also recommended that under the Chips Act a new funding stream be introduced to support fabrication plants to implement the latest and best abatement technologies to ensure tightly controlled and monitored emissions of substances deemed hazardous under the European Chips Act Chemical Strategy framework, this would synergise with the wider abatement technology innovation funding suggested in section 6.4 above.

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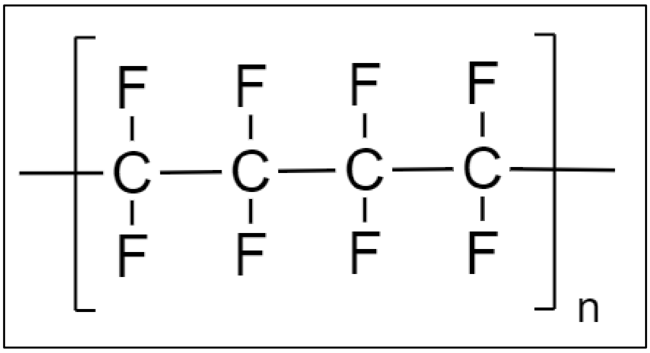
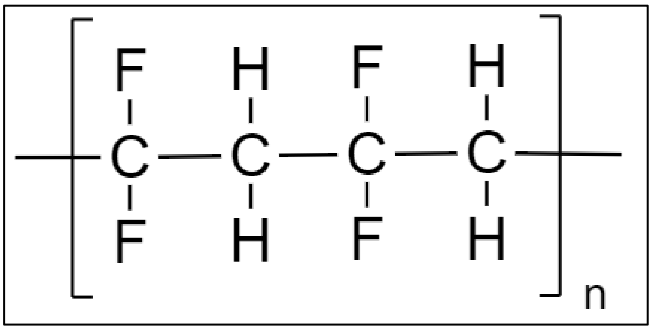
ANNEX 1 CHEMICAL STRUCTURES OF IN SCOPE FLUOROPOLYMERS

Figure A1: Chemical structure of PTFE



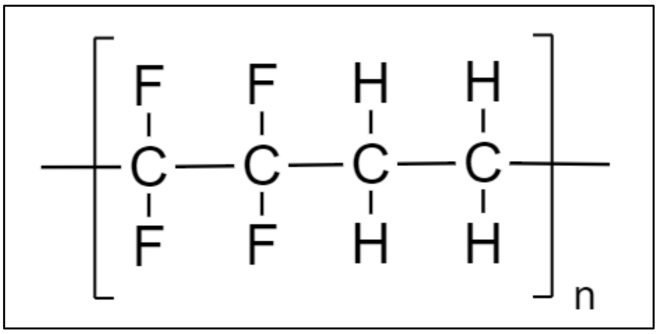
Source: Authors' own elaboration.

Figure A2: Chemical structure of PVDF



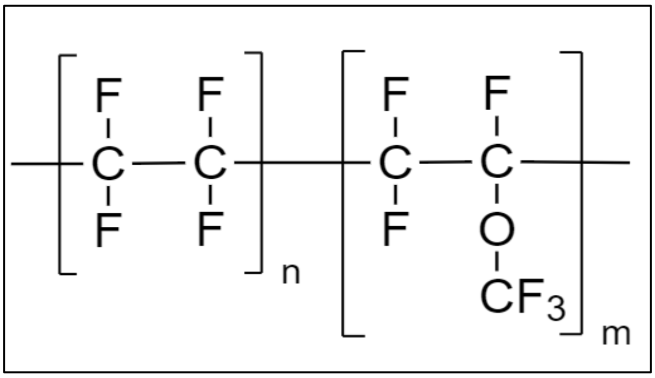
Source: Authors' own elaboration.

Figure A3: Chemical structure of ETFE



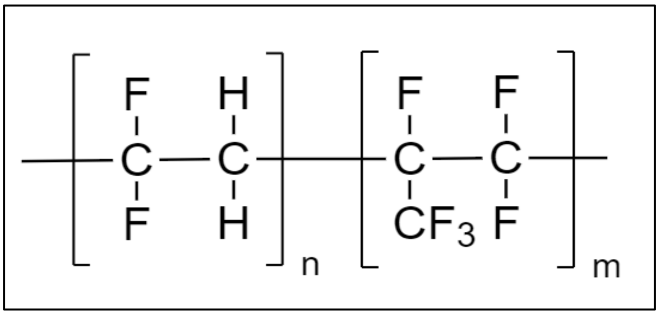
Source: Authors' own elaboration.

Figure A4: Chemical structure of PFA



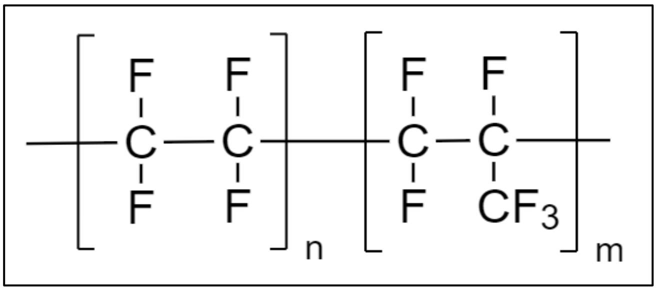
Source: Authors' own elaboration.

Figure A5: Chemical structure of FKM



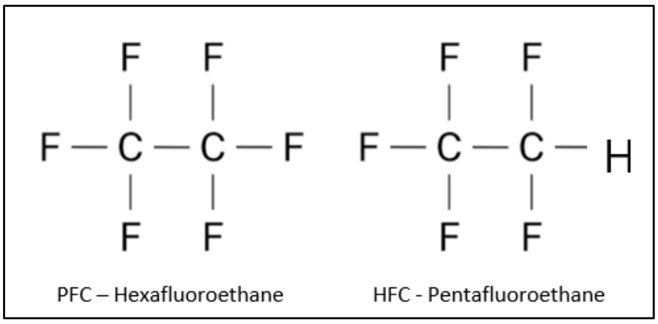
Source: Authors' own elaboration.

Figure A6: Chemical structure of FEP



Source: Authors' own elaboration.

Figure A7: Example chemical structures of F-gases



Source: Authors' own elaboration.

ANNEX 2 ADDITIONAL SOCIO-ECONOMIC DATA

a. Identified NACE and PRODCOM codes per sector used for impact modelling

Table A1: Identified NACE and PRODCOM codes for aerospace sector

	Code and description
NACE	C20.41 – Manufacture of soap and detergents, cleaning and polishing preparations C20.59 – Manufacture of other chemical products n.e.c. C22.11 – Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres C22.19 – Manufacture of other rubber products C22.21 – Manufacture of plastic plates, sheets, tubes and profiles C22.29 – Manufacture of other plastic products C23.12 – Shaping and processing of flat glass C23.99 – Manufacture of other non-metallic mineral products n.e.c. C25.61 – Treatment and coating of metals C25.62 – Machining C26.51 – Manufacture of instruments and appliances for measuring, testing and navigation C27.32 – Manufacture of other electronic and electric wires and cables C27.90 – Manufacture of other electrical equipment C28.12 – Manufacture of fluid power equipment C28.13 – Manufacture of other pumps and compressors C28.14 – Manufacture of other taps and valves C28.15 – Manufacture of bearings, gears, gearing and driving elements C28.29 – Manufacture of other general-purpose machinery n.e.c. C28.99 – Manufacture of other special-purpose machinery n.e.c. C29.31 – Manufacture of electrical and electronic equipment for motor vehicles C30.30 – Manufacture of air and spacecraft and related machinery
PRODCOM	20.41.42.80 – Artificial and prepared waxes (including sealing waxes) (excluding of polyethylene glycol) 20.59.41.59 – Lubricants having a bio-based carbon content of at least 25 % by mass and which are biodegradable at a level of at least 60 % 20.59.41.79 – Lubricating preparations not containing petroleum oil or bituminous mineral oils, excluding the ones used for treatment of textiles, leather, hides, furskins or other materials 20.59.42.70 – Additives for lubricating oils 20.59.42.90 – Additives for mineral oils or for other liquids used for the same purpose as mineral oils (including gasoline) (excluding anti-knock preparations, additives for lubricating oils) 20.59.43.30 – Hydraulic brake fluids and other prepared liquids for hydraulic transmission; not containing or containing < 70 % by weight of petroleum oils or oils obtained from bituminous mineral

	Code and description
	20.59.52.50 – Preparations and charges for fire-extinguishers; charged fire-extinguishing grenades 22.11.13.70 – New pneumatic rubber tyres for aircraft 22.11.20.90 – Retreaded tyres of rubber (including of a kind used on aircraft; excluding of a kind used on motor cars; buses or lorries) 22.19.73.23 – Seals, of vulcanised rubber 22.21.21.70 – Rigid tubes, pipes and hoses of plastics (excluding of polymers of ethylene, of polymers of propylene, of polymers of vinyl chloride) 22.21.29.20 – Flexible tubes, pipes and hoses of plastics, with a burst pressure >= 27,6 MPa 22.21.29.35 – Flexible tubes, pipes and hoses of plastics, not reinforced or otherwise combined with other materials, without fittings 22.21.29.37 – Flexible tubes, pipes and hoses of plastics, not reinforced or otherwise combined with other materials, with fittings, seals or connectors 22.21.29.50 – Plastic tubes, pipes and hoses (excluding artificial guts, sausage skins, rigid, flexible tubes and pipes having a minimum burst pressure of 27,6 MPa) 22.21.29.70 – Fittings, e.g. joints, elbows, flanges, of plastics, for tubes, pipes and hoses 22.29.91.80 – Plastic parts for aircraft and spacecraft 23.12.12.10 – Toughened (tempered) safety glass, of size and shape suitable for incorporation in motor vehicles, aircraft, spacecraft, vessels and other vehicles 23.99.19.30 – Mixtures and articles of heat/sound-insulating materials n.e.c. 25.61.12.30 – Plastic coating of metals (including powder coating) 25.62.10.07 – Turned metal parts for aircraft, spacecraft and satellites 26.51.11.50 – Instruments and appliances for aeronautical or space navigation (excluding compasses) 26.51.65.00 – Hydraulic or pneumatic automatic regulating or controlling instruments and apparatus 27.32.11.50 – Other insulated winding wire (including anodised) 27.90.12.30 – Electrical insulators (excluding of glass or ceramics) 28.12.14.20 – Pressure-reducing valves combined with filters or lubricators 28.12.16.30 – Hydraulic systems, with cylinders as actuators 28.12.16.80 – Hydraulic systems, with actuators other than cylinders 28.13.11.25 – Pumps fitted or designed to be fitted with a measuring device, for dispensing liquids (excl.pumps for dispensing fuel or lubricants, of the type used in filling stations or in garages) 28.14.11.20 – Pressure-reducing valves of cast iron or steel, for pipes, boiler shells, tanks, vats and the like (excluding those combined with lubricators or filters) 28.14.11.40 – Pressure-reducing valves for pipes, boiler shells, tanks, vats and the like (excluding of cast iron or steel, those combined with filters or lubricators) 28.15.10.30 – Ball bearings 28.15.10.53 – Tapered roller bearings (including cone and tapered roller assemblies) 28.15.10.55 – Spherical roller bearings

	Code and description
	28.15.10.57 – Cylindrical roller bearings (excluding roller bearings, needle roller bearings) 28.15.10.70 – Needle roller bearings 28.15.10.90 – Roller bearings (including combined ball/roller bearings) (excluding tapered roller bearings, spherical roller bearings, needle roller bearings) 28.15.23.30 – Bearing housings incorporating ball or roller bearings 28.15.23.50 – Bearing housings not incorporating ball or roller bearings, plain shaft bearings 28.29.22.10 – Fire extinguishers 28.29.23.00 – Gaskets and similar joints of metal sheeting combined with other material or of two or more layers of metal; mechanical seals 28.29.83.40 – Parts for mechanical appliances for projecting, dispersing or spraying liquids/powders; fire-extinguishers, spray guns and similar appliances and steam/sand-blasting machines 28.99.39.65 – Aircraft launching gear and parts thereof, deck-arrestor or similar gear and parts thereof, for civil use 29.31.10.00 – Insulated ignition wiring sets and other wiring sets of a kind used in vehicles, aircraft or ships 30.30.11.00 – Aircraft spark-ignition internal combustion piston engines, for civil use 30.30.12.00 – Turbo-jets and turbo-propellers, for civil use 30.30.13.00 – Reaction engines, for civil use (including ramjets, pulse jets and rocket engines) (excluding turbojets, guided missiles incorporating power units) 30.30.15.00 – Parts for aircraft spark-ignition reciprocating or rotary internal combustion piston engines, for use in civil aircraft 30.30.16.00 – Parts of turbo-jets or turbo-propellers, for use in civil aircraft 30.30.31.00 – Helicopters, for civil use 30.30.31.10 – Helicopters, for civil use (excluding drones) 30.30.32.00 – Aeroplanes and other aircraft of an unladen weight <= 2 000 kg, for civil use 30.30.32.10 – Aeroplanes and other aircraft of an unladen weight ? 2 000 kg, for civil use (excluding drones) 30.30.32.20 – Unmanned aircraft whether or not for remote-controlled flight only, with maximum take-off weight more than 7 kg but not more than 150 kg 30.30.32.22 – Unmanned aircraft whether or not for remote-controlled flight only of an unladen weight ? 2 000 kg and maximum take-off weight more than 150 kg 30.30.32.30 – Unmanned aircraft, designed for the carriage of passengers, of an unladen weight <= 2000 kg 30.30.33.00 – Aeroplanes and other aircraft of an unladen weight > 2 000 kg, but <= 15 000 kg, for civil use 30.30.33.10 – Aeroplanes and other aircraft of an unladen weight > 2 000 kg, but ? 15 000 kg, for civil use (excluding drones) 30.30.33.20 – Unmanned aircraft whether or not for remote-controlled flight only, of an unladen weight > 2 000 kg

	Code and description
	30.30.33.30 – Unmanned aircraft, designed for the carriage of passengers, of an unladen weight > 2000 kg 30.30.34.00 – Aeroplanes and other aircraft of an unladen weight > 15 000 kg, for civil use 30.30.34.10 – Aeroplanes and other aircraft of an unladen weight > 15 000 kg, for civil use (excluding drones) 30.30.40.00 – Spacecraft, satellites and launch vehicles, for civil use 30.30.50.10 – Seats for aircraft; parts thereof 30.30.50.30 – Propellers and rotors and parts thereof for dirigibles, gliders, and other non-powered aircraft, helicopters and aeroplanes, for civil use 30.30.50.50 – Undercarriages and parts thereof for dirigibles, gliders, hang gliders and other non-powered aircraft, helicopters, aeroplanes, spacecraft and spacecraft launch vehicles, for civil use 30.30.50.90 – Parts for all types of aircraft excluding propellers, rotors, under carriages, for civil use 30.30.50.91 – Parts of aeroplanes, helicopters or unmanned aircraft, kites, spacecraft, suborbital and spacecraft launch vehicles, balloons and dirigibles; gliders, hang gliders and other non-powered aircraft n.e.c. 30.30.60.30 – Reconditioning of civil aircraft engines 30.30.60.50 – Reconditioning of civil helicopters 30.30.60.70 – Reconditioning of civil aeroplanes and other aircraft (excluding helicopters, aircraft engines)

Source: Authors' own elaboration.

Table A2: Identified NACE and PRODCOM codes for defence sector

	Code and description
NACE	None identified due to defence sector data not being recorded in Eurostat
PRODCOM	None identified due to defence sector data not being recorded in Eurostat

Source: Authors' own elaboration.

Table A3: Identified NACE and PRODCOM codes for green energy and clean technology sector

	Code and description
NACE	C22.11 – Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres C27.11 – Manufacture of electric motors, generators and transformers C27.20 – Manufacture of batteries and accumulators C27.90 – Manufacture of other electrical equipment C28.11 – Manufacture of engines and turbines, except aircraft, vehicle and cycle engines C28.25 – Manufacture of non-domestic air conditioning equipment C29.10 – Manufacture of motor vehicles C29.32 – Manufacture of other parts and accessories for motor vehicles
PRODCOM	22.11.11.00 – New pneumatic rubber tyres for motor cars (including for racing cars) 22.11.13.55 – New pneumatic rubber tyres for buses or lorries with a load index <= 121 22.11.13.57 – New pneumatic rubber tyres for buses or lorries with a load index > 121 22.11.20.30 – Retreaded tyres of rubber of a kind used on motor cars 22.11.20.50 – Retreaded tyres of rubber of a kind used on buses and lorries 27.11.10.70 – DC motors and generators of an output > 75 kW but <= 375 kW (excluding starter motors for internal combustion engines) 27.11.10.71 – DC motors and generators of an output > 75 kW but ? 375 kW (excluding starter motors for internal combustion engines and photovoltaic DC generators) 27.11.10.90 – DC motors and generators of an output > 375 kW (excluding starter motors for internal combustion engines) 27.11.10.91 – DC motors and generators of an output > 375 kW (excluding starter motors for internal combustion engines and photovoltaic DC generators) 27.11.10.95 – Photovoltaic DC generators of an output not exceeding 50 W 27.11.10.96 – Photovoltaic DC generators of an output exceeding 50 W 27.11.25.30 – Multi-phase AC traction motors of an output > 75 kW 27.11.26.80 – Photovoltaic AC generators 27.11.32.50 – Generating sets (excluding wind-powered and powered by spark-ignition internal combustion piston engine) 27.11.61.10 – Parts suitable for use solely or principally with electric motors and generators, electric generating sets and rotary converters, n.e.c. (excluding fuel cells) 27.20.11.00 – Primary cells and primary batteries 27.20.11.10 – Manganese dioxide cells and batteries, alkaline, in the form of cylindrical cells (excl. spent) 27.20.11.15 – Other manganese dioxide cells and batteries, alkaline (excl. spent, and cylindrical cells) 27.20.11.20 – Manganese dioxide cells and batteries, non-alkaline, in the form of cylindrical cells (excl. spent) 27.20.11.25 – Other manganese dioxide cells and batteries, non-alkaline (excl. spent, and cylindrical cells) 27.20.11.30 – Mercuric oxide primary cells and primary batteries (excl. spent)

	Code and description
	27.20.11.40 – Silver oxide primary cells and primary batteries (excl. spent) 27.20.11.50 – Lithium primary cells and primary batteries, in the form of cylindrical cells (excl. spent) 27.20.11.55 – Lithium primary cells and primary batteries, in the form of button cells (excl. spent) 27.20.11.60 – Lithium primary cells and primary batteries (excl. spent, and in the form of cylindrical or button cells) 27.20.11.70 – Air-zinc primary cells and primary batteries (excl. spent) 27.20.11.75 – Dry zinc-carbon primary batteries of a voltage of >= 5,5 V but <= 6,5 V (excl. spent) 27.20.11.90 – Other primary cells and primary batteries, electric (excl. spent, dry zinc-carbon batteries of a voltage of >= 5,5 V but <= 6,5 V, and those of manganese dioxide, mercuric oxide, silver oxide, lithium and air-zinc) 27.20.12.00 – Parts of primary cells and primary batteries (excluding battery carbons, for rechargeable batteries) 27.20.22.50 – Lead-acid accumulators (excluding traction accumulators and accumulators for starting piston engines) 27.20.23.00 – Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators 27.20.23.10 – Hermetically sealed nickel-cadmium accumulators (excl. spent) 27.20.23.20 – Not hermetically sealed nickel-cadmium accumulators (excl. spent) 27.20.23.30 – Nickel-iron accumulators (excl. spent) 27.20.23.40 – Nickel-metal hydride accumulators (excl. spent) 27.20.23.50 – Lithium-ion accumulators (excl. spent) 27.20.23.95 – Other electric accumulators 27.20.23.96 – Other electric accumulators (including nickel-iron accumulators) 27.20.24.00 – Parts of electric accumulators including separators 27.20.24.10 – Parts of electric accumulators. Separators. 27.20.24.20 – Parts of electric accumulators. Other than separators. 27.90.42.00 – Fuel cells 27.90.51.00 – Fixed capacitors for 50/60 Hz circuits having a reactive power handling capacity >= 0,5 kvar 27.90.52.20 – Fixed electrical capacitors, tantalum or aluminium electrolytic (excluding power capacitors) 27.90.52.40 – Other fixed electrical capacitors n.e.c. 27.90.53.00 – Variable capacitors (including pre-sets) 27.90.81.00 – Parts of fixed, variable or adjustable (pre-set) electrical capacitors 28.11.22.00 – Hydraulic turbines and water wheels 28.11.24.00 – Generating sets, wind-powered 28.11.32.00 – Parts for hydraulic turbines and water wheels (including regulators) 28.25.11.30 – Heat exchange units 28.25.13.80 – Heat pumps other than air conditioning machines of HS 8415 28.25.30.70 – Parts of refrigerating or freezing equipment and heat pumps, n.e.s.

	Code and description
	29.10.24.50 – Motor vehicles, with only electric motor for propulsion 29.10.42.13 – Motor vehicles for the transport of goods with only electric motor for propulsion 29.10.43.13 – Road tractors for semi-trailers with only electric motor for propulsion 29.32.10.00 – Seats for motor vehicles 29.32.20.30 – Safety seat belts 29.32.20.50 – Airbags with inflator system and parts thereof 29.32.30.40 – Road wheels and parts and accessories thereof

Source: Authors' own elaboration.

Table A4: Identified NACE and PRODCOM codes for semiconductor sector

	Code and description
NACE	C26.11 – Manufacture of electronic components C26.12 – Manufacture of loaded electronic boards C26.20 – Manufacture of computers and peripheral equipment C26.30 – Manufacture of communication equipment C26.40 – Manufacture of consumer electronics C26.51 – Manufacture of instruments and appliances for measuring, testing and navigation C26.70 – Manufacture of optical instruments and photographic equipment C28.25 – Manufacture of non-domestic air conditioning equipment C28.41 – Manufacture of metal forming machinery C28.49 – Manufacture of other machine tools C28.99 – Manufacture of other special-purpose machinery n.e.c.
PRODCOM	26.11.21.20 – Semiconductor diodes 26.11.21.80 – Semiconductor thyristors, diacs and triacs 26.11.22.20 – Semiconductor light emitting diodes (LEDs) 26.11.22.40 – Photosensitive semiconductor devices; solar cells, photo-diodes, photo-transistors, etc. 26.11.22.60 – Semiconductor devices (excluding photosensitive semiconductor devices, photovoltaic cells, thyristors, diacs and triacs, transistors, diodes, and light-emitting diodes) 26.11.30.03 – Multichip integrated circuits: processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits 26.11.30.06 – Electronic integrated circuits (excluding multichip circuits): processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits 26.11.30.23 – Multichip integrated circuits: memories 26.11.30.27 – Electronic integrated circuits (excluding multichip circuits): dynamic random-access memories (D-RAMs)

	Code and description
	26.11.30.34 – Electronic integrated circuits (excluding multichip circuits): static random-access memories (S-RAMs), including cache random-access memories (cache-RAMs) 26.11.30.54 – Electronic integrated circuits (excluding multichip circuits): UV erasable, programmable, read only memories (EPROMs) 26.11.30.65 – Electronic integrated circuits (excluding multichip circuits): electrically erasable, programmable, read only memories (E^2PROMs), including flash E^2PROMs 26.11.30.67 – Electronic integrated circuits (excluding multichip circuits): other memories 26.11.30.80 – Electronic integrated circuits: amplifiers 26.11.30.91 – Other multichip integrated circuits n.e.c. 26.11.30.94 – Other electronic integrated circuits n.e.c. 26.11.40.70 – Parts of diodes, transistors and similar semiconductor devices, photosensitive semiconductor devices and photovoltaic cells, light-emitting diodes and mounted piezo-electric crystals 26.11.40.90 – Parts of integrated circuits and microassemblies (excluding circuits consisting solely of passive elements) 26.11.50.20 – Multilayer printed circuits, consisting only of conductor elements and contacts 26.11.50.50 – Printed circuits consisting only of conductor elements and contacts (excl. multiple printed circuits) 26.12.10.20 – Bare multilayer printed circuit boards 26.12.10.50 – Bare printed circuit boards other than multilayer 26.12.20.00 – Network communications equipment (e.g. hubs, routers, gateways) for LANs and WANs and sound, video, network and similar cards for automatic data processing machines 26.20.11.00 – Laptop PCs and palm-top organisers 26.20.12.00 – Point-of-sale terminals, ATMs and similar machines capable of being connected to a data processing machine or network 26.20.13.00 – Desk top PCs 26.20.14.00 – Digital data processing machines: presented in the form of systems 26.20.15.00 – Other digital automatic data processing machines whether or not containing in the same housing one or two of the following units: storage units, input/output units 26.20.16.60 – Other input or output units, whether or not containing storage units in the same housing 26.20.21.00 – Storage units 26.20.22.00 – Solid-state, non-volatile data storage devices for recording data from an external source (flash memory cards or flash electronic storage cards), unrecorded 26.30.22.10 – Smartphones 26.40.60.50 – Video game consoles (not operated by means of payments) 26.51.45.20 – Instruments and apparatus for measuring or checking semiconductor wafers or devices

	Code and description
	26.70.24.90 – Exposure meters, stroboscopes, optical instruments, appliances and machines for inspecting semiconductor wafers or devices (including integrated circuits) or for inspecting photomasks or reticles used in manufacturing semiconductor devices (including integrated circuits), profile projectors and other optical instruments, appliances and machines for measuring or checking 28.25.20.10 – Fans of a kind used solely or principally for cooling microprocessors, telecommunication apparatus, automatic data processing machines or units of automatic data processing machines 28.41.11.80 – Machine tools for working any material by removal of material, operated by ultrasonic processes, for the manufacture of semiconductor devices or of electronic integrated circuits 28.49.21.40 – Tool holders, self-opening dieheads and workholders of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays 28.99.20.20 – Machines and apparatus used solely or principally for the manufacture of semiconductor boules or wafers 28.99.20.40 – Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits 28.99.39.45 – Machines and apparatus used solely or principally for (a) the manufacture or repair of masks and reticles, (b) assembling semiconductor devices or electronic integrated circuits, and (c) lifting, handling, loading or unloading of boules, wafers, semiconductor devices, electronic integrated circuits and flat panel displays 28.99.51.00 – Parts and accessories of machines and apparatus used solely or principally for (a) the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays, (b) the manufacture or repair of masks and reticles, (c) assembling semiconductor devices or electronic integrated circuits, and (d) lifting, handling, loading or unloading of boules, wafers, semiconductor devices, electronic integrated circuits and flat panel displays

Source: Authors' own elaboration.

b. Detailed aerospace data modelling results tables

Table A5: Detailed aerospace data modelling by supply chain segment

Supply chain segment	Profits (€ millions)	Number of enterprises	Number of employees	Social cost of unemployment (€ millions)	Social security cost of unemployment (€ millions)
Seals, gaskets, bearings, hoses, tubing and fluid lines	44	332	12,412	1,680	200
Wiring, cable, and thermal/electrical insulation	26	172	6,405	736	103
Coatings and surface treatment	2	271	2,884	286	46.4
Fluids, lubricants and hydraulic oils	12	42	1,511	291	24.3
Systems integration	146	145	7,762	1,280	125
Engine manufacturing	3,680	739	190,331	39,800	3,060
General aircraft components	66	445	12,508	201	1,630
Aircraft assembly	7,860	739	190,331	38,900	3,060
Operations and maintenance	6	189	5,342	860	86
Additional aircraft parts	630	1,413	10,194	1,070	164
Total	12,500	4,487	439,680	87,400	7,074

Source: Authors' own elaboration.

Note: The continued use scenario and RO3 SEA findings are equal to the profit's column.

The RO1 and RO2 presented in the SEA are the negative sum of the profits, social cost of unemployment, and social security cost of unemployment columns.

The social cost of unemployment and social security cost of unemployment costs will only be experienced by Europe in the first year following introduction of an RO, subsequent years costs will be equal to only lost profits.

c. Detailed green energy and clean technology data modelling results tables

Table A6: Detailed green energy and clean technology data modelling by supply chain segment

Supply chain segment	Profits (€ millions)	Number of enterprises	Number of employees	Social cost of unemployment (€ millions)	Social security cost of unemployment (€ millions)
Solar panels	10	86	2,595	329	41.8
Inverters	411	114	2,597	298	41.8
Binders and separators	267	7	414	45.9	6.66
Li-ion batteries	5,600	327	20,722	2,300	333
BEVs	6,230	1,424	499,994	108,000	8,040
Energy storage	537	441	23,319	2,600	375
Fuel cells	20	114	2,597	298	41.8
HFCVs	242	1,338	497,399	108,000	8,000
Additional vehicle parts	6,920	8,437	936,343	108,000	15,100
Wind turbines	1,170	12	2,278	476	36.7
Generators	5	98	4,873	804	78.4
Other renewable technology	1	86	2,595	329	41.8
Heat pumps	934	71	2,433	313	39.2
Total	22,300	12,554	1,998,157	332,000	32,100

Source: Authors' own elaboration.

Note: The continued use scenario and RO3 SEA findings are equal to the profit's column.

The RO1 and RO2 presented in the SEA are the negative sum of the profits, social cost of unemployment, and social security cost of unemployment columns.

The social cost of unemployment and social security cost of unemployment costs will only be experienced by Europe in the first year following introduction of an RO, subsequent years costs will be equal to only lost profits.

d. Detailed semiconductor data modelling results tables

Table A7: Detailed semiconductor data modelling by supply chain segment

Supply chain segment	Profits (€ millions)	Number of enterprises	Number of employees	Social cost of unemployment (€ millions)	Social security cost of unemployment (€ millions)
Equipment manufacturers	9,200	300	9,969	1,520	160
Semiconductor foundries	12,300	3,671	120,949	14,800	1,950
Electronics manufacturers	16,500	18,007	370,345	46,200	5,960
Total	38,000	21,978	501,263	62,500	8,065

Source: Authors' own elaboration.

Note: The continued use scenario and RO3 SEA findings are equal to the profit's column.
The RO1 and RO2 presented in the SEA are the negative sum of the profits, social cost of unemployment, and social security cost of unemployment columns.
The social cost of unemployment and social security cost of unemployment costs will only be experienced by Europe in the first year following introduction of an RO, subsequent years costs will be equal to only lost profits.

ANNEX 3 FULL PFAS REGULATORY REVIEW DATA

The table below provides a summary of the regulatory review, which was undertaken, key findings from this were presented in section 5.

Table A8: Regulatory frameworks for managing PFAS across selected countries and regions.

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
International	Stockholm Convention on Persistent Organic Pollutants (POPs) • Signatories to the Stockholm Convention include 190 countries and the EU. • Parties must restrict the use of substances in Annex B which (since 2009) includes PFOS, its salts and POSF. • Parties to the Stockholm Convention must take measures to eliminate the production and use of substances in Annex A which (since 2019) includes PFOA, its salts and PFOA-related compounds. • PFHxS, its salts and PFHxS-related compounds were added to Annex A in 2022. • In 2022 the POPs Review Committee recommended adding long-chain perfluorocarboxylic acids (PFCAs), their salts and related compounds to Annex A, this was agreed in May 2025 (UNEP, 2025).	Exemptions to the Stockholm Convention restriction on PFOA, its salts and PFOA-related compounds include, amongst others: • **Textiles** for oil and water repellency for the protection of workers from **dangerous liquids** that comprise risks to their **health and safety** • **Fire-fighting foam** for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems, including both mobile and fixed systems • Manufacture of polytetrafluoroethylene (**PTFE**) and polyvinylidene fluoride (**PVDF**) for the production of: • High-performance, corrosion-resistant gas filter membranes, water filter membranes and membranes for **medical textiles** • Manufacture of polyfluoroethylene propylene (**FEP**) for the production of high-voltage electrical wire and cables for **power transmission**	The Stockholm Convention List of acceptable purposes includes for PFOS and its salts and POSF: • Photo imaging • Photo resist and anti-reflective coatings for **semi-conductors** • Etching agent for compound **semi-conductors** and ceramic filters • **Aviation hydraulic fluids** • **Metal plating** (hard metal plating) only in **closed-loop systems** • Certain medical devices (such as ethylene tetrafluoroethylene copolymer (**ETFE**) layers and radio-opaque **ETFE** production, in vitro diagnostic medical devices, and CCD colour filters) • **Fire fighting foam** • Insect baits for control of leaf-cutting ants from Atta spp. and Acromyrmex spp.

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
		• Manufacture of **fluoroelastomers** for the production of O-rings, v-belts and plastic accessories for **car interiors**	
EU/EEA	The POP Regulation (EC) No 850/2004 POP Regulation (EC) No 850/2004	Annex I, M1 **excludes** the following PFOA-related compounds: • C_8F_{17}-X, where X = F, Cl, Br • fluoropolymers where $CF_3[CF_2]_n$-R, where R'=any group, n>16 • perfluoroalkyl carboxylic acids (including their salts, esters, halides and anhydrides) with ≥ 8 perfluorinated carbons • perfluoroalkane sulfonic acids and perfluoro phosphonic acids (including their salts, esters, halides and anhydrides) with ≥ 9 perfluorinated carbons • perfluorooctane sulfonic acid and its derivatives (PFOS)	Annex I, M1 included derogation e) which expired in July 2023 for the: • manufacture of polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF) for the production of: (i) high-performance, corrosion-resistant gas filter membranes, water filter membranes and membranes for medical textiles (ii) industrial waste heat exchanger equipment (iii) industrial sealants capable of preventing leakage of volatile organic compounds and PM2.5 particulates
	Delegated Regulation (EU) 2025/718 amended Regulation (EU) 2019/1024 on PFOS and its derivatives, removing exemptions for certain uses in the EU; therefore in effect PFOS and its uses are banned for these uses including:	The last remaining exemption in the EU is the use of PFOS and its derivatives in mist suppressants for non-decorative hard chrome plating, has been deleted by Commission Delegated Regulation 2025/718, with new limits applying from 3 December 2025.	

<table>
<tr><th>Region/ country</th><th>Regulatory framework for PFAS</th><th>Exemptions</th><th>Acceptable uses</th></tr>
<tr><td rowspan="2"></td><td>Photo imaging, for example photographic coatings
Photolithography and anti reflective coatings for semiconductors
Etchants for compound semiconductors and ceramic filters
Aviation hydraulic fluids
Metal plating in closed loop systems, hard chrome only
Certain medical devices, for example ETFE layers, radio shielded ETFE, IVD devices, CCD colour filters
Fire fighting foams – a time limited derogation expired in July 2025</td><td></td><td></td></tr>
<tr><td><u>REACH restrictions</u>
REACH restrictions:
I. perfluorocarboxylic acids (C9-14 PFCAs) since February 2023;
II. undecafluorohexanoic acid (PFHxA) from April 2026.
ECHA proposed a restriction of PFAS in firefighting foams (FFF) in 2020
Five Member States (the Dossier Submitters) proposed a universal PFAS restriction; derogations were published in June 2025 (as outlined in the 'exemptions' column to the left).</td><td>Polymers are currently exempted from registration and evaluation under REACH, but may be subject to authorisation and restriction (ECHA, 2023d). The producer or importer of a polymer is usually not obliged to submit information on the polymer's intrinsic properties to ECHA, except where classification and labelling are required for the Classification, Labelling and Packaging Regulation (EC No 1272/2008). Registration with ECHA is required by the manufacturer or importer if the polymer has not yet been registered higher up the supply chain.</td><td></td></tr>
</table>

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
		The proposed derogations published by ECHA in August 2025 include the following: • Semiconductors: • 12-year derogation plus 18-month transition period for: Semiconductor manufacturing. • Green energy and clean technology: • Li-ion batteries (binders and electrolytes): 12-year derogation plus 18-month transition period; • Li-ion batteries (separator coatings): 5-year derogation plus 18-month transition period; • Fuel cells and electrolysis technology: a transition period of 18-months and a 12-year derogation; • Separator coatings for batteries and PTFE nozzles in high voltage (>145 kV) switchgears and circuit breakers: a transition period of 18-months and a 5-year derogation; • Front- and backsheets in photovoltaic cells: a transition period of 18-months and a 5-year derogation; and	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
		• Heat pumps: No derogation proposed for domestic, commercial and industrial applications. • Defence (military) applications: • As a whole: 12-year derogation plus 18-month transition period; • Use of fluoropolymers (fluoroelastomers): a derogation of 12 years; • All uses of PFAS for explosives in military applications: a transition period of 18-months and a 12-year derogation; and • Personal protective equipment (PPE) specifically designed for the armed forces: 12-year derogation; • Aerospace (where safety is provided by fluoropolymers or perfluoropolyethers): 12-year derogation plus 18 month transition period. This is a very brief overview of the derogations, for the full details please see ECHA, 2025b.	
	The 2020 Chemical Strategy • The 2020 Chemical Strategy sets out a clear goal to eliminate the use of PFAS in non-essential applications.	In theory there are exemptions for essential applications from European regulations. The European definition for 'essential use' is: *"A use of a most harmful substance is essential for society if the following two criteria are met:* *1) that use is necessary for health or safety or is critical for the functioning of society, and*	• Necessary for health and safety • Critical for the functioning of society

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
		2) there are no acceptable alternatives"	
Australia	• A PFAS Taskforce operated from 2017-2022 to oversee a Government-wide coordinated response to PFAS contamination. • Regulations focusing on the import, use and disposal of PFAS and avoiding contamination by PFAS since 2015. • Strict requirements for importers and manufacturers of PFAS: registration with the Australian Industrial Chemicals Introduction Scheme (AICIS) before selling any substances in Australia.	• According to theAustralian criteria, Polymers of Low Concern (PLC) are exempted from the requirements for introduction to the Australian market.	
	PFAS ban in Australia • PFAS banned from 1 July 2025 include: PFOA, PFOS, PFHxS plus their salts, isomers and any substances that degrade into those same substances.	• Exemptions to this ban include: • Trace contamination below defined thresholds • Use in goods in service before the ban • Imports under hazardous waste regulations	Exemptions to the ban (in effect acceptable uses) include PFAS used in: • **Scientific research** or analytical testing
Canada	• Chemicals Management Plan • Prohibition of the manufacture, sale, use, import of PFOA, PFOS and LC-PFCAs (LC-PFCAs) excludes fluoropolymers	Phased risk management approach **excludes fluoropolymers**	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• Phased risk management approach for PFAS from 2027 (see below table)		
China	• China is party to the Stockholm Convention on POPs, under which certain PFAS are regulated (see 'International' region above) • Prohibition of the import or export of PFOS and related salts and PFOSF from January 2024 (with some exemptions, see right) • China has been developing a "new pollutants" framework for the risk management of chemicals which includes: screening, assessment, monitoring, and control of chemicals. The framework is not yet fully implemented, but by 2025 the aim was that substances of high-concern and high-volume would have been screened and the first batch of chemicals would have been assessed. • Many PFAS are currently unregulated or in draft indicative lists, such as a list consulted on February 2025 to fulfil requirements under the Stockholm Convention in China (to include PFOA, its salts and PFOA-related compounds; PFHxS, its salts and PFHxS-related compounds; and long-chain PFCAs, their salts and related compounds).		Exemptions for acceptable uses of PFOS (and related substances) under the Stockholm Convention are applied in China: • R&D research • Reference products • Photoresists and anti-reflective coatings for semiconductor manufacture • Etching agents for compound semiconductors and ceramic filters • Aviation hydraulic fluids • Metal plating in closed loop systems, hard chrome only • Certain medical devices, for example ETFE layers and radio-shielded ETFE, in vitro diagnostic devices, CCD colour filters • Fire-fighting foams

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• Regulation is currently piecemeal, focused on the PFAS regulated under the Stockholm Convention, rather than regulation of PFAS in general. • Implementation and enforcement varies between provinces and industries, because much Chinese regulation is at the ministerial or departmental level. • In Sichuan province, local discharge limits have been set for PFOA and PFOS for enterprises in chemical industrial parks, new permitted industrial operations had to comply from July 2025 but existing operations have a 2-year transition period to comply by mid-2027 (under standard DB51/3202–2024). This standard could become a model to be rolled out more widely for PFAS regulation across China. Other provinces are reportedly expected to copy this example.		
Japan	Chemical Substances Control Law (CSCL) • Ban on the manufacture, import and use of 138 PFOA related substances – took effect January 2025 with no time derogations (Ram, H, 2025).	Importers and manufacturers registered in Japan can apply for an exemption for notification of the import or manufacture of Polymers of Low Concern under the CSCL.	Use of PFOI and 8:2FTOH in fire extinguishers and fire extinguishing agents if they comply with specific technical standards (UL Solutions, 2024)

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• 138 PFAS are classified as Class I Specified Chemical Substances, including: • PFOA related substances and salts; • Perfluorinated carboxylic acids; • PFAS derivatives used in coatings, **fluropolymers**[5], electronics, batteries and textiles		
South Korea	2024 POPs Control Act (Act No 15841/2018) • Strict restrictions for manufacturers, importers, exporters and users of PFOS • The exemptions outlined in Annex 2 of the above Act include PFOA and PFOS for certain uses The ban was due to be reviewed in 2024, and every 3 years after that.	Exemptions listed under the Stockholm Convention (see above) Annex 2 exemptions include: • Substances in trace amounts as an unintentional impurity or as an unintentional byproduct in the process	Acceptable uses listed under the Stockholm Convention (see above)
	2013 Act on the Registration and Evaluation of Chemical Substances (K-REACH) which entered into force in 2015, amended in 2019 • Requirement for registration of the manufacture or import of polymers at volumes greater than one tonne per year (in theory this includes fluoropolymers, but see exemptions).	• Manufacture or import of polymers at volumes less than one tonne per year. • Certain polymers which meet the criteria for 'polymer of low concern (PLC)' are exempt from registration.	• R&D substance • Export-only use

[5] In other words, PFAS used as raw materials, processing aids, or additives in the production of fluoropolymers.

<table>
<tr><th>Region/
country</th><th>Regulatory framework for PFAS</th><th>Exemptions</th><th>Acceptable uses</th></tr>
<tr><td rowspan="2">UK</td><td><u>UK POPs Regulations 2007 (retained EU law)</u>
Ban on producing, placing on the market or using POPs including:
PFOS and its derivatives
PFOA, its salts and PFOS-related substances
PFHxS), its salts, and PFHxS-related compounds
The POPs regime also governs the management of several POPs in waste</td><td>Exemptions listed under the Stockholm Convention (see above)</td><td>Acceptable uses listed under the Stockholm Convention (see above)</td></tr>
<tr><td><u>UK REACH restrictions on PFAS</u>
PFOA and its salts; and
certain perfluorinated silane substances
A Regulatory Management Options Analysis (RMOA) on PFAS published by the HSE in April 2023 recommended that the UK should consider using UK REACH restrictions for the use of PFAS-containing: fire-fighting foams; textiles; furniture; coatings and cleaning products.
An Annex 15 dossier on PFAS in fire-fighting foams is being finalised by the HSE during 2025.</td><td></td><td></td></tr>
</table>

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• The HSE is gathering evidence for an Annex 15 dossier on the use of PFAS in coatings and in cleaning agents during 2025. • The HSE is gathering evidence for an Annex 15 dossier on the use of PFAS in manufacture and placing on the market of consumer articles from which PFAS are likely to be released into air, water or soil, or directly transferred to humans; these uses include textiles, coatings and cleaning products.		
	COSHH substances classified as carcinogens or mutagens Control of PFAS: PFOA, PFDA, PFNA and PFOS so far		

	PFAS Action Act, 2021 (H.R.2467)
	• Hazardous substance designation of:
	  ○ perfluorooctanoic acid and its salts, and
	  ○ perfluoroactanesulfonic acid and its salts
	• This designation requires remediation of releases of those PFAS into the environment under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as 'Superfund'
		Exemption for Aqueous Film-Forming Foam (AFFF fire fighting foam) at airports, provided that users comply with safe-handling requirements.	**Firefighting foam used at airports – see left.**
			
			Subsequently proposed Industry-Driven Exemptions under CERCLA (2023-2025) at the time of writing remain bills in committee rather than law. Exemptions for use by the following sectors were proposed:
			• Agricultural operations
			• **Airports**
			• Entities using **AFFF fire-suppression** (aqueous film-forming foam)

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• Future decision by 2026 on whether to designate all perfluoroalkyl and polyfluoroalkyl substances • The EPA must test all PFAS for toxicity to human health The EPA must regulate the disposal of materials containing PFAS		• Solid waste facilities • Public and private drinking water systems and treatment facilities
US	Toxic Substances Control Act (TSCA), introduced 1976 • The New Chemicals Review Program is used to regulate new chemicals before their import or manufacture in the US. • For PFAS listed as 'inactive' on the TSCA Inventory of existing substances, the EPA has issued Signification New Use Rules (SNURs) under TSCA to restrict the re-introduction of PFAS that were previously inactive, requiring companies to notify the EPA before manufacturing, importing or processing these substances. • Under the 2023 one-time PFAS reporting rule, any manufacturers or importers of PFAS since January 2011 must report data to the US EPA by October 2026.	There is an exemption from the regulatory requirements for the manufacture and distribution of new chemicals if they meet the US criteria for PLCs. Small entities importing PFAS in articles have an extended deadline to report to the US EPA by April 2027.	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	• Council on PFAS created in 2021 by the EPA • PFAS Strategic Roadmap • Data collection to inform regulation		

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ANNEX 4 CREDIBILITY MATRIX ASSESSMENT CRITERIA

The credibility matrix approach has been used to validate sources of literature used in this report. This task was conducted after the literature review for the analysis of alternatives and is used to ensure that only data from credible sources is used in the analysis. The credibility matrix works by the following procedure:

1. Sources of information are identified and recorded in the matrix;
2. Criteria for what are important factors in the reliability of sources for the task are defined and a scoring system is established;
3. Weighting is given to each of the reliability criteria defined in step 2 based on the relative importance of the criteria on the overall reliability of a source;
4. For each reliability criteria, the source is given a score and justification by the author for why this score was attributed;
5. The scores are multiplied by the weighting and added together to produce a total weighted score for the source;
6. The total weighted score is compared against the maximum possible weighted score and a percentage is given;
7. Depending on the percentage value literature is graded as:

   Grade 1 – reliable source to be used in analysis;

   Grade 2 – likely reliable source although data should be caveated before use;

   Grade 3 – unreliable source and should not be used in the analysis

For the purposes of this study the following criteria were identified for the review of literature before use in the analysis of alternatives.

Type of Article: The type of article relates to what kind of source the data has come from. More formal, factual based publications will be favoured over less formal sources of information. The scoring for this criterion is:

3 - Technical data sheets, Literature reports, Industry Reports, Safety data sheets, Webpages (summarising data from scientific or industry reports).

2 - Webpages of manufacturers, organisations, research institutions or associations (with data published online only and not substantiated by any of the reports mentioned above).

1 - Webpages from other third parties, blog pages, news articles.

Authors credentials: The author of the data should be from a reliable source and should have access to reliable and truthful data regarding the properties of the substance. This criterion will filter out those without expert knowledge on the substance and will remove the potential of inaccurate data being included. The scoring for this criterion is:

3 - Trusted data generators including manufacturers, industry associations, market research institutions, national/international agencies, independent researchers.

2 – Authors who have received data from trusted generators including distributors, consultants, advocacy groups, affiliated experts.

1 – Other third-party authors including unaffiliated webpages/people, blogs, news articles.

Geography: Information required for the economic, market and hazard and risk assessment needs to be European specific as market shares, hazards and prices can vary between global regions. The scoring for this criterion is:

2 – Specific to European markets, pricing and hazard classifications (not applicable for technical criteria and so if a source only contains technical data automatically score as 2).

1 – Specific to Global or other regional markets, pricing and hazard classifications.

Theoretical or real-world data: Data may be generated either by observed testing or via other forms of primary generation, or data can be inferred based on existing data and applying assumptions. The preferences is always for original primary data and would score higher in this criterion. The scoring for this criterion is:

2 – Data generated are from primary sources or authors are owners of the primary information;

1 – Data are generated from secondary sources or involve assumptions/extrapolation of similar primary data.

Of the above criteria, highest weighting was given to the type of article and author credentials whilst lower weighting was given to the geography and theoretical or real-world data criteria. The use of the credibility matrix resulted in 113 grade 1 literature sources, 17 grade 2 literature sources and 8 grade 3 literature sources. As previously stated, grade 1 and 2 literature (130 sources) were taken forward for analysis whilst the 8 grade 3 literature sources were excluded from the analysis. Typically grade 3 sources related to economic data which is less prevalent from reliable sources and explains the lack of data indicated in the economic, availability and hazard and risk table of Annex 5.

The general principles for screening literature as set out in the credibility matrix were applied to all sources before inclusion in this report.

ANNEX 5 SUMMARY TABLES OF THE ANALYSIS OF ALTERNATIVES

Table A9: Summary table of technical feasibility criteria of PFAS and alternatives

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
Polytetrafluoroethylene (PTFE)	341-344°C (Teflon PTFE Granules/ Fine Powder resin) (2) 327°C (powder) (3) 335°C (resin) (6)		V-0 (6)	High chemical resistance (6) High: all except stated (7) Low: B-M (molten or dissolved), Fluorine gas, specific high temperature compounds (7)		285 V/Mil (6) 22-24 kV/mm (7)			27.6- 48.3 MPa [psi] (2) 3900 psi (6) 210-375 kgf/cm² (7)	320-600% (granular resin) (2) 300% (PTFE resin) (6) 250-400% (PTFE products) (7)	50 (PTFE resin) (6) 58-52 (PTFE products) (7)	3.5 ft-lb/in) - Izod test (6)	
Polyvinylidene fluoride (PVDF)	155-175°C (powder/g		V-0 (1)	High chemical resistance (8)	UV resistant (1)	20-25kV/mm (1)	High purity (1)	0.2–0.4 (static) and 0.15–0.35	Between 30-50 MPa (powder and	20-300% (1) *25-500% (11)	70-80(1)	170-1000 J/m (IZOD	Readily melt-processibl

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
	ranules) [1] 175°C (raw material-values from supplier) [8] 165°C (powder) [10] * 154-184°C (form not stated) [11]		V-0 [8] * V-0. PVDF is non-flammable and non-dripped. It is self-extinguishing. The LOI is 44%. [11]	High: S, most aggressive substances [1] *A, Ar, H, Alc, S-H [11] Low: not stated	* good resistance to UV [11]	*260-950kV/mm [11]	*High purity [11]	(dynamic) [1]	granules) [1] 60MPa [8] *36-56Mpa [11]		Ball indentation hardness value was 110 N/mm^2 and Rockwell hardness value was M78 [8]	impact-notched) [1] 10 kJ/m^2 (Charpy impact strength-notched; unnotched had no break) [8] * 160-530 J/m (IZOD impact) [11]	e [1] *Readily melt-processible [11]
Ethylene tetrafluoro ethylene (ETFE)	*254-279°C[12] 290°C (pellets)[14]	*-200-150°C[12] 100°C-150°C[15]	V-0 [15]	*High chemical resistance [12]	*High UV resistance and light transmission [12]	*14.6kV/mm[12] 59kV/mm (at 0.25mm thick) [15]		0.4[15]	38-48MPa or 5500-7000psi [15]	*150-300% [12] 100-350% [15]		No break (Izod) [15]	Readily melt-processible and possible for wire coating[12]

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
	225- 270°C [15]												
Perfluoroalkoxy alkanes (PFA)	305°C (resin)[16] 300°C (pellets)[18]		V-0 (resin) [16] V-0 (resin) [19]	High chemical resistance (resin) [16] High chemical resistance (pellets) [19]		80 kV/mm or 2,000V/mil (resin)[16] 35-40kV/mm (pellets)[19]	Ultra-high purity (resin)[16]		300MPa or 4,000psi (at 23°C) and 14MPa or 2,000psi (at 250°C) (moulding and extrusion resin) [16] >=22MPa or >=3190psi (pellets) [19]	300% at 23°C and 500% at 250°C (resin) [16] >=200% (pellets) [19]	55D (Hardness Durometer) (resin) [16] 55-60 (Shore D) (pellets) [19]	No break (Izod notched) [19]	Readily melt-processible [16] [19]
Perfluoroelastimer (FKM/FFKM) AKA Perfluoroelastomer		-10°C to 230°C[20] -5°C to 300°C (FFKM seals) [21]	Non-Flammable with a flash point of >204°C (399°F) [23]	High chemical resistance [21] [22] High: A-hT, Alc, Ald, B, E, H, K, W,			High purity (FFKM seals) [21]		16.3 MPa (65 Shore A), 18.5 MPa (70 Shore A), 21.6 MPa (80 Shore A), 17.3 MPa (90 Shore A) [20]	168% (65 Shore A), 150% (70 Shore A), 135% (80 Shore A), 119% (90 Shore A) [20]	65 (65 Shore A), 71 (70 Shore A), 79 (80 Shore A), 92 (90 Shore		

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
		-20°C to 320°C [22]		ethylene and propylene oxide, active pharmaceutical ingredients, cleaning agents [20] Low: not stated					Up to 15 MPa [22]	Up to 320% [22]	A)[20] Between 60-90 (FFKM seals)[21] Between 70-95 (shore A) [22]		
Fluorinated ethylene propylene (FEP)	270°C [27] 270°C [28]	-60°C to 205°C [25] Max operating temperature of 204°C (powder carrier) [26]		High chemical resistance [26] [27]	UV resistant [27]	50kV/mm (D149 specification) [27]		Low coefficient of friction [26] [27]	30 MPa (D1708, D638 specification) [27]	300% (D 1708, D 638 specification) [27]	90 (shore A) [25] 55-60 (D2240 specification) [27]	No break (D256 bij + 23°C) [27]	

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
		-200-205°C [27]											
Common alternatives for fluoropolymers													
Polyether ether ketone (PEEK)	343°C [29] 340°C [31] 340-343°C [32] *343°C [33]	Max operating temperature 260°C (no min temp) [29] *Max operating temperature 260°C (no min temp) [33]	V-0 [29] V-0 [31] V-0 [32] *V-0 [33]	High chemical resistance [32] High: A, S, aggressive chemicals [29] High: A, B, H, S, W [32] High: *S [33] Low: High temperature nitric acid, high temperature methyl acetone, high temperature	*Low resistance to UV [33]	20 kV/mm [29] *20 kV/mm [33]	High purity (granules) [31] *Inherently pure [33]	0.31-0.4 (sliding friction 23°C, 1N), 0.23-0.41 (23°C, 20N), 0.26-0.32 (200°C, 1N), 0.3-0.32 (200°C, 20N) [31]	97 MPa at 23°C [29] >=95MPa at 23°C [32]	20% [29] >=10% [32] *30-150% [33]	99 (Rockwell M) [29] >=90 (Rockwell M) [32]	6.5 kJ/m² [29] 5kJ/cm² [31] No break (CHARPY impact strength at either 23°C or -30°C), 5-6 kJ/cm² at 23°C (CHARPY notched impact strength)	Can be injection moulded [31] *Extrusion and 3D printing possible [33]

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
				methanoic acid (31)								and 6kJ/cm² at -30°C (32) *80-94 J/m (Notched Izod) (33)	
Polyethylene	113°C (Metallocene Polyethylene (mPE))(37) 126-136°C (Polyethylene) (38) 120°C (C4 Linear Low Density Polyethylene) (39)		May be combustible at high temperatures (38)						36 MPa (TD) and 45MPa (MD) (C4 Linear Low Density Polyethylene) (39) 41MPa (TD) and 44MPa (MD) (C6 Linear Low Density Polyethylene) (40)	910% (TD) and 550% (MD) (C4 Linear Low Density Polyethylene) (39) 990% (TD) and 760% (MD) (C6 Linear Low Density Polyethylene) (40)		90g (Dart drop impact), (C4 Linear Low Density Polyethylene) (39) <60g (Dart drop impact), (C6 Linear	Readily melt-processible and can be applied as a coating (mPE) (37) Can be injection moulded (Ethylene Vinyl Acetate Copolymer) (41)

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
	129°C (C6 Linear Low Density Polyethylene) [40] 86°C (Ethylene Vinyl Acetate Copolymer) [41] 69°C (Ethylene Vinyl Acetate Copolymer Resin) [42] 109°C (Low Density Polyethylene) [45] 124°C (C6 Linear Density								28MPa (TD) and 27Mpa (MD) (Ethylene Vinyl Acetate Copolymer) [41] >4.0MPa (Ethylene Vinyl Acetate Copolymer Resin) [42] 37 MPa (High Density Polyethylene) [43] 21 MPa (TD) and 28 MPa (MD) (Low Density Polyethylene) [45] 47Mpa (TD) and 60 (MD) (C6 Linear	640% (TD) and 210% (MD) (Ethylene Vinyl Acetate Coplymer) [41] >800% (Ethylene Vinyl Acetate Copolymer Resin) [42] 590% (TD) and 190% (MD) (Low Density Polyethylene) [45] 710% (TD) and 550% (MD) (C6 Linear Low Density		Low Density Polyethylene) [40] 400g (Dart drop impact), (Ethylene Vinyl Acetate Copolymer) [41] 120 ft-ib/in² (Tensile impact strength), (High Density Polyethylene) [44]	

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
	Polyethylene) [46]								Low Density Polyethylene) [46]	Polyethylene) [46]		110g (Dart drop impact), (Low Density Polyethylene) [45] 580g (Dart drop impact), (C6 Linear Low Density Polyethylene) [46]	
Ultra-high molecular weight polyethylene (UHMWPE)	135°C [34] 130°C [47] 135°C [48]	Max operating temperature 90°C (no min temperat	HB [34, 47]	High chemical resistance [34] High: H, S-H, W [35]		25kV/mm [34] 45 kV/mm [47] 44 kV/mm [48]		0.25 µ (dynamic) [35] 0.29 (friction against	40 MPa (at 23°C) [34]	300% [34] 50% [35] 50% [47]	64 (Shore D) [34] 60-65 (Shore	No break (test method: ASTM D256) [34]	

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
		ure) [35] Minimum operating temperature -200°C; Max service temperature in air 80°C (continuously-5000h) and 120°C (short periods, no load) [47]		Low: sulphuric acid, O, Chlorine [35]				hardened and ground steel, P=0.05 N/mm² and v=0.6m/s) [48]			D) [35] 60 (Shore D) [47] 64 (Shore D) [48]	No break (Charpy impact strength-unnotched), 115 kJ/mm² (Charpy impact strength - notched) [47] No break (ASTM D256) [48]	
Polyamide (PA)	220°C [51]	-40-80°C (continuous) and	HB – V0 [50] HB [51]	High: H, S [50] High: H [51]	Fairly resistant [50]	10-120 kV/mm [50] 22 kV/mm [51]		Low coefficient of friction [51]	45-90-MPa tensile strength at	5-150% [50] 40% [51]	80 (Shore D) [51]	3-80 kJ/m² (Izod	Easy to manufacture and

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
		160°C (intermittent) (50) Max operating temperature 120°C(51)		Moderate: weak B (50) Low: strong A, strong B, O (50)					yield (50) 80 MPa (23°C) (51)			notched), 3-90 kJ/m² (Charpy notched) (50) 7kJ/m² (ASTM D256) (51)	machine (52)
Polyvinyl chloride (PVC)	170°C to 200°C (57)	Maximum 60°C, Minimum -15°C (PVC Rigid sheets) (54)	PVC is self-extinguishing per UL flammability tests. Fire retardant properties (54) Not flammable (55,57)	High: A, B, Alc, H, S, W (54) Excellent weather resistance (54) Low: oxidising agents (56) Low: oxidising				Static friction factor 0.4-0.5; dynamic friction factor 0.23*(59)	At yield: 55 MPa (54) 63 MPa (81)	>=10% (54) 200% - 450%*(59)	60, Shore D (54) 110, Rockwell R (91)	No break (ISO 179-test method) (54) 2.3 J/cm (Izod notched) (81)	Easy to join using Solvent Cement and easy to weld like other thermoplastics (54) The material leads to easy processing

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
				agents, halogens (57)									for fabrication of various useful products (55)
Polymethyl methacrylate (PMMA) (acrylic)	160°C (82) 130-140°C (84) 80°C (86)	94°C-176 °C (86)	HB (82,83)	High: weak A, weak B, S (84) Low: Ar, E, H, K (84)	Excellent UV resistance (82) Excellent transparency among all plastics (transmits more than 92% of visible rays- LG PMMA, not direct but related) (84) UV- resistant (86)	15 kV/mm (82) 20 kV/mm (PMMA optical and extrusion grade) (83) 80kV/mm (86)			70 MPa (at 23°C)(82) 64- 72MPa depending on optical and extrusion grade (83) 8,000 - 11,000psi (84) 48psi (86)	2% (84)	90 M (82) 96-99, Rockwell, depending on optical and extrusion grade (83) 80-100, Rockwell (84)	10 kJ/m² (82) 0.3 ft-ib/in (Izod notched) (84)	
Polyester	256°C(88)								150 MPa (88) 57 MPa (89)	80% (88) 2.3% (89)			

	Melting point (ºC)	Operational temperature range (ºC)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
									50 MPa (95)				
Polycarbonate (PC)	149 ºC(90)	-60 to 115 ºC (90) -60 to 125/115 ºC (94)											
Polypropylene (PP)		+0 to +100 ºC (115)	HB (97) B2 (115)			58 kV/mm (97, 115)		0.3(97)	30 MPa (97) Modulus 380 MPa, at Yield 13 MPa (98) 32 MPa (115)	210% (98)	70, shore D (97) 54, shore D (98) 70, Shore D(115)	10.5 kJ/m^2 (98) not broken (115)	
Stainless steel									380 - 2030 MPa (60) 290 MPa (61) 500-700 Rm N/mm2 (62)	4 - 45% (60) 55% (61) =>45/35% (62)	25- 444 (60) B82 (61) 215 (62)		
Hydrogenated nitrile butadiene rubber (HNBR)		-20 to +150°C (63)							=>23 MPa (63) 100 kg/cm^2 (64) > 102 Kg/cm^2 (65)	=>240% (63) 200% (64) > 250% (65) 200% Minimum (66)	75 (+/- 5), Shore A (63)		

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
		-35°C to + 160°C [64] -30 to 150 ºC [65] -30 to 150 ºC [66]							15 MPA Minimum [66]		70° ± 5°, Shore A [64] 70-75, Shore A-2 [65] 70° Shore +5 / -5° [66]		
Styrene butadiene rubber (SBR)		High Temperature Usage (Fº) to 225º. Low Temperature Usage (Fº) 0º to -50º[67] -25 to 70 ºC[68] -10 °C to 70 ºC[69]		Moderate: weak A, weak, B, O [68] Low: strong A, strong B, H, S [68]					Tensile range: 500 – 3000 PSI [67] 5 MPa Minimum [69] 22.5 MPa [70]	600% [67] 200% [68] 220% [69] Minimum 510% [70]	65, shore A [68] 60° Shore +/- 5° [69]		

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance	UV resistance (% absorbance)	Dielectric strength (V/mm)	Chemical purity	Co-efficient of friction	Tensile strength (MPa)	Elongation at break (%)	Hardness	Impact resistance (KJ)	Ease of processing
Silicone		-40 °C to +100 °C (71) -30°C to +80°C(72) -60°C to +230°C (73) -30°C to +150°C (74)	F (72)		Excellent UV Resistance (71)	23 kV/mm (73)			1.11N/mm2 (71) 7.0 - 9.0 MPa (73) 0.2MPa @ 60% (74) 7.5 Mpa (75)	215% - 525% (73) >200% (74) 750% (75) 700% (76)	15 - 25, shore A (74) 33, shore A (75) Ca. 15 ± 5, Shore A (76)		
Ethylene propylene diene terpolymer (EPDM)		-22 to 266 °F(80)	Class E, EN 13501-1 (78)		UV exposure pass EN1297 test (78)			0,50 (80)	8.0 - 12.5 MPa 77) ≥ 8.0 N/mm²(78) 1015 psi min(79)	230 - 324% (77) ≥300% (78) 350% min (79) ≤ 600% (80)	53 - 72 shore A (77) 50-60 shore (79) 75 - 90, Shore A (80)	≤ 150 mm, Load-hard substrate (78)	

Note: for chemical resistance – A=Acid, A-hT=Acid at high temperature, Alc=alcohols, Ald=aldehyde, Ar=Aromatics, B=Bases, B-M= alkaline metals, B-hT=Baes at high temperature, E=Esters, H=hydrocarbons, K=Ketones, O=Ozone, S=Solvents, S-H=Halogenated solvents, W=water/steam

* Indicates the literature was recorded as grade 2 after the credibility matrix assessment (see Annex 4) and may therefore be less reliable than other data.

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Table A10: Summary table of economic, market, and hazard criteria of PFAS and alternatives

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
Polytetrafluoroethylene (PTFE)	*Europe- $14.3/kg [5]		*257.49 hundred tonnes in 2020 [127]		Causes serious eye irritation, skin irritation and may cause respiratory irritation (if inhaled) [4] Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic [17]	May cause long lasting harmful impacts to aquatic life [4] Fluoropolymers are practically insoluble in water and not subject to long-range transport [17]
Polyvinylidene fluoride (PVDF)			*12,690.37 Tonnes for PVDF resin in 2020 [131] *12,690.37 Tonnes for PVDF resin in 2020 [132]	*$1.5 billion in 2024 [130]	Causes skin irritation and serious eye irritation and may cause respiratory irritation [9] Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic [17] *PVDF is generally	Not considered to be either persistent, bioaccumulative or toxic. Not considered to have endocrine disrupting properties [10]

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					regarded as non-toxic and biocompatible (11)	
Ethylene tetrafluoroethylene (ETFE)					Hazard class not classified (13) Does not contain components considered to have endocrine disrupting properties but largely unstudied (14) Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic (17)	Hazard class not classified (13) Relatively few studies have been conducted on environmental hazards (14) Fluoropolymers are practically insoluble in water and not subject to long-range transport (17)
Perfluoroalkoxy alkanes (PFA)					Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic (17) Lack of data available for many aspects of	Hazard class not classified (13) Relatively few studies have been conducted on environmental hazards (14) Fluoropolymers are practically insoluble in water and not subject

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					toxicological information. Fumes generated during burning may cause "polymer fume fever" (flu-like symptoms such as fever, chill, cough). Fumes are not absorbed in skin. No sensitizing effect are known [(18)]	to long-range transport [(17)]
Perfluoroelastimer (FKM/FFKM) AKA Perfluoroelastomer					Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic [(17)] Contact with uncured polymer may cause irritation with discomfort to both skin and eyes. Inhalation of fumes from burning polymer may cause temporary lung	The environmental effects of this product have not been investigated; not expected to cause significant adverse effects. No evidence currently available on the effects on plants, animals or aquatic life [(23)]

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					irritation effects with cough, discomfort, difficulty breathing, or shortness of breath. No direct toxicity data available for this substance [23]	
Fluorinated ethylene propylene (FEP)	*Resin prices between $25/kg and $38kg of FEP resin during 2022-2023 (for established manufacturers they secure multi-year supply contracts at fixed rates below $28/kg).[136]				Fluoropolymers like PTFE are not bioavailable or bioaccumulative and are therefore not known to be toxic or carcinogenic [17] No data available on toxicological effects. Source states substance does not contain components considered to have endocrine disrupting properties [28]	Fluoropolymers are practically insoluble in water and not subject to long-range transport. [17] No data available on persistence, degradability, bioaccumulative potential or mobility in soil. But source states substance does not contain components considered to have endocrine disrupting properties. (28)
Polyether ether ketone (PEEK)					No data available on toxicological effects [30]	No data available on the chemical, physical,

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
						and toxicological effects [30]
Polyethylene	0.86 (EUR/kg) [120]				Dust may cause irritation to the upper respiratory tracts and skin contact with heated polymer can cause serious burns. No effects are expected for ingestion of small amounts but may be a choking hazard. Not a known carcinogen. Repeated exposure is not known to aggravate medical conditions. Very low toxicity to humans or animals- not considered to be dangerous to humans [38]	Very low toxicity to humans or animals. Avoid release to the environment. This product is not expected to bioaccumulate through food chains in the environment. Not readily biodegradable, persistent in the environment. Because of its physio-chemical properties, it has low soil mobility and floats on water. [38]
Ultra-high molecular weight polyethylene (UHMWPE)					No data available for toxicological information but the product does not contain any known or	Contains no substances known to be hazardous to the environment or that are not degradable in wate water

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					suspected endocrine disruptors [36]	treatment plants. Insoluble in water. May have some potential to bioaccumulate. Spillage unlikely to penetrate soil as product is insoluble and floats on water so not likely to be mobile in the environment due to its low water solubility. Product does not contain any known or suspected endocrine disruptors. Product does not contain any known or suspected substance which is a persistent organic pollutant with ozone depletion potential. [36]
Polyamide (PA)					FDA compliant for food contact (specific grades) [52] Harmful if swallowed, causes severe skin	No data available on toxicity, persistence and degradability, bioaccumulative potential, mobility in

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					burns and damage, may cause an allergic skin reaction, harmful if inhaled, may cause respiratory irritation. (53)	soil. Substance does not have components considered to be either persistent, bioaccumulative and toxic or very persistent and very bioaccumaltive at levels of 0.1% or higher. (49) Recyclability: Nylon PA6 is recyclable and commonly reused in many industrial applications. Environmental Impact: Nylon PA6 has moderate water absorption, which can affect its properties but is generally stable in a wide range of environments. (52) Toxic to aquatic life with long lasting impacts. (53)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
Polyvinyl chloride (PVC)					Identified as non-hazardous. Non-Toxic, inhalation may irritate and cause discomfort in nose and throat. [55] If inhaled can cause coughing and breathing difficulties other than that it is not classified as toxic, skin irritating, eye irritating, or carcinogenic. [56] Not test data available for weather it is sensitising for inhalation or skin or respiratory system. No test data available for Mutagenicity or Carcinogenicity. [57]	Not classified as being hazardous to the aquatic environment and does not contain an endocrine disruptor at a concentration of >=0.1%. No data available on persistence and degradability, bioaccumulative potential and mobility in soil. [56] Not classified as dangerous to the environment. Not readily biodegradable in water. No data on mobility in soil or bioaccumulative potential. Acute toxicity to fishes. [57]
Polymethyl methacrylate (PMMA) (acrylic)	€0.49 per kg*[107]				Exposure to airborne concentrations above statutory or recommended	PMMA is considered environmentally safe and inert under normal usage. It resists UV

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					exposure limits may cause irritation of the nose, throat and lungs. Exposure to airborne concentrations above statutory or recommended exposure limits may cause irritation of the eyes and redness. Not known to have significant effects or critical hazards in relation to skin contact or ingestion. Data not available on endocrine disrupting properties. (85)	degradation and is often long-life applications. (82) No data available on toxicity, persistence and degradability or mobility in soil. (85)
Polycarbonate (PC)	0.95 EUR/kg*(107)		Production capacity of 1,240,000 t per year (111)		No adverse health effects (92)	It doesn't harm the environment but it is not biologically degradable. (92)
Polypropylene (PP)	*0.46 (EUR/kg) (107) 0.82 (EUR/kg) (120)				Polypropylene heated to 700 deg. F can	This substance/mixture contains no components considered to be either

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					irritate the respiratory tract. (103) Eye: Lacrimation. Eye: Ptosis. Convulsions or effect on seizure threshold. Tremor. Body temperature decrease. (104)	persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher. The substance/mixture does not contain components considered to have endocrine disrupting properties (104)
Stainless steel	Europe: US$2.81/KG July 2025*(120)	Europe: August 2025, 2.1% up (US$2.87/KG)*(120)	257.5 million metric tonnes in 2024(119)	1,839.5 million metric tonnes in 2024(119)	Constituent products may be classified as Acute Tox. 5;H303 May be harmful if swallowed. Eye Irrit. 2;H319 Causes serious eye irritation. Skin Sens. 1;H317 May cause an allergic skin reaction. Resp. Sens. 1;H334 May cause allergy or asthma symptoms of breathing	Toxic to aquatic life (99) Not likely to be mobile or biodegrade. (100) Not soluble in water. Immobile. No known harmful effects. (101)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					difficulties if inhaled. Some components are classified as Carc. 2;H351 Suspected of causing cancer. STOT RE 1;H372 Causes damage to organs through prolonged or repeated exposure. Specific Target Organ Toxicity: (lungs) (99). Skin irritation (Category 2). Eye irritation (Category 2). Specific target organ toxicity – single exposure (Category 3). Acute toxicity, Dermal (Category 3). May cause respiratory irritation.(100) Constituent products may be classified as Carc. 2 H351 Carc. Cat 3, R40; STOT RE 1* H372 T;R48/23; Skin	

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					Sens. 1 H317 R43; Resp. Sens. 1 H334 R42/43. The exposure route of concern is inhalation. These stainless steel products are in massive form, not capable of being inhaled. Nickel is classified as a skin sensitiser. It causes skin sensitisation in susceptible individuals through prolonged intimate contact with the skin. (101)	
Hydrogenated nitrile butadiene rubber (HNBR)					Degradation by chemicals, aging, heat or fire may produce a toxic and/or corrosive residue depending on the circumstances of degradation and other materials involved. (102) Skin contact: Contact with hot material will cause thermal burns.	The product is not expected to be substantially biodegradable. (102) No known significant effects or critical hazards. (105) Acute aquatic toxicity. The product is insoluble in water. (106)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					Reddening, itching, swelling, burning and possible permanent damage. (105) High concentrations may cause severe irritation, pulmonary edema (body fluid in the lungs) with coughing, wheezing, and abnormal lung sounds. Dust may irritate the eyes and skin. Contact with hot material can cause thermal burns which may result in permanent damage. Acute toxicity. Two ingredients of the substance, carbon black and crystalline silica, can cause cancer. (106)	

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
Styrene butadiene rubber (SBR)	Europe: US$2.63/KG July 2025*[125]	Europe: August 2025, -1.5% down (US$2.59/KG)* [125]			Produces smoke and fumes when heated over 300° F. There is no toxicology information on this material; however, the components possess irritancy potential. The oil component has been classified by IARC as a carcinogen in mice; however, the carcinogen potential of a polymeric material containing this oil has not been established. Specific target organ toxicity (repeated exposure): Lung. Information on the likely routes of exposure: Primary Route(s) of Entry is for inhalation of hot fumes, skin absorption. Potential acute health	Avoid release to the environment. Prevent entry to sewers and public waters. The product is not considered harmful to aquatic organisms nor to cause long-term adverse effects in the environment. [109,110]

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					effects Inhalation: Inhalation of hot fumes may cause lung irritation. (108) Symptoms/effects after inhalation: None under normal use. Thermal decomposition can lead to the release of irritating gases and vapours. Symptoms/effects after skin and eye contact: None under normal conditions. Risk of thermal burns on contact with molten product. Symptoms/effects after ingestion: Gastrointestinal complaints. (109,110)	
Silicone	8 US$ KG in Europe July 2025* (124)	Europe: August 2025, -1.8% down (US$7.86/KG)* (124)		Market Volume (2025) 3.17 Million tons (123)	Eye contact: Causes serious eye irritation. Skin contact: Causes skin irritation.	The product components are not classified as environmentally

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
					Ingestion: Irritating to mouth, throat, and stomach. This product contains methylpolysiloxanes, which can generate formaldehyde upon exposure above 300 degrees centigrade in atmospheres that contain oxygen. Formaldehyde is a skin, eye, and throat irritant.(112) Particles in the eyes may cause irritation and smarting. May cause discomfort if swallowed. (113) Acute oral toxicity and Acute inhalation toxicity of one of the components. Skin sensitisation: May cause an allergic skin reaction. (114)	hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment. (113) Toxicity to fish: LC50 (Fish): 0,0027 mg/l. M-Factor (Acute aquatic toxicity): 100. M-Factor (Chronic aquatic toxicity): 100. Harmful to aquatic life with long lasting effects. (114)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (GHS hazard statement)	Environmental hazards (GHS hazard statement)
Ethylene propylene diene terpolymer (EPDM)					Skin Contact: May cause mild skin irritation with repeated contact. Irritation/Corrosivity Data My cause skin irritation with repeated contact. (116) Inhalation: Not relevant at normal room temperatures. When heated, toxic vapours may be formed. (118)	Persistence and degradability: This product is not expected to be readily biodegradable. (118)

Note: * Indicates the literature was recorded as grade 2 after the credibility matrix assessment (see Annex 4) and may therefore be less reliable than other data.

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The study examines how PFAS support European industrial competitiveness and the potential impact of a full or partial restriction. Focusing on six key fluoropolymers and F-gases used in aerospace, defence, green energy, and semiconductor sectors, it finds that substitution is often unfeasible, particularly in aerospace, defence and semiconductors. Substantial economic losses and job impacts are predicted under both above restriction options, with risks to Europe's global competitiveness. The study recommends permanent or long-term derogations for critical sectors, extending transition periods for green technologies, and excluding F-gases from the restriction. Further research and an innovation fund to develop alternatives are recommended. Overall, a balanced approach that protects the environment while preserving industrial and technological strength is proposed.

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