STUDY

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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, the study finds that substitution is often unfeasible, particularly in aerospace, defence and semiconductors. Substantial economic losses and employment impacts are expected under both restriction options, with associated risks to Europe's global competitiveness. Amongst other recommended policy steps, the study recommends time unlimited derogations for critical sectors, the extension of transition periods for green technologies, and the exclusion of F-gases from the restriction. Further research and the creation of an innovation fund to support the development of alternatives are also recommended. Overall, the study proposes a balanced approach that protects the environment while preserving industrial and technological capability.

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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
ECHA	European Chemicals Agency
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)
HVARC	Heating, Ventilation, and Air Conditioning
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
MTV	Magnesium, Teflon®, Viton®
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)
NGOs	Non-Governmental Organisations

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
PFHpA	Perfluoroheptanoic acid
PFHxS	Perfluorohexanesulfonic acid
PLC	Polymer of Low Concern
PMMA	Polymethyl Methacrylate
POP	Persistent Organic Pollutant
POSF	Perfluorooctanesulfonyl fluoride
PPE	Personal protective equipment
PRODCOM	"Production Communautaire" in English: Community Production
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
R&D	Research and Development

RAC	Risk Assessment Committee
REACH	Registration Evaluation Authorisation and restriction of Chemicals (EU regulation)
RMOA	Regulatory Management Options Analysis
RO	Regulatory Option (assessed in this study)
RQ	Research questions
SBR	Styrene-Butadiene Rubber
SDS	Safety Data Sheet
SEA	Socio-economic analysis
SEAC	Socio-Economic Assessment Committee
SF_6	Sulphur hexafluoride
SME	Small or Medium sized Enterprise
TSCA	Toxic Substances Control Act (US)
UHMWPE	Ultra-High-Molecular-Weight Polyethylene
UK	United Kingdom
US	United States
UPFAS	Universal PFAS restriction in the EU and EEA
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 Fire Fighting Foams (FFF). A universal restriction dossier for the EU and EEA 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 industrial 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 in substituting PFAS solutions which are often considered to be high performing. The aerospace and semiconductor sectors have limited substitution potential due to few or no alternatives being readily available for certain critical applications throughout highly complex supply chains 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 includes many varied PFAS applications, with substitution potential varying within this sector on an application-by-application basis. This variability is expected to be reflected within the defence sector due to the expected wide range of products containing or dependent upon PFAS.

Findings from the SEA: The indicative SEA estimates that there will be significant economic impacts under both restriction scenarios. A full ban (RO1) is the more 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 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 options.

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 Universal PFAS (UPFAS) Restriction in the EU and EEA 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 sectors.

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 careful, 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 ten to fifteen years is proposed. 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 support the gradual substitution of 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 support the development of alternatives where possible in a more gradual way, while still ensuring the EU retains the capacity to innovate in green technologies.

- A more detailed review of the proposed and potential new time-limited derogations for green energy and clean technology uses of PFAS. There is evidence of research and development into alternatives, 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 support European innovation and competitiveness. Finally, given that green and clean technologies are expanding 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, including at end of life, are placed on companies in this sector.

- A time unlimited derogation for PFAS for the semiconductor sector. Modern technologies, digital services, and AI depend entirely on semiconductors. Without semiconductors, Europe's digital activity would be significantly compromised. 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 under the European Genesis Programme to support the eventual phase out of PFAS in semiconductor manufacturing, a new funding stream under the Chips Act could enable the adoption of the best available abatement technologies, and support the development of next generation and more cost-effective 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 PFAS 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 in the context of chemical and environmental regulation.

The European Chemicals Agency (ECHA) took early regulatory steps to reduce PFAS use by developing a restriction on the use of PFAS in Fire Fighting 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, and in line with the policy goals of the European Commission, ECHA began preparing a universal restriction dossier. This dossier was submitted by five authorities, Germany, Norway, Sweden, Denmark, and the Netherlands, to reduce the use and sale of PFAS and limit emissions. The initial dossier was submitted in early 2023 (ECHA, 2023b) with an updated dossier released in August 2025 (ECHA, 2025a). The proposed universal EU and EEA restriction (UPFAS), based on the Organisation for Economic Co-operation and Development (OECD) definition of PFAS, covers more than 10,000 substances, excluding only a few fully degradable PFAS subgroups (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 consultation on the proposed EU restriction, two options were assessed:

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

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

The time-limited derogations, lasting five or twelve years after the general eighteen-month transition period, are based on socio-economic considerations and the availability of alternatives. Some time-unlimited derogations have been proposed for PFAS that are already regulated under other legislation, such as active substances in plant protection products, biocides and human and veterinary medicinal products.

Non-Governmental Organisations (NGOs) have also contributed to PFAS discussions. Organisations such as the CHEM Trust, European Environmental Bureau and Client Earth have focused on advocacy, public awareness, and legal action, seeking a universal, group-based restriction on PFAS, with exceptions only for essential uses where no alternatives exist. At the time of writing, 114 organisations have signed a manifesto for an urgent end to so called 'forever chemicals'[1].

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

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

1.1.1. Research sub questions

The broader RQ have been subdivided to add nuance to the in-depth analysis and to support more targeted research and literature review. Table 1-1 presents the sub questions derived from the RQ and where they are addressed. These sub questions are also quoted in each relevant section.

Table 1-1: Research sub questions under each RQ

RQ	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. Study research questions (RQs) and overview of approach

For an assessment to coherently analyse PFAS and their uses in strategic sectors, a set of clear research questions (RQ) has been defined:

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. Overview of the methodology for the study

The study involved several steps:

1. **A review of the substances in scope and the markets of strategic relevance** (Section 2): A literature review provided an overview of why PFAS, and fluoropolymers in particular, are used in the markets of strategic relevance.
2. **An analysis of alternatives (AoA)** (Section 2.2.4): An AoA was conducted to identify potential alternatives and to infer substitution potential for the six fluoropolymers in scope. Alternatives were assessed against key criteria, including technical and economic feasibility, market availability and risk profiles. An AoA precedes and informs the Socio-Economic Analysis.
3. **A Socio-Economic Analysis (SEA)** (Section 4): This enabled an analysis of the value of PFAS to the economy and society; and an impact assessment of four policy scenarios for PFAS regulation.
4. **Competitiveness assessment** (Section 5)**:** A regulatory review of selected countries and regions sets the global regulatory context for PFAS. This is followed by a European competitiveness impact assessment which combines the key findings of the AoA, the SEA and the regulatory review to draw high level conclusions under four policy scenarios for each of the four sectors of interest.

The following table sets out the key sections where the RQ are addressed, the main approaches and data sources used, and how findings from one section inform later sections.

Table 1-2: Methodology approach and RQ 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,[2] and their uses in strategic sectors. A short timeframe was allocated for the study, thirteen weeks. Thus, the study relies on readily available literature, illustrative examples of alternatives for specific applications, and limited consultation with each strategic sector to address key gaps. Certain PFAS, such as perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), have been studied more than others in terms of their environmental and human health effects, whereas little published research exists on the effects of fluoropolymers. The results and conclusions of this study should be read in the context of these limitations. The specific limitations of each component of the study are explained below.

Additional consultation and hypothesis testing is recommended to validate the conclusions. However, gathering primary data from industry on novel alternatives may be difficult, as such information is often considered confidential while companies seek competitive advantage. Thus, industry may be unwilling to share detailed information. The authors recommend further analysis to validate the conclusions of this study.

[2] F-gases are defined in section 2.1.7 as short chain gases which meet the definition of PFAS as defined by the OECD.

1.3.1. Limitations of the Analysis of Alternatives (AoA)

The AoA was conducted at a relatively high level, and the findings should not be viewed as definitive in terms of substitution potential. The AoA is based on identifying the number of applications which may involve PFAS within a strategic sector, and providing examples to illustrate the main challenges with substitution. Whilst this approach captures 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 were available. This supports an independent analysis but limits the detail required to conclude definitively on substitution potential. Addressing this would require industry consultation, which was not possible within the timeframe of this study.

Substitution potential can vary within a strategic sector depending on the specific application. This reflects the broad range sub-sectors and the varied applications of PFAS within them. To accurately conclude on substitution potential, assessments should be carried out at the application level, as each application has different performance requirements and acceptability criteria. This leads to considerable variation in substitution potential within strategic sectors, and conclusions at high sectoral level are therefore not reliable.

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

1.3.2. Limitations of the Socio-economic analysis

An SEA would usually include extensive industry consultation with a representative selection of stakeholders to gather robust data on each in scope sector and its fluoropolymer uses. This was not possible due to time and budget constraints. Public data from the NACE[3] (Nomenclature of Economic Activities) and PRODCOM[4] (Production Communautaire (Community Production)) databases were used to supply economic data for valuation and modelling. While this approach enabled access to data on the number of enterprises, employees and profits generated from relevant products, the portion of these products attributable to fluoropolymer use is not known. To address this and permit socio-economic analysis, the study employed a low market share assumption model, described in Section 4.1.

The SEA provides indicative evidence of the possible scale of impact of a fluoropolymer restriction, but it does not estimate the true level of impact on the EU or EEA economy. The uncertainties are therefore considerable and require contextual interpretation when using the 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 industry-specific data. The full explanation of this modelling approach is provided in Section 4.1.

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[3] 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.

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

1.3.3. Limitations of the European competitiveness impact assessment

The competitiveness assessment focused on selected countries and regions, 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 they include the major PFAS manufacturers. Other regions and countries not reviewed may have fewer restrictions on PFAS.

Monitoring of the regulation in countries excluded from this study is recommended to ensure that limited regulation does not pose a potential threat to European competitiveness. For example, according to Koulini *et al* (2024), PFAS use and disposal were unregulated in India in 2024. Regulation may also be limited in other low-and middle- income countries with chemical manufacturing industries, such as Argentina, Bangladesh, Egypt and Zambia. Countries with weaker PFAS regulation may become attractive to companies wishing to continue manufacturing using fluoropolymers after the UPFAS Restriction. In the past, manufacturing has shifted to regions or countries with lower labour costs and less regulation, such as China, effectively 'offshoring' pollution from production (Saussay and Zugravu-Soilita, 2023; Li and Zhou, 2017). As wages and regulation increase in China, (see Annex 3) manufacturing may move to 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 several countries, but the criteria for defining them varies. There is currently no international agreement, (or example by the OECD, on the definition of PLC. To inform fluoropolymer regulation in Europe, we recommend a thorough assessment of the criteria used in different countries to identify common elements. These could be considered in the UPFAS restriction, or used to inform more detailed competitiveness assessment.

The competitiveness analysis is largely informed by stakeholder consultation. The analysis aims to present the impacts on industry under different policy scenarios across dimensions such as costs, price, capacity to innovate and international competitiveness. Consultation with industry is a reliable source for competitiveness analysis, as stakeholders understand market competition and dependencies. Stakeholder engagement included consultation with one industry association from each sector, aerospace, defence, and semiconductors; and two organisations from the green energy and clean technology sector. Although the sample was small. the consultation provided useful supplementary data for the AoA and SEA and helped identify the factors and issues faced by the sectors for policy recommendations.

2. SCOPE OF THE IN-DEPTH ANALYSIS

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

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

2.1. Substances in scope

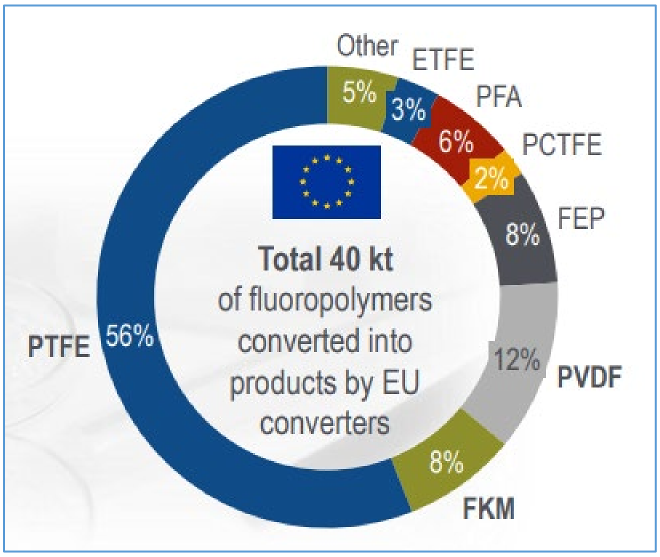
Box 1: Research questions addressed in Section 2.1

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 characterised 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. A standardised definition of PFAS was published in 2021 by the OECD and used to define PFAS in the proposed EU REACH Restriction. While many PFAS exist, this assessment prioritises fluoropolymers and a single category of fluorinated gases used as refrigerants. 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 identified in literature as being 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 is 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.

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.

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.

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.

2.1.6. FKM/FFKM – 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.

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 (according to the OECD definition) 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.

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 interlinked sectors, aerospace, defence, green energy and green technology, and semiconductors, and the use in of F-gases only in green energy and clean technology. All these sectors are of strategic importance to the EU and EEA, 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).

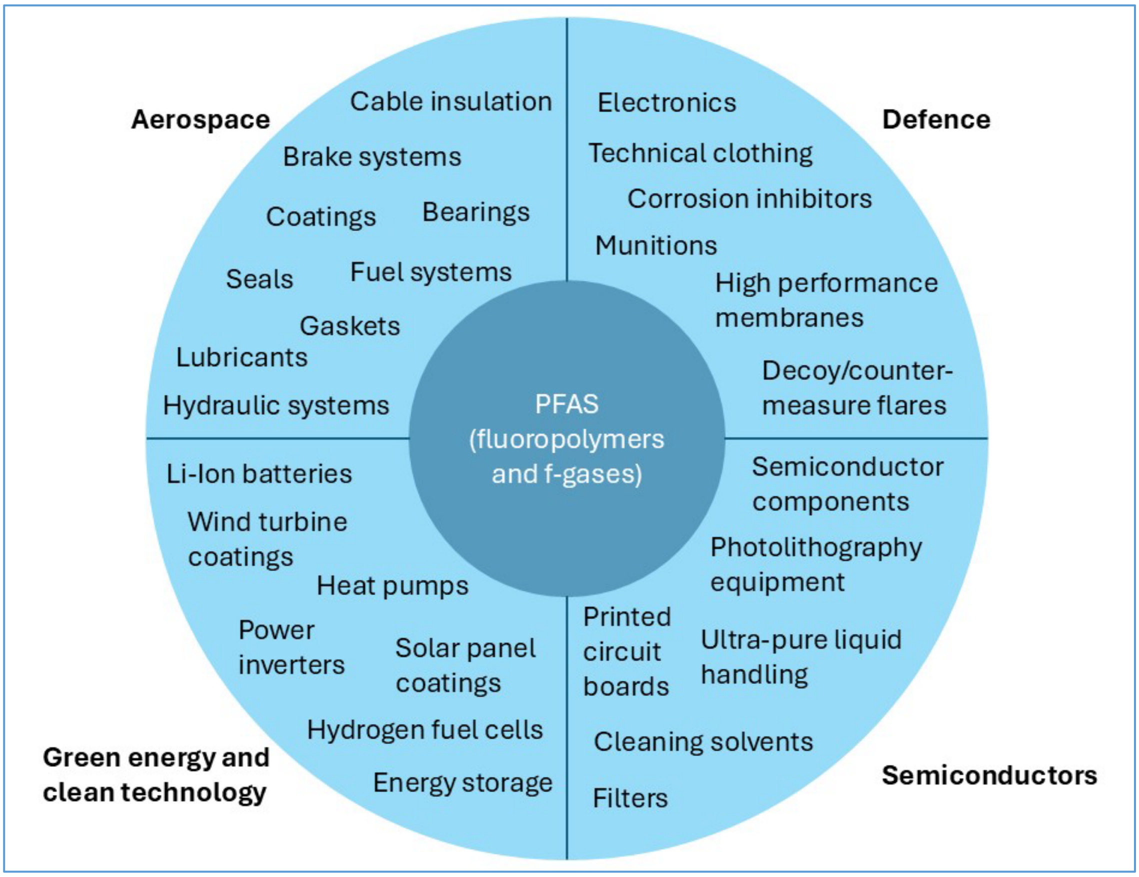
Under the European Green Deal, the EU climate change and defence roadmap sets out actions for the defence sector to address climate change risks and become more sustainable.

The green energy and clean technology sector are critical to developing and delivering a sustainable green transition within the EU 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

The markets of strategic interest were screened for use of PFAS and the following PFAS applications were identified for each sector (Figure 2), confirming relevance and potential implications from the UPFAS Restriction. This is a non-exhaustive list based on the literature review conducted for 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 around 405,000 jobs in the EU, with research and development estimated at €8 billion in 2019, although production rates declined after the COVID 19 pandemic (EC, n.d. a). More recently, the civil aerospace sector had an estimated turnover of €118.9 billion in 2023 (ASD, 2024).

The aerospace sector is being driven by the Transition Pathway for the Aerospace Ecosystem (EU, 2024), with the Clean Sky 2 R&D programme developing cleaner, quieter, and lower-emission aircraft technologies (Clean Aviation, 2025).

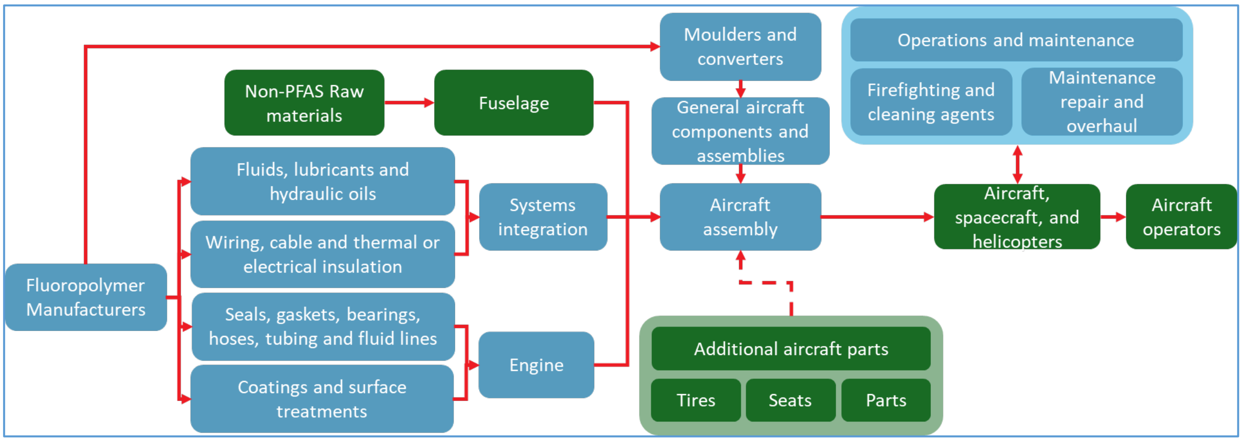
The sector has complex engineering requirements, due to the stringent safety and regulatory standards. Component failures can have severe consequences, and development cycles are therefore long and resource intensive. Aircraft have long service lives, requiring components that perform reliably over extended periods.

Research efforts typically focus on safety, reliability, and fuel efficiency. The need for consistent performance in extreme conditions and long service life has driven the sector's use of fluoropolymers.

Fluoropolymers are used in a wide range of aerospace components. While some final products may not contain fluoropolymers, they may have been manufactured using fluoropolymers or rely on parts made from fluoropolymers. Specific applications are discussed in Section 3.3.1.

The European aerospace supply chain is a highly complex and multi-tiered, characterised by deep integration across EU Member States. The 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.

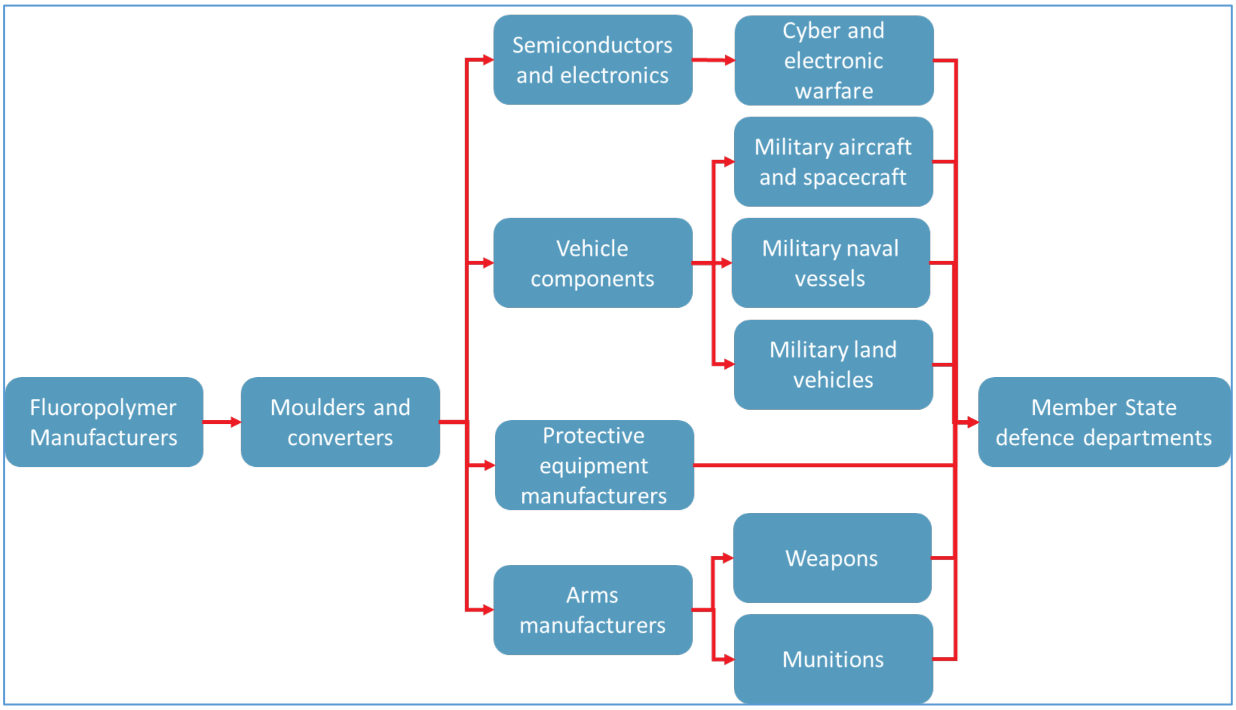
2.2.2. Defence

The defence sector comprises industries and Member State governments involved in developing, manufacturing, purchasing, and deploying military hardware. This includes 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. Combined EU Member State defence expenditure increased from €189 billion in 2014, to €343 billion in 2024 (Consilium, 2025).

Fluoropolymers are used in weaponry, ammunition, personal protective equipment (PPE) and military electrical systems. Fluoropolymer applications also occur in military aircraft, overlapping with the Aerospace strategic sector.

Defence applications are highly complex, with thousands to millions of interconnected components. Each application has its own development cycle but all require absolute reliability. Specific applications are discussed 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 includes technologies and products aimed at decarbonising European industry and consumer activity while maintaining energy security. Green energy includes wind, solar and other renewable energy sources. Clean technology includes hydrogen fuel cells for energy production or vehicles (hydrogen fuel cell vehicles or HFCVs), lithium-ion batteries for electric vehicles (EVs), and heat pumps for domestic heating and cooling. The definition of this sector was agreed with the European Parliament for this study and may differ from definitions used in other analyses.

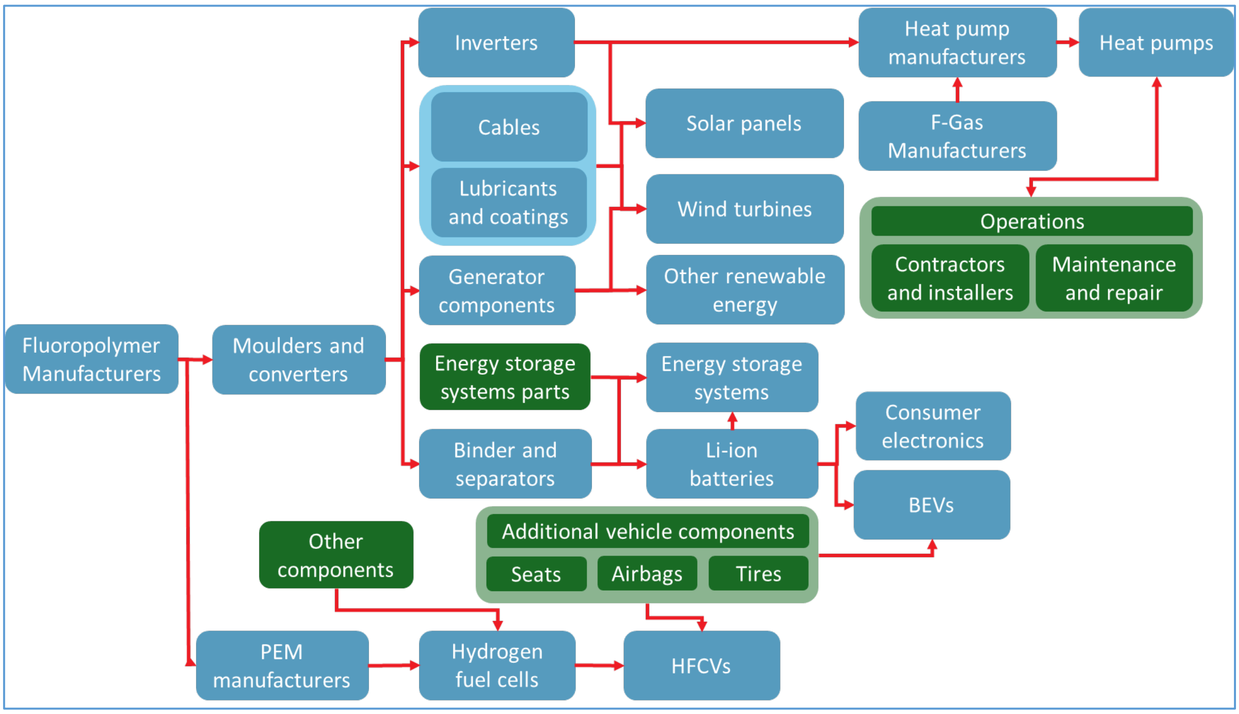
There is no single authoritative figure for the value of this sector due to the diversity of technologies and definitions. It is estimated that the global clean technology market had a market size of about $916.2 billion in 2024 (Grand View Research, n.d.). In 2023 the EU renewable energy industry outperformed the overall economy 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 strong 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 imports of solar PV and batteries, but a positive trade balance for wind and district heating. In 2022 the renewable energy sector employed around 1.7 million people across Europe.

Fluoropolymers and F-gases have become critical materials in many developing green technologies. For example, fluoropolymers are used in solar panels, wind turbines and all lithium-ion batteries currently on the market. Fluoropolymer proton exchange membranes (PEM) are essential for hydrogen fuel cells. Specific uses are discussed in Section 3.3.3.

The supply chain for this sector 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 essential components in energy storage systems.

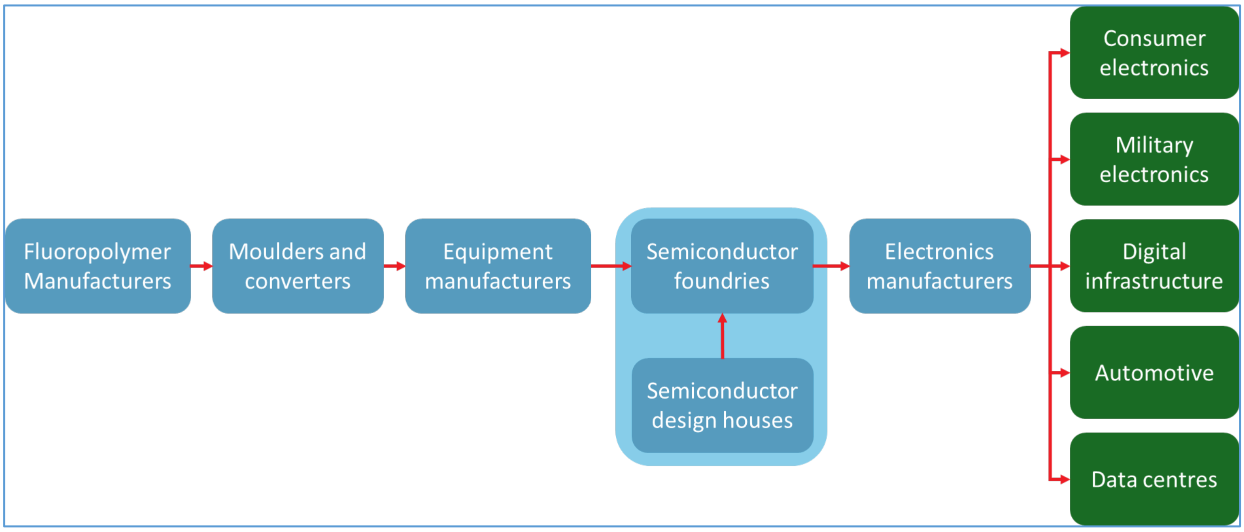
2.2.4. Semiconductors

The semiconductor sector underpins all modern electronics and the wider technology industry. European sales in 2022 were estimated at around €50 billion, with strong medium and long term growth expected (ERM, 2023). The exact value is difficult 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 semiconductor production.

The supply chain is presented below (Figure 6).

Fluoropolymers are required to prevent contamination throughout the manufacturing process. Semiconductor production requires sterile conditions, which strongly supports the use of fluoropolymers. Applications are discussed 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 emerging or experimental alternatives. This section presents an AoA for each strategic sector, using commonly cited alternatives. The list of alternatives is drawn from the authors' experience of PFAS AoAs since the start of the UPFAS Restriction process. The alternatives identified through this experience have been frequently investigated by industry in previous work and are therefore solutions that are currently available on the EU market. It is possible that wider alternatives are in development but have not yet reached the market. Industry often treats such developments as confidential. Because these alternatives cannot be verified through public data, they are not assessed in this study, although they may become relevant 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 profiles (Annex 5). These comparisons are contextualised against sector performance requirements to infer substitution potential. This approach allows broad coverage of multiple applications, but it lacks the nuance of application-specific AoAs. Some critical application-specific examples are presented, assessing technical feasibility and where 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 its reliance on literature data alone, the substitution potential identified should be seen as indicative and not a definitive conclusion.

Future consultation would help gather data on alternatives**.** Confirmation of substitution potential requires test data from industry R&D, which would require extensive consultation. Stakeholder consultation undertaken for this study was used to support the analysis wherever possible and highlighted the 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 some alternatives can replicate some fluoropolymer properties, few provide all the required characteristics. 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 examines possible alternatives defined by the authors as regularly considered alternatives, informed by previous experience working with PFAS data gathering and evaluation. Substitution poses challenges, and alternatives must be assessed case by case with full understanding of application requirements. In most cases, alternatives replicate only some fluoropolymer functionality, and few provide all beneficial properties. A selection of applications is examined further in Section 3.3.

Throughout these sections, data from the tables in Annex 5 are used to indicate whether alternatives perform comparably, better, or worse than fluoropolymers against each performance criterion. This is then contextualised within the specific end use to understand the inferred substitution potential. Conclusions on substitution potential should be treated as indicative and not as 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 (PE) (multiple grades)	Elasticity	Processability	High temperature resistance and flammability
Ultra-high molecular weight Polyetheylene (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 (PC) (Little available data)		Low temperature resistance	High temperature resistance
Polypropylene (PP)		Elasticity	Temperature resistance and flammability
Stainless steel (Solid fluoropolymer parts only – little available data)	Mechanical properties		
HNBR (FFKM/FKM only)		Low temperature resistance and elasticity	High temperature resistance
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 FKM/FFKM only is indicated in the possible alternative column, the comparison relates to fluoroelastomer uses only.

3.3. AoA findings and results

Box 5: RQ 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?*

This section provides an overview of the findings of the high level AoA. Information is organised by strategic sector to indicate the range of fluoropolymer applications, 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.

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 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)
- 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, indicating that there are potentially more fluoropolymer applications than those listed above. Therefore, the list should not be seen as exhaustive, as it is estimated that over one million individual components may contain fluoropolymers in a large aircraft (ECHA public consultation comment ID 7624). Consultation for this study with the European aerospace industry confirmed that thousands of components containing fluoropolymers are integrated within systems, subsystems and assemblies in this sector.

b. Substitution potential

Consultation for this study indicated that fluoropolymers are used at every level of the aerospace supply chain, meaning the substitution potential is highly variable within the sector and cannot be assessed for the sector as whole. Consultation also indicated that all components involved in the manufacture of an aircraft are considered critical, as failure of any single component may compromise reliability and safety. Industry stakeholders noted that fluoropolymers are relied upon for high specification, safe and reliable products and that in many cases there are no suitable alternatives that meet the demanding 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 also identified cases where redesign of equipment would be required, adding further time to the substitution process.

As the substitution potential of all applications of fluoropolymers within the aerospace sector cannot be assessed in 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 as electrical insulation coatings. The IAEG 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 also reported as widely used critical applications; however, this application was not selected as an example because performance requirements for coatings vary depending on where they are applied on the aircraft, making sector wide conclusions on substitution potential more challenging.

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 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 performing alternatives could increase the risk of failures during engine operation, which would be unacceptable from a safety perspective.

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, including potential impacts on the manufacture of aircraft components and systems, such as engines.

For wiring coating, some alternatives appear theoretically feasible, but further case by case analysis would be required to confirm the extent of substitution potential to avoid drawing inaccurate sector wide conclusions.

Overall, it is likely that the aerospace industry would not be able to substitute fluoropolymers with alternatives in the many applications required to manufacture 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 to apply 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)
- FFF – general (Conflict and environment observatory, 2025; Gaines, 2023)
- High performance membranes – general (IAEG, 2024)
- Military electronics - general (Conflict and environment observatory, 2025)
- Military technical clothing (PPE) - general (Henry *et al*, 2018)
- Munitions – general (Conflict and environment observatory, 2025; Gaines, 2023)

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

b. Substitution potential

Substitution potential has been investigated for munitions and decoy flares and shows variable results. These selected priority applications could not be informed by literature. Instead, the authors have drawn on previous experience and selected two applications known to relate to the protection of life and prevention of injury, munitions and decoy flares (Table 3-3). Both applications relate to the protection of human life and are therefore considered critical applications of PFAS.

In munitions, PFAS are used as binders in the explosive component to provide stability and reduce the risk of misfiring, including after long periods of storage. In decoy or countermeasure flares, PFAS are used in the explosive composition to recreate the heat signal of aircraft to misdirect heat seeking missiles, protecting aircraft and crew. Other applications are less well documented and are likely to be difficult to assess due to confidentiality 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 necessitates the use of an elastomeric compound. As such, all possible alternatives other than HNBR, SBR, Silicone and EPDM are not technically feasible. To be a technically feasible alternative, these substances would need to demonstrate 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 influenced by resistance to various factors, so comparisons are made for thermal, chemical and UV resistance to infer service life. In comparison to fluoropolymers, HNBR, SBR and EPDM have lower thermal resistance, whilst EPDM and Silicone also have relatively low fire resistance. SBR shows 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 is not available. 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 munitions, 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 present challenges should a fire occur in a munitions storage area. Considering economic and availability factors, no data was identified. Hazards and risks, however, can be considered. For HNBR, degradation of the polymer during ageing may produce corrosive residues which may damage the munitions, meaning it may not be a suitable alternative. For silicone materials, increased use would increase exposure to siloxanes and raise the risk profile relative to fluoropolymers, making silicone a regrettable substitution. For EPDM, no additional considerations are identified, and its risk profile is considered comparable to fluoropolymers. EPDM may therefore represent a possible substitution for fluoropolymers in munitions; although further assessment would be needed to confirm this conclusion.

Application	Substance	Performance criteria	Substitution potential
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 unique use of PFAS within the defence sector. These 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, substitution of PFAS in 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 is expected to vary, based on the examples presented in this report. From the authors' experience, sectors involving high specification equipment, such as defence, typically make extensive use of fluoropolymers due to their technical performance, including in applications that overlap with aerospace where substitution potential can be regarded as low.

Only a limited number of fluoropolymer applications are identified in the literature, and it is likely that many more exist, restricting the ability to fully assess criticality. In munitions, some alternatives appear potentially feasible, whereas in applications such as decoy flares the chemistry is designed around the current fluoropolymers and substitution appears unlikely to be feasible.

These examples illustrate the different situations the defence sector may face under a full PFAS restriction.

The scale of any market effects would depend on how many defence applications rely on PFAS for essential performance and whether technically viable alternatives exist.

The conclusions of this study should be viewed in light of the limitations outlined in Section 2.3.

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 technologies and applications that are expected or known to use fluoropolymers and F-gases.

The following 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)
- 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 PFAS outside the scope of this study. This reflects the wide range of applications in this sector and the potential for extensive numbers of specific applications, each with its own 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 technology sector. Examples of substitution potential in this sector have been selected based on the authors' experience of working with PFAS and consultation with industry on critical applications. The examples 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).

These applications were identified as critical to the functioning of the equipment. Lithium-ion batteries are important for the transition to green transportation and for energy storage, heat pumps are important for the transition to green infrastructure, and photovoltaic panels are a major investment area in green energy generation. Assessing these applications provides insight into how PFAS are used to support energy efficient infrastructure, low carbon energy generation and transport decarbonisation.

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/Moderate.** 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 by performance, application requirements and safety factors. 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. This makes substitution more feasible in industrial applications than residential. Reduced efficiency also means alternatives may not be technically feasible in all climate zones based on differences in average ambient temperatures. Heat pumps are 3–5 times more expensive than boilers, and added costs reduce viability. Propane also raises safety concerns due to flammability. Overall, substitution is currently feasible only for specific applications given economic, technical, and safety constraints of alternatives.

Application	Substances	Performance criteria	Substitution potential
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, substitution potential is expected to be highly variable. This strategic sector includes a significant number of fluoropolymers and F-gases, as identified in the literature review. These applications range from protective coatings to refrigerants and present a wide range of functional requirements for alternatives.

The sector also covers many subsectors, including Heating, Ventilation, and Air Conditioning (HVACR), energy generation, electronics, automotive and hydrogen technologies. Substitution is therefore likely to vary, as each subsector and application poses different performance requirements.

In the illustrative examples, none of the alternatives assessed appear suitable to replace PVDF as a cathode binder in lithium-ion batteries, whereas polymethyl methacrylate (PMMA) may be considered a possible technical alternative to ETFE in solar panel front and back sheet coatings. This indicates that while substitution may be feasible in some applications, it is not possible to draw a single conclusion on substitution potential for the sector as a whole and a more nuanced approach is required.

The example of F-gases used as refrigerants in heat pumps also indicates the level of nuance required. Consultation with industry for this study identified issues such as increased costs due to the need for higher pressure systems in an already challenging market situation. This leads to a different conclusion from 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.

For green energy and clean technology, substitution potential is therefore expected to be varied, and impacts may be significant for interconnected supply chains within the sector. Further research is needed on specific applications due to divergent findings, including for F-gases used in heat pumps.

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 all products in the semiconductor industry either contain or depend on fluoropolymers. It was noted that every semiconductor is manufactured with fluoropolymers in either the chip itself, in packaging, in manufacturing equipment or in other complimentary components.

Consultation also revealed applications not found in 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 - general (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)
- Wafer fabrication– FFKM (Plackovic and Walker, 2024; Barnwell, n.d.)
- Wafer surface treatment machines– FFKM (Plackovic and Walker, 2024)
- Vacuum pumps – general (consultation)

PVDF and F-gases are also used in unspecified semiconductor 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 that mentioned the use of ETFE or FEP in the semiconductor sector, however their use was reported by industry during consultation.

b. Substitution potential

Substitution potential varies depending on the specific PFAS application. However, all PFAS applications are involved in successful semiconductors production, making them all effectively critical, as the inability to substitute one application can prevent manufacture. Consultation identified many applications for PFAS, both fluoropolymers and F-gases. A large number were described as essential to manufacture, and several critical applications were selected for more detailed consideration. The examples presented in Table 3-5 relate to ultrapure water piping systems and photoresists and were selected based on previous experience of the authors in this sector. This selection was substantiated in stakeholder discussions during consultation and provides justification for examining these two applications further.

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 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 the 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 lower 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 were identified 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 be considered viable alternatives. 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, particularly concerning 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 potential replacements for topcoats applied in the lithography process.

Source: Authors' own elaboration.

c. Key conclusions

The semiconductor industry uses PFAS extensively throughout semiconductor manufacturing. Although semiconductors appear as a single product type, they are highly specialised for different end uses, creating variation in design and manufacturing equipment. PFAS are used both in the semiconductors themselves and in the processing equipment, largely due to the demanding extreme conditions required to manufacture semiconductors that meet modern performance expectations.

The illustrative examples of ultrapure water systems and topcoats for photoresists in lithography represent two critical applications. In the first example, PEEK is theoretically able to provide the desired properties for substitution into ultrapure water systems. However, as no suitable alternatives were identified for photoresist topcoats, semiconductor manufacturing would still not be possible. This reflects the industry's dependence on multiple PFAS applications and shows that substitution in one application does not remove impacts for the industry.

The AoA therefore indicates that the semiconductor industry would likely not be able to substitute PFAS across all required applications and 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

An SEA helps 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 be used to determine whether a certain action is justified by applying use scenarios and analysing the impacts under each one. The SEA process is strengthened by combining information identified in the AoA. If there are very few or no viable alternatives to PFAS for a sector or group of industrial uses, economic costs will be expected to be higher compared with situations where 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 assessment of 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 chains. The supply chains for the strategic sectors assessed by this SEA are presented 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 values presented in this section are linked to company profits 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 receive less income from employers while social security and welfare costs increase. Quantified damages to human health and the environment are the typical elements that the previous two cost factors are compared against.

Exposure to some PFAS groups such as PFOA, PFOS, 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 (Boyd, Ahmad, Singh, Fazal, Prins, Madak Erdogan, Irudayaraj, Spinella, 2022). However, to date minimal research has been conducted into possible health effects arising from exposure to the in-scope fluoropolymers as distinct from these other PFAS groups. At present there are no known human health effects arising from exposure to these fluoropolymers.

This does not imply that fluoropolymers are safe for use but reflects that any possible human health effects are not currently known due to insufficient scientific data and research.

Likewise, while fluoropolymers are very persistent in the environment, a specific quantifiable environmental damage arising from their presence has not been identified from research. Therefore, due to limited research, there are currently no known environmental damages identified from fluoropolymer emissions. As a result, neither human health nor environmental damage quantification can take place.

As outlined below, the study team has 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 in updating the Restriction Dossier, specifically Annex E.

The low market share assumption model involves identifying relevant PRODCOM codes in Eurostat which relate to fluoropolymer products and applications identified by the AoA. The public PRODCOM data allow statistics on EU wide production, importation and exportation of products to be extracted. Similarly, identifying relevant PRODCOM codes allows relevant sectoral NACE codes to be identified, which allow for public statistics on the number of enterprises, employees, turnovers, SME distributions, average salaries, and average operating margins. However, these codes include companies and products not related to fluoropolymers; therefore, market share assumptions must be made to derive value estimates.

Because of the wide range of applications associated with fluoropolymers in these sectors, it has not been possible to identify a fluoropolymer market share for every application or product. Therefore, this assessment assumes a very low market share value for fluoropolymers to derive an indicative socio-economic impact estimate. Where a more specific market share could not be identified or deduced, a market share value of 1% has been applied. This value is assumptive and is used to demonstrate a low market share and establish conformity between this assessment and the Dossier Submitters' assessments, which also used a 1% market share assumption. Given that fluoropolymers are typically specialty products used for specific properties, as identified in the AoA, the study team considers the low market share assumption appropriate.

The 1% market share was first applied to all identified NACE and PRODCOM codes in each sector as standard. However, some codes were identified to have market shares related to fluoropolymers much higher than 1%. Some product categories were found to be fully, or nearly fully, connected to fluoropolymers, and market shares greater than 1% were applied in those cases. This is explained in each sector's results discussion below. It should be noted that due to the use of the NACE and PRODCOM databases, all the data used for this assessment have been sourced from Eurostat.

The principle of this approach is to establish indicative evidence as to the possible scale of cost from a regulatory decision. If the economic impacts calculated using low market shares are already high, there is evidence that the true impact of a regulatory decision would also be high or very high. Therefore, the presented results are indicative only, meaning that true impacts may be higher.

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 are the profits from businesses operating and selling products. Employment will also continue; however, the economic 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, and benefits being human health savings and environmental savings. However, as no human health or environmental assessment can be conducted due to the unknown effects of fluoropolymers, the benefits under the non-use scenarios are assumed to be zero.

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 substitution potential of the in scope critical sectors, this analysis has assumed that all sectors would not be able to substitute fluoropolymers within a 13.5-year period (12-year derogation plus the 18-month transition period). Therefore, the impacts under RO2 are set equal to those estimated under RO1. There are some exceptions to this which are explained in sector specific discussions below.

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 broad sector description which encompasses a large range of applications and technologies with different derogation recommendations. Therefore, 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 that RO2 impacts are 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

The indicative estimates produced for the aerospace industry do not account for impacts on airline and air freight operators, only component and aircraft manufacturers. As illustrated in Figure 3, the aerospace supply chain is highly complex and consists of many suppliers and manufacturers culminating in the manufacture and then operation of civil aircraft. A total of 71 PRODCOM codes and 21 NACE codes were identified by the study team, although more may exist, with the list presented in Annex 2. The identified codes cover 10 supply chain segments, including products made from or using fluoropolymers and products which do not contain fluoropolymers but depend on them via the wider supply chain (for example aircraft seats contain no fluoropolymers yet rely on demand generated by the rest of the chain. 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, the associated codes contain many unrelated products in PRODCOM, therefore the low market share of 1% has been applied.

From the AoA and the study team's prior experience, it is understood that 100% of downstream products, such as aircraft engines and complete aircraft, either contain or rely on fluoropolymers. For NACE and PRODCOM codes relating to these downstream products, a 100% market share has therefore been applied. The results of the indicative economic impact analysis by regulatory option and supply chain segment are presented in Table 4-1 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

Supply chain segment	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
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 benefits of €12.5 billion per year. After accounting for industry average profit margins, incomplete capture of applications in PRODCOM, uncertain true market shares, and the exclusion of airline and airfreight operators, this value could be underestimated by a factor of 10 or more. As RO3 effectively represents continued use, the benefits under this option are at least €12.5 billion.

The total cost under RO1 (a full PFAS ban) and RO2 (a ban with 12-year derogation) for 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. Due to the low substitutability of fluoropolymers across the aerospace industry, RO1 and RO2 would result in cessation of the market. An estimated minimum of nearly 4,500 business would close with 97% of these being micro, small, or medium businesses and 71% micro alone. The SEA indicative model estimates a minimum of nearly 440,000 people employed within industries connected to the aerospace sector. Due to the low substitutability identified in the AoA, business closure is considered the most likely industry response under both RO1 and RO2, and it is assumed that 100% of the employees in this sector would be made unemployed.

These unemployment costs would occur only in the first year after entry into force of the restriction. The socio-economic cost experienced in the first year and subsequent years would be the value of lost industry profits, valued at €12.5 billion per year. 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 the longer transition period would allow non-PFAS related component manufacturers to secure export business. It is assumed this will not occur under RO1.

4.2.2. Defence

Unfortunately, due to the confidentiality of the defence sector, an indictive cost assessment cannot be conducted. European defence spending in 2024 reached €343 billion, equivalent to 1.9% of EU Member States GDP, and this is expected to rise to 2.1% in 2025 (Consilium, 2025). The defence industry 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 domains. In the same year, the sector was estimated to employ over 581,000 people with more than 2,500 SMEs operating in the European defence industry.

Given the interconnectivity of the aerospace and semiconductor sectors with the defence sector, it can be reasonably assumed that the defence sector would be significantly affected by a fluoropolymer restriction, including major employment losses. The economic costs to the EU and EEA arising from such a restriction could be substantial. In times of increasing geopolitical tension, minimising risks to defence supply chains is paramount.

4.2.3. Green energy and clean technology

The green energy and clean technology sector encompasses 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, a 1% market share has been applied; however, for fuel cell, solar panel, and battery related applications, a 100% market share has been applied (see rationale in Section 4.2). Similarly, for fuel cells and lithium-ion batteries, their downstream automotive applications have been assigned a 100% market share.

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.

Under the continued use scenario and RO3, the sector is estimated to contribute €22.3 billion annually. Many green technologies are still emerging, and the automotive industry is transitioning to electric vehicles, so long term economic benefits may be substantially higher.

As with the aerospace and defence sectors the currently understood low substitutability of fluoropolymers means that a fluoropolymer restriction under RO1 or RO2 would likely result in significant economic damage as businesses close and withdraw from the market. Indicative estimates suggest that over 12,500 businesses would close, the vast majority SMEs, and nearly 2 million people would become unemployed. This results in indicative first year cost estimates of €354 billion and €353 billion for RO1 and RO2 respectively. The slightly lower RO2 value reflects the assumption that exporters would have time to secure their export business under a longer transition period; this is not assumed under RO1. The total cost of unemployment is estimated at a minimum of €332 billion for the social cost of unemployment and €32.1 billion for the social security cost under both ROs.

These unemployment costs would occur only in the first year after entry into force. The socio-economic cost experienced in the first year and subsequent years would be the value of lost industry profits, valued at €22.3 billion per year. 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, a fluoropolymer ban would also result in substantial lost potential, as for example, fluoropolymers have been key enablers in the green hydrogen economy. Restricting fluoropolymers would close new markets and prevent the development of new green technologies, placing the EU and EEA at a global disadvantage in green technology and undermining ambitions for a green industrial transition under initiatives such as the Green Deal.

4.2.4. Semiconductors

Semiconductors are an essential component of modern technology, from consumer electronics to data centres. A total of 42 PRODCOM codes and 11 NACE codes across 3 supply chain segments were identified, covering the manufacture of semiconductor equipment, semiconductors themselves, and electronic items using semiconductors. Due to the broad nature of semiconductor applications, a full-scale impact assessment would require substantially more time and methodological development, as the value of digital services, data centres, and AI, all of which depend on semiconductors, would also need to be captured.

The results of the indicative economic impact analysis by regulatory option and supply chain segment are presented in Table 4-3 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

Under a continued use scenario, the semiconductor sector and related electronics manufacturing are estimated to generate at minimum, annual benefits of €38 billion. These benefits reflect only the manufacture and sale of semiconductors and electronic devices and do not account for digital services or productivity gains enabled by semiconductors.

In the event of a fluoropolymer restriction, the semiconductor industry would cease to operate in the EU and EEA, and semiconductors and electronic devices could not be imported, which, based on the identified codes and model assumptions, would produce first year economic costs of at least €109 billion. Once accounting for the wider digital economy, a ban on fluoropolymers and the subsequent loss of semiconductors has been estimated to reduce the size of the European economy by 50% (SEMI, 2020), which, based on the 2024 GDP value, could result in economic costs of nearly €9 trillion.

An estimated minimum of nearly 22,000 enterprises would close, 98% of these being SMEs, and around 500,000 employees would lose their jobs. This results in indicative first year cost estimates of €109 billion for both RO1 and RO2. The values are the same as it is assumed that even under RO2 there would not be sufficient time for the semiconductor industry to transition away from PFAS. The total cost of 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 under both ROs.

These unemployment costs would occur only in the first year after entry into force. The socio-economic cost that will be experienced in the first year and subsequent years would be the value of lost industry profits, estimated at €38 billion per year.

4.3. Summary of findings

The socio-economic assessment conducted for this study 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. These ranged from no regulatory change (the continued use scenario) to a full ban on PFAS (RO1) and included options with derogation periods (12 years under RO2 and time unlimited under RO3).

Using the supply chain maps presented in Section 2.2, PRODCOM and subsequent NACE codes were identified for each supply chain node. These codes were used to collect statistics on domestic production, earnings, profitability, number of enterprises, number of employees, average salaries, and SME distribution. Applying a 1% low market share assumption and higher percentages where more of a market is known to rely on fluoropolymers allowed indicative impact estimates for each regulatory option to be derived. The results of the SEA are 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, RO3 (time unlimited derogations for these critical sectors), is the least damaging to the economy and society. RO3 is effectively equivalent to continued use in the short term, with strategic sectors seeing little to no disruption to PFAS access which, as highlighted in the AoA, is often essential. Under RO3, the European economy would benefit from a minimum annual contribution of €72.8 billion.

In contrast, the European economy and society would be significantly impacted under both RO1 (a full PFAS ban) and RO2 (a full PFAS ban with a 12-year derogation). RO1 is the most damaging regulatory option, with first year minimum costs of €562.8 billion, and with recuring annual costs of €72.8 billion. Under RO2, these costs are marginally reduced, with first year costs of €561.7 billion and recurring annual costs of €71.7 billion. The slight reduction under RO2 reflects the assumption that some manufacturers and exporters of non-fluoropolymer products will have time to stabilise and secure export business.

For example, an aircraft seat manufacturer would still be permitted to manufacture their goods as they do not contain PFAS or fluoropolymer sand although domestic demand would cease under RO2 because manufacturing aircraft would be impossible, they could still export seats globally. However, due to the low substitutability of fluoropolymers and the interdependencies outlined in the AoA, overall economic impacts under RO2 remain very close to RO1.

In addition to quantified economic damages arising from lost output and unemployment, the SEA also indicatively quantified the possible scale of business closures and job losses that each regulatory option may incur. These results 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 secure their export businesses for non-fluoropolymer products, however due to public data constraints it cannot be accurately determined what scale of job loss or business closure reduction this may have, this impact reduction is not expected to be significant.
Results under RO3 are marked with an asterisk to represent the possibility that while a time unlimited derogation on in-scope sectors should not result in business closure or job losses, it cannot be guaranteed that some may occur. There remains a possibility that disruption to other sectors could have knock on or negative multiplier effects which could cause some unintentional job loses or business closures in the in-scope sectors.

Under RO1, over 39,000 European companies, based on a low market share impact estimate, are expected to close, affecting over 2.9 million jobs. Under RO2, some businesses may continue to operate through export markets, but public data limitations prevent accurate estimation of the scale of this reduction. It is not expected to be substantial.

Under RO3, very few business closures or job losses are estimated to occur. It cannot be ruled out, however, that some loses may occur due to wider or other supply chain disruptions.

5. EUROPEAN COMPETITIVENESS IMPACT ASSESSMENT

5.1. Overview of approach

The current regulatory frameworks 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 for comparison 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), headquartered 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 identify regulations in the countries and regions of interest. The search results were then screened for relevance, with Member State and US State regulations 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 5-4 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 to 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 5-8 to Table 5-11.

5.2. Identified legislative landscape of PFAS in selected third countries

The full results of the regulatory review for PFAS in select third countries are presented in Annex 3. Below is a summary of the PFAS regulatory landscape (Section 5.2.1), regulation of F-gases in the EU (Section 5.2.2), the potential impact of the proposed UPFAS Restriction on competitiveness in the context of existing regulatory frameworks (Section 5.2.3) and future restrictions on PFAS (Section 5.2.4). The regulatory landscape is then 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 perfluorocarboxylic acids (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 FFF (China, Japan, and US airports), and activities related to R&D 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 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 (unless they are derived from registered monomers), but not necessarily from authorisation or restriction (ECHA, 2023d). Monomers must be registered under REACH if they meet certain criteria (ECHA, 2021). The proposed EU UPFAS 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 Persistent Organic Pollutant (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 related compounds were added to Annex A in 2022 (UNEP, 2025a); and 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 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.

The regulation introduces 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 UPFAS Restriction on competitiveness in the context of other existing regulatory frameworks

The proposed UPFAS Restriction is more comprehensive compared to other regions, although some derogations have been proposed (see Table 5-4 to Table 5-7). 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 the UPFAS Restriction. 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 important point is how 'polymers of low concern' (PLCs), including fluoropolymers, are defined and exempted from regulation in different jurisdictions. The OECD explored PLC criteria in the 1990s and 2000s but did not reach agreement (Oziel, 2024), so countries set their own criteria. In Australia, Japan, South Korea and the US, PLCs are exempt from certain regulatory requirements (Table 5-1). Under the proposed EU UPFAS Restriction, there is no equivalent exemption for PLC fluoropolymers. Therefore, these countries could become more attractive to companies wishing to continue to manufacture or use fluoropolymers. Under EU REACH polymers are exempt from registration and evaluation, but some remain 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 PLC, for R&D substances, or for export-only uses.	South Korea
Manufacture and distribution of 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

Several reviews of potential PFAS restrictions and future measures are scheduled globally, although exact timelines are not yet confirmed (Table **5-2**). These developments show that regulatory agencies worldwide are continuing to reviewing PFAS and tighten regulatory regimes. ECHA announced on 30 October 2025 that the final decision on the EU UPFAS Restriction is expected to be made by the European Commission and Member States in early 2027. The latest timeline at the time of writing for adopting the UPFAS Restriction in the EU and EEA is outlined in Table 5-3.

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 FFF could lead to future restriction. Evidence on the use of PFAS in coatings and cleaning agents could lead to future restriction. Evidence for 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)[5] 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 FFF.	Canada
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
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; and public and private drinking water systems and treatment facilities.	US
TBC	UK REACH Annex XVII Restrictions proposed – use of PFAS in FFF	UK

5 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	Placing an unsafe product on the market is a criminal offence under the General Product Safety Regulations (GPSR) 2005. 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 on 22 April 2025.

Table 5-3: Latest timeline for EU UPFAS restriction process (as announced 30 October 2025 by ECHA).

Date	Regulatory step
Jan 2023	Restriction proposed by five countries (Netherlands, Germany, Denmark, Sweden, and Norway)
Mar – Sep 2023	Consultation on proposal
Jun 2025	Update of proposed restriction: • Assessment of 8 additional sectors of use (printing, sealing, machinery, other medical, military, explosives, technical textiles, broader industrial uses) • Proposal to implement measures to control risks
Autumn -winter 2025	Evaluation by ECHA's Committees: Committee for Risk Assessment (RAC) and Committee for Socio-Economic Analysis (SEAC)
Mar 2026	RAC and SEAC evaluation expected to conclude: • Adoption of RAC opinion (end of RAC process) • Agreement of SEAC draft opinion
Spring 2026	Launch of SEAC draft opinion consultation
Nov/Dec 2026	Expected adoption of SEAC opinion
Dec 2026	Expected combining of RAC and SEAC opinions into one and submission to European Commission
Early 2027	Decision by European Commission and EU Member States

Source: ECHA (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 5-4: 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 FFF at airports.	US

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

Table 5-5: 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 5-6	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 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 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 CERCLA, also known as 'Superfund'.	US

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

Table 5-7: 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 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

The competitiveness assessment brings together the results from the AoA, SEA, regulatory review and stakeholder interviews. As the assessment considers the likely impacts of different policy options on industry, stakeholder consultation is particularly important and has been triangulated with the other analyses where possible. A qualitative analysis of the impacts on SMEs has been drawn from the SEA. The findings are presented in tables for each strategic sector (Table 5-8 to Table 5-11). The policy scenarios are shown on the X axis:

0. Continued use scenario (no regulatory change is implemented)
1. RO1, a full ban on PFAS
2. RO2, a ban with use-specific (mainly) time limited derogations
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
- International competitiveness

These findings are indicative, as the underlying qualitative and quantitative data is limited, as explained in Section 1.3. Some tables therefore contain gaps. In the below write up, the term 'industry' is often used to reflect stakeholder consultation feedback.

For all strategic sectors, the chemicals industry often represents the top of the supply chain and may be impacted by both any loss of PFAS manufacturing capacity and by impacts on downstream chemical products that rely on PFAS based supply chains.

5.3.1. Aerospace

Table 5-8: 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[6] 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 entire supply chain may lose**	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.**

6 In this write up, the term 'industry' is often used to reflect stakeholder consultation feedback.

	Continued use	RO1	RO2	RO3
		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 competitiveness	No impact.	The AoA and SEA indicate that due to low substitution potential, many aerospace SMEs would close under RO1 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.	No impact.
Cost competitiveness	The AoA identified that some alternatives to fluoropolymers, e.g. PMMA, are low-cost and readily available. Others, e.g. silicone, pose risk concerns that could lead to regrettable substitution.	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
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 5-4).	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 5-9: 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; FFF; 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. 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	ECHA has recommended various derogations for this sector as a whole, for defence applications, for explosives and for military PPE (Table 5-5). **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
		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 competitiveness	No impact.	Unknown.	Unknown.	No impact.
Cost competitiveness	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.		
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.			

	Continued use	RO1	RO2	RO3
International competitiveness	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 5-10: 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, 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.**	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 5-6). **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. The necessary redesign for heat pumps to use alternatives would take an unknown amount of time, so even if they had been	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
		Like defence, **this sector relies on multiple supply chains, with impacts varying by substitution potential and upstream dependencies**.	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
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.

	Continued use	RO1	RO2	RO3
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 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.	Industry warns EU PV production would be at risk if PFAS rules are stricter than 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 the EU and EEA would also stop or move abroad, as alternatives like propane remain unsafe and impractical.	Industry says a derogation is needed for PFAS used in PV module production to avoid 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 5-11: 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 the EU and EEA 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 demand for other associated chemical products.	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 5-7), 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 technically feasible and little will change in this timeframe.	More feasible, see below.
Stakeholder consultation inputs	According to the semiconductor industry, every sector of the economy depends on semiconductors; any systems	Industry says removing PFAS from semiconductors would set the economy back to the 1970s. PFAS are used in about 60% of	The impact remains significant as few alternatives exist and development takes time, for example heat transfer fluids may	This option is more feasible, but some alternatives may take over 50 years to develop according to industry. Alternatives must be

	Continued use	RO1	RO2	RO3
	containing a battery and industry in the broadest sense use semiconductors.	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.	need 5–8 years according to industry. For semiconductors, many applications lack substitutes, and some may take over 50 years to replace.	qualified and adapted to high-precision, high-volume semiconductor production, which takes time.
SME competitiveness	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 productivity and competitiveness for SMEs across nearly all industries.	The lack of alternatives identified by the AoA and long development time in this industry, indicate the SME impacts under RO2 are would be the same as RO1. The SEA indicates that business closures would occur.	No impact
Cost competitiveness		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 competitiveness	No impact.	Industry 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

This scoping study examined the complex trade-offs between environmental regulation of PFAS, industrial competitiveness and technological innovation. The conclusions are based on evidence gathered during the AoA, SEA, regulatory review and competitiveness assessment for the four strategic sectors within scope.

Environmental and human health impacts could not be quantified due to the lack of published studies on the in-scope fluoropolymers. All findings should therefore be interpreted in light of the limitations outlined in Section 1.3. True costs or impacts may be significantly higher, as the assessments outlined in this study are indicative and intentionally conservative.

6.1. Conclusions from the AoA

The AoA, indicates low to variable substitution potential across the four strategic sectors, reflecting the complexity of supply chains and the specific performance requirements of each application. The indicative findings of the AoA are summarised in Table 6-1 followed by summary of the substitution potential in each sector.

Table 6-1: Summary of the indicative AoA presented in Section 3.3.

Strategic sector	Application	Substitution potential	Justification
Aerospace (Section 3.3.1)	Engine sealings	Low	Alternatives do not meet required technical performance.
	Wiring coatings	Moderate	Most alternatives do not meet required technical performance. Further information is required to assess technical, economic, market and hazard and risk factors of PMMA and PVC.
Defence (Section 3.3.2)	Binder in munitions	Low/ Moderate	Most alternatives do not meet required technical performance. More information is required to assess economic, market, hazard and risk factors of EPDM.
	Decoy flares	Low	Alternatives do not meet required technical performance.
Green energy and clean technology (Section 3.3.3)	Coating of front and backsheets for photovoltaic panels	Moderate	PFAS free alternatives are available but have reduced durability. Substitution in applications requiring high durability may not be possible.
	F-gas refrigerants in heat pumps	Low/ Moderate	Alternatives face technical, economic and safety constraints. Feasibility varies by application.

Strategic sector	Application	Substitution potential	Justification
	Cathode binders in Li-Ion batteries	Low	Alternatives do not meet required technical performance.
Semiconductors (Section 3.3.4)	Ultra-pure water piping	Low/ Moderate	Most alternatives do not meet required technical performance. More information required to assess economic, market and hazard and risk factors of PEEK.
	Topcoats in photoresists during lithography	Low	Alternatives do not meet required technical performance.

Summary of the substitution potential in each in scope sector:

- **Aerospace**: **Substitution potential for the sector is considered low** (Section 3.3.1). PFAS are integral to many safety critical components and are present throughout aerospace supply chains, with certain applications, such as engine seals, having no feasible alternatives. Lengthy transition times are expected due to stringent testing and certification requirements. The interdependence of components and the large number of PFAS based products across the supply chain further limit the sectors' ability to substitute.
- **Defence**: Available evidence is limited. Some theoretical alternatives such as for munitions binders may be feasible, but many high-specification applications, including decoy flares, are unlikely to be substitutable (Section 3.3.2). **Substitution potential for the sector is largely unknown and expected to vary** depending on the specific performance requirements of each PFAS application**.**
- **Green energy and Clean Technology**: PFAS-free options are available for solar panels; industry sources indicate that full substitution of PFAS for batteries and inverters (which solar panels and batteries rely upon) is not feasible at present. Heat pump refrigerants present further challenges due to efficiency, safety and necessary redesigns. **Substitution potential for the sector is considered variable** and is dependent on the specific product requirements of each PFAS application (Section 3.3.3).
- **Semiconductor Industry**: Manufacturing processes are complex and rely heavily on or produce PFAS based components. Alternatives are not yet available for a large number of applications, and the interdependence of PFAS throughout the supply chain means that **substitution potential is considered low for the sector.** Only limited applications may be substitutable (Section 3.3.4).

While substitution may be feasible for certain specific applications, the widespread replacement of PFAS across all strategic sectors is likely to face significant challenges. Many current alternatives do not match the high-performance requirements of applications.

Research and innovation efforts are ongoing and may develop viable PFAS alternatives and improve the adaptability of supply chains. Collaboration between industry, academia, and regulatory bodies may yield incremental advances. However, widespread substitution will require considerable time, testing and investment. As such, policy frameworks and support mechanisms could play a crucial role in facilitating the transition to alternatives for affected sectors.

6.2. Conclusions from the SEA

The SEA assessed the aerospace, green energy and clean technology, and semiconductor sectors in detail. Using a low market share assumption, these sectors are estimated to comprise around 39,000 enterprises and over 2.9 million employees connected to fluoropolymers. SMEs represent about 90% of the enterprises connected to or reliant upon fluoropolymers. The low market share model estimates minimum annual benefits of continued PFAS use in the sum of these sectors to be €72.8 billion (Table 6-2). The total indicative socio-economic impacts by regulatory option are summarised below.

Table 6-2: Indicative socio-economic impacts to in-scope sectors by regulatory option

Sector in-scope	Continued use (€ millions)	RO1 (€ millions)	RO2 (€ millions)	RO3 (€ millions)
Aerospace (see Section 4.2.1)	+12,500	-99,800	-99,700	+12,500
Defence (see Section 4.2.2)	n/a	n/a	n/a	n/a
Green energy and clean technology (see Section 4.2.3)	+22,300	-354,000	-353,000	+22,300
Semiconductors (see Section 4.2.4)	+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.

RO1 is the most damaging regulatory option, with first year minimum costs of €562.8 billion, and with recuring annual costs of €72.8 billion. Under RO2, these costs are marginally reduced, with first year costs of €561.7 billion and recurring annual costs of €71.7 billion. The slight reduction under RO2 reflects the assumption that some manufacturers and exporters of non-fluoropolymer products will have time to stabilise and secure export business.

The implications of the SEA findings for each sector are as follows:

- **Aerospace:** Under RO1, the sector would face severe negative impacts, including widespread business closure and significant job losses. These impacts are somewhat mitigated under RO2 as some companies may maintain export businesses, but this would not offset the broader disruption. Therefore, the above regulatory options indicate that a PFAS ban would greatly impact aircraft and passenger safety and the ability for aircraft to operate within Europe (see Section 4.2.1).
- **Defence**: A ban would disrupt production, servicing, and supply chains, with serious consequences for EU and national defence capability. Although a SEA could not be conducted due to data confidentiality, considerable overlap with critical civilian applications, such as semiconductors for computers and engines in aircraft, indicates that a PFAS ban would undermine European and national security due to supply chain disruption which would be challenging at a time of heightened geopolitical tensions (see Section 4.2.2).
- **Green energy and clean technology**: Innovation in this sector often depends on fluoropolymers. A ban, under RO1 and RO2, could stifle early technology development and uptake, weaken EU innovation and competitiveness and hinder delivery of EU Green Deal and Fit-for-55 objectives. The impacts would have a disproportionate impact on emerging technologies, such as green hydrogen which would worsen the estimated financial impacts under RO1 and the slightly mitigated damages under RO2 (see Section 4.2.3).
- **Semiconductor industry**: A ban, under RO1 and RO2, would impact the entire sector and generate far reaching downstream impacts across the European economy. As semiconductors are used in almost all modern technologies, any disruption would stall the digital economy within Europe and impede progress towards both green and digital transitions. Unlike other assessed sectors the semiconductor industry is not expected to see its estimated costs and impacts be partially mitigated under RO2 compared to RO1 (see Section 4.2.4).

The SEA therefore concludes that a full PFAS ban in these strategically important sectors would result in substantial economic disruption. SMEs, constituting most of the affected enterprises, are particularly vulnerable to these shocks, potentially leading to job losses and a reduction in the EU's technological edge. Over 35,000 SMEs could be affected by a full PFAS ban. Many would need to invest heavily in re-engineering products or processes and/or reorganising supply chains to adopt alternatives, making them less competitive than non-EU competitors that continue to use PFAS.

6.3. Conclusions from the European competitiveness impact assessment

The proposed European restriction on PFAS is more comprehensive than regulatory regimes in other regions, although some derogations have been proposed by ECHA. Companies wishing to continue manufacturing or using fluoropolymers may find relocation to countries with weaker PFAS regulation more attractive. This includes jurisdictions where polymers of low concern (PLCs which include fluoropolymers, although the definition varies by country) are exempt from regulatory requirements. As a result, the economic consequences of a PFAS ban could extend beyond immediate financial losses, affecting investment decisions and European competitiveness.

On the other hand, global regulatory trends are increasingly restrictive, and global chemical companies are being advised by investors to phase out PFAS voluntarily. Therefore, the EU and EEA could fall behind if they do not support progress on PFAS alternatives. Effective policymaking will therefore require ongoing monitoring of international regulatory developments and careful comparison with the evolving EU context to understand their implications for the EU and EEA's industrial position and competitiveness.

6.4. Recommendations

6.4.1. General recommendations

There is a need for nuanced, sector-specific and application-specific approaches rather than blanket restrictions, recognising both the essential role PFAS play in the four strategic sectors in scope and the ongoing efforts to identify and develop viable alternatives.

Two key non-sector specific, cross-cutting recommendations from this scoping study are to:

- **Prioritise and fund research on fluoropolymers**: While some PFAS are known or suspected human carcinogens, this cannot be assumed for all PFAS. Commissioning studies on the six common fluoropolymers should be a high priority, as findings could justify exemptions under the UPFAS restriction if minimal risk is demonstrated. Studies should also be commissioned to better understand aircraft decommissioning processes and PFAS emissions at end-of-life, with recommendations for improved monitoring, abatement and remediation of emissions.
- **Support innovation in PFAS abatement and remediation**: Beyond regulatory restrictions, the EU should explore establishing an EU-level innovation and investment fund, to accelerate the development of technologies that prevent PFAS emissions or remove PFAS from end-of-life technologies or products. This approach could achieve environmental and health goals while maintaining industrial competitiveness. Any such framework should align with EU environmental principles such as pollution prevention, precaution, and polluter pays to ensure sustainable and responsible implementation. Since existing technologies to remove PFAS from wastewater are expensive, investing in these technologies is advantageous if further research finds significant negative health or environmental effects for fluoropolymers and PFAS in general.

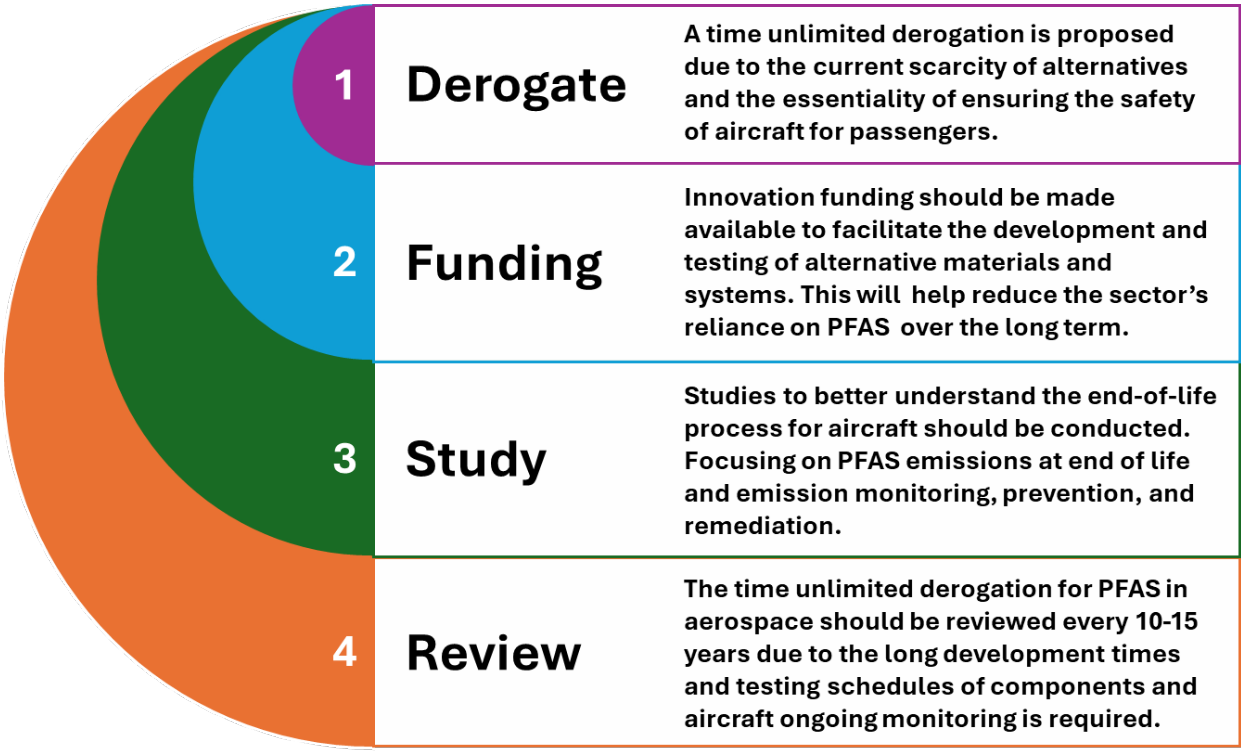
6.4.2. Sector specific recommendations

The sector-specific recommendations from this scoping study are summarised below.

a. Recommendations for aerospace

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. The diagram below provides a step-by-step guide to the proposed recommendations for the sector, showing the interlinkages between the various steps and proposals.

Figure 11: Proposed recommendations for the aerospace sector

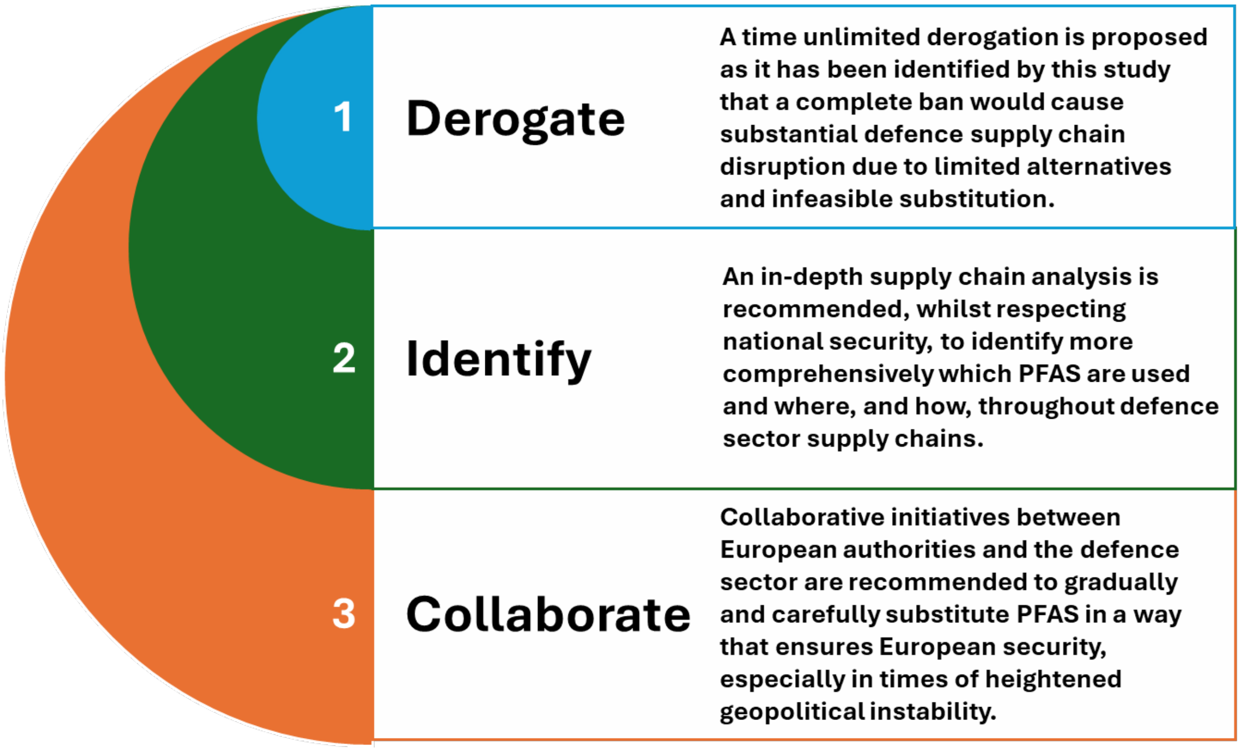


Source: Authors' own elaboration.

b. Recommendations for defence

A time unlimited derogation for the defence sector, due to growing global geopolitical insecurity and the possibility for substantial disruption to supply chains. An in-depth analysis is recommended, whilst respecting national security, to identify more comprehensively which PFAS are used and where throughout the defence sector. Following this study, collaborative initiatives between European authorities and the defence sector are recommended to gradually and carefully substitute PFAS in a way that ensures European security. The diagram below provides a step-by-step guide to the proposed recommendations for the sector, showing the interlinkages between the various steps and proposals.

Figure 12: Proposed recommendations for the defence sector



Source: Authors' own elaboration.

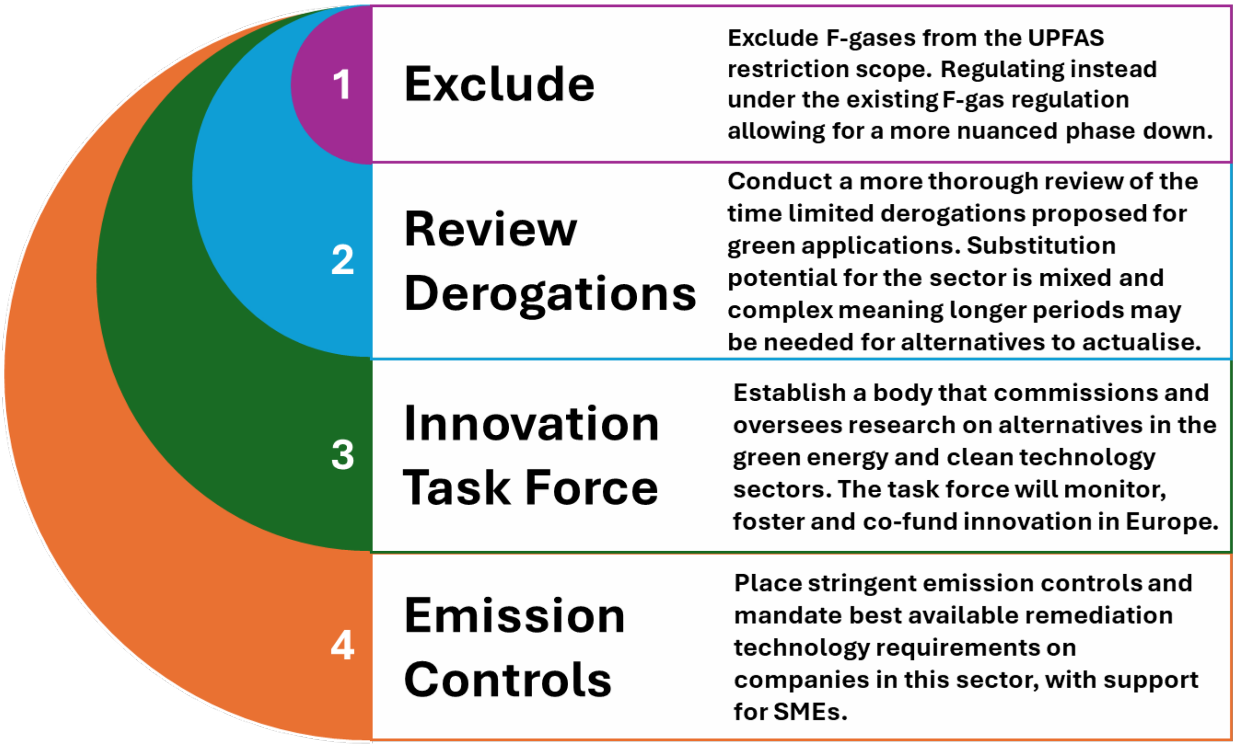
c. Recommendations for green energy and clean technology

Recommendations for this sector are divided into F-gases and PFAS in general.

Alternatives for F-gases, which are used in technologies like heat pumps, exist, but are not yet universal. As there is already comprehensive EU legislation for F-gases, it is recommended to exclude them from the scope of PFAS restrictions and instead regulate them under the existing F-gas Regulation. This will foster the development of alternatives where possible in a more gradual way, while still ensuring that the EU and EEA retain the capacity to innovate in green technologies.

A more detailed review of the proposed time-limited derogations for green energy and clean technology uses is recommended for PFAS. It is recommended that this review also assess applications which currently do not have a derogation proposed as well. 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. The diagram below provides a step-by-step guide to the proposed recommendations for the sector, showing the interlinkages between the various steps and proposals.

Figure 13: Proposed recommendations for the green energy and clean technology sector

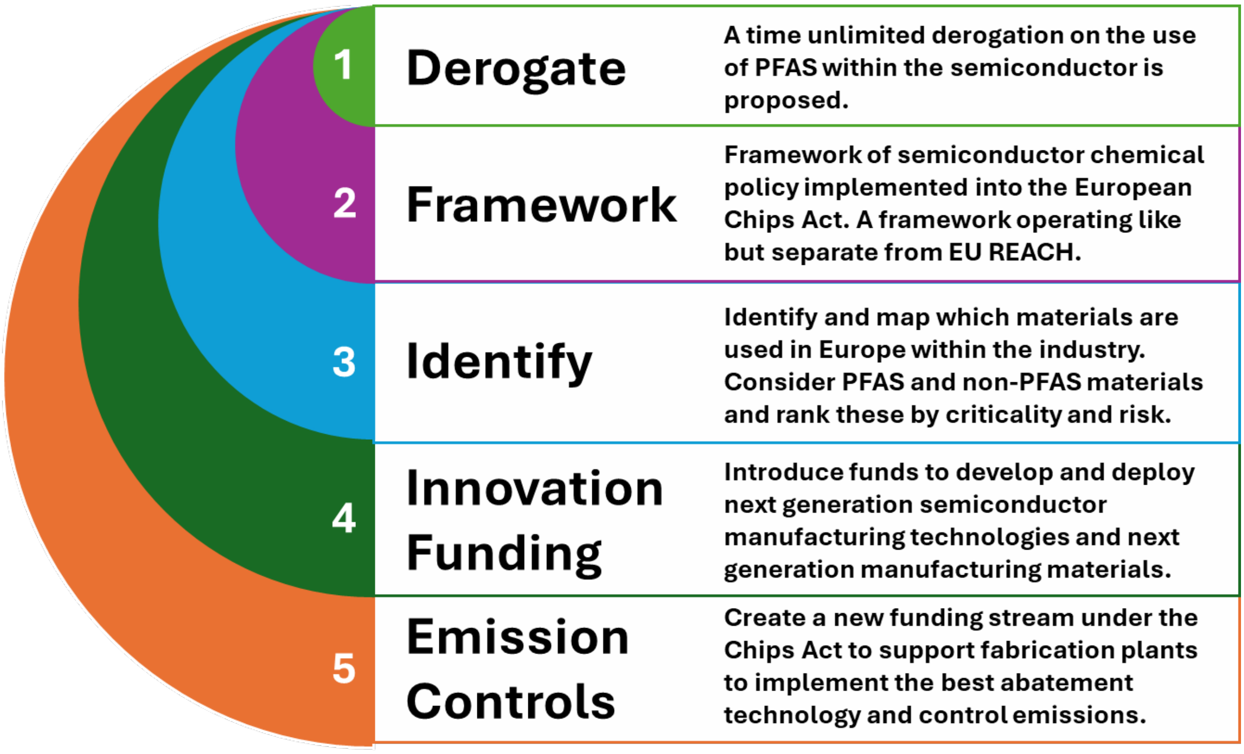


Source: Authors' own elaboration.

d. Semiconductors

A time unlimited derogation for PFAS for the semiconductor sector is recommended. Modern technologies, digital services, and AI depend entirely on semiconductors. Without semiconductors, Europe's digital economy would 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 under the European Genesis Programme to eliminate PFAS from semiconductor manufacturing, a new funding stream under the Chips Act could enable the adoption of the best available abatement technologies and foster the development of next generation and cheaper abatement technologies, to ensure strict emissions control of PFAS. The diagram below provides a step-by-step guide to the proposed recommendations for the sector, showing the interlinkages between the various steps and proposals.

Figure 14: Proposed recommendations for the semiconductor sector



Source: Authors' own elaboration.

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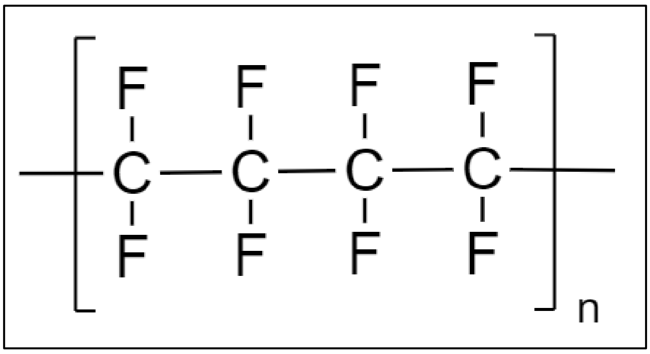
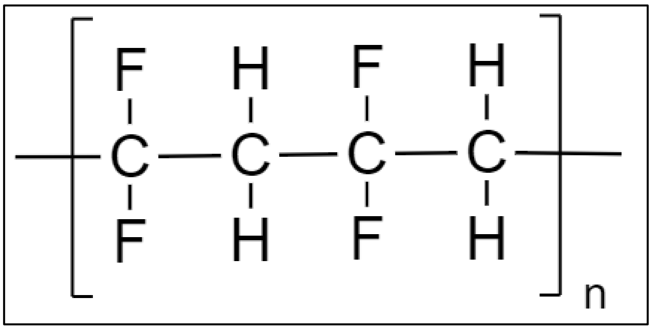
ANNEX 1 CHEMICAL STRUCTURES OF IN SCOPE FLUOROPOLYMERS

Figure A1: Chemical structure of PTFE



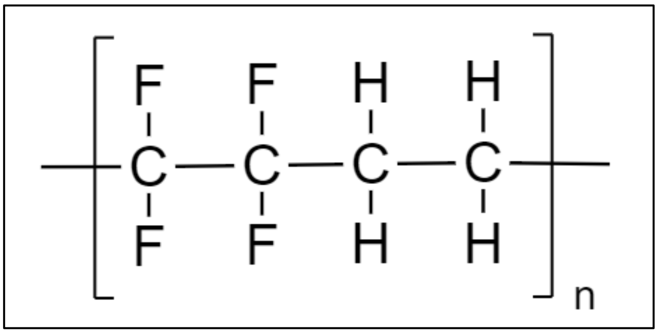
Source: Authors' own elaboration.

Figure A2: Chemical structure of PVDF



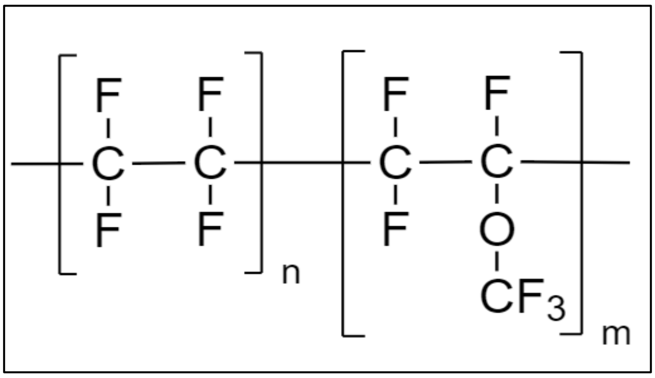
Source: Authors' own elaboration.

Figure A3: Chemical structure of ETFE



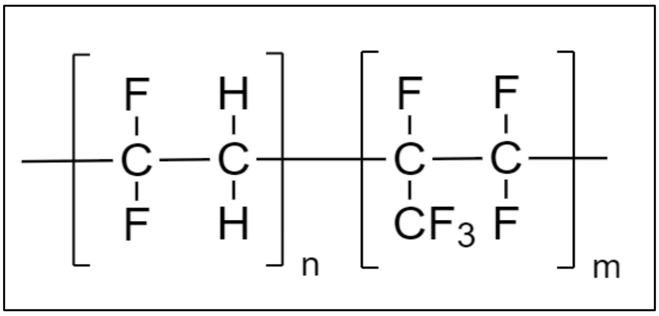
Source: Authors' own elaboration.

Figure A4: Chemical structure of PFA



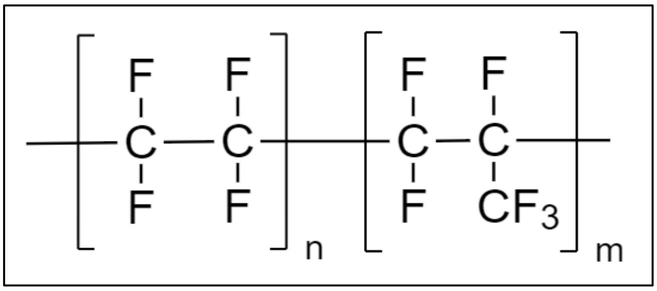
Source: Authors' own elaboration.

Figure A5: Chemical structure of FKM



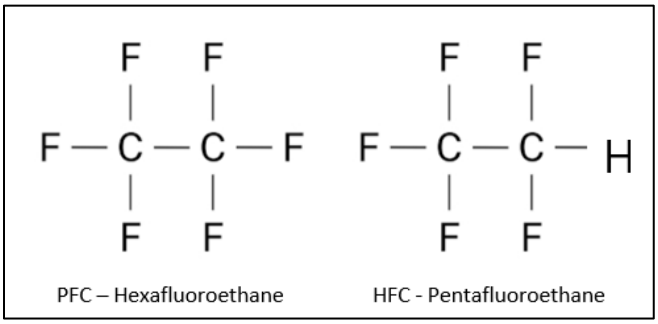
Source: Authors' own elaboration.

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

	Code and description
	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) 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)

	Code and description
	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. 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) 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.

	Code and description
	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 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

	Code and description
	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[1].
		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	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: • Photo imaging, for example photographic coatings	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.	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	•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 oams – a time limited derogation expired in July 2025		
	<u>REACH restrictions</u> • REACH restrictions: •perfluorocarboxylic acids (C9-14 PFCAs) since February 2023; •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).	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.	

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 • Heat pumps: No derogation proposed for domestic, commercial and industrial applications. • Defence (military) applications:	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
		• 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 • 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* *2) there are no acceptable alternatives"*	• Necessary for health and safety • Critical for the functioning of society

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
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 the Australian criteria, Polymers of Low Concern (PLC) are exempted from the requirements for introduction to the Australian market.	

	<u>PFAS ban in Australia</u>
	• 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 for PFAS from 2027 (see below table)	Phased risk management approach **excludes fluoropolymers**	

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
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). • Regulation is currently piecemeal, focused on the PFAS regulated under the Stockholm Convention, rather than regulation of PFAS in general.		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
	• 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).
	• 138 PFAS are classified as Class I Specified Chemical Substances, including:
	  • PFOA related substances and salts;
	  • Perfluorinated carboxylic acids;
		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
	• PFAS derivatives used in coatings, **fluropolymers**[7], 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
UK	UK POPs Regulations 2007 (retained EU law) • Ban on producing, placing on the market or using POPs including: ○ PFOS and its derivatives	Exemptions listed under the Stockholm Convention (see above)	Acceptable uses listed under the Stockholm Convention (see above)

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

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	○ 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		
	UK REACH restrictions on PFAS • 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. • 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		

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	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'
	• Future decision by 2026 on whether to designate all perfluoroalkyl and polyfluoroalkyl substances
	• The EPA must test all PFAS for toxicity to human health
		Exemption for Aqueous Film-Forming Foam (AFFF) 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)
			• Solid waste facilities
			• Public and private drinking water systems and treatment facilities

Region/ country	Regulatory framework for PFAS	Exemptions	Acceptable uses
	The EPA must regulate the disposal of materials containing PFAS		
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.	
	• 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 (see table notes)	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)	

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance (see table notes)	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
Polyvinylidene fluoride (PVDF)	155-175°C (powder/granules) (1) 175°C (raw material-values from supplier) (8) 165°C (powder) (10) * 154-184°C (form not stated) (11)		V-0 (1) V-0 (8) * V-0. PVDF is non-flammable and non-dripped. It is self-extinguishing. The LOI is 44%. (11)	High chemical resistance (8) High: S, most aggressive substances (1) *A, Ar, H, Alc, S-H (11) Low: not stated	UV resistant (1) * good resistance to UV (11)	20-25kV/mm (1) *260-950kV/mm (11)	High purity (1) *High purity (11)	0.2–0.4 (static) and 0.15–0.35 (dynamic) (1)	Between 30-50 MPa (powder and granules) (1) 60MPa (8) *36-56Mpa (11)	20-300% (1) *25-500% (11)	70-80(1) Ball indentation hardness value was 110 N/mm² and Rockwell hardness value was M78 (8)	170-1000 J/m (IZOD impact-notched) (1) 10 kJ/m² (Charpy impact strength-notched; unnotched had no break) (8) * 160-530 J/m (IZOD impact) (11)	Readily melt-processible (1) *Readily melt-processible (11)

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance (see table notes)	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
Ethylene tetrafluoroethylene (ETFE)	*254-279°C[12] 290°C (pellets)[14] 225-270°C [15]	*-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]
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]

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance (see table notes)	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
Perfluoroelastimer (FKM/FFKM) AKA Perfluoroelastomer		-10°C to 230°C[20] -5°C to 300°C (FFKM seals) [21] -20°C to 320°C [22]	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, ethylene and propylene oxide, active pharmaceutical ingredients, cleaning agents [20] Low: not stated			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] Up to 15 MPa [22]	168% (65 Shore A), 150% (70 Shore A), 135% (80 Shore A), 119% (90 Shore A) [20] Up to 320% [22]	65 (65 Shore A), 71 (70 Shore A), 79 (80 Shore A), 92 (90 Shore A)[20] Between 60-90 (FFKM seals)[21] Between 70-95 (shore A) [22]		

	Melting point (°C)	Operational temperature range (°C)	Flammability (UL-94)	Chemical resistance (see table notes)	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
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] -200-205°C [27]		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]	
Common alternatives for fluoropolymers													

Common alternatives for fluoropolymers														
	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
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 methanoic acid [31]	*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) and 6kJ/cm² at -30°C [32] *80-94 J/m (Notched Izod) [33]	Can be injection moulded [31] *Extrusion and 3D printing possible [33]

Polyethylene	113°C (Metallocene Polyethylene (mPE))[37] 126-136°C (Polyethylene) [38] 120°C (C4 Linear Low Density Polyethylene) [39] 129°C (C6 Linear Low Density Polyethylene) [40] 86°C (Ethylene Vinyl Acetate Copolymer) [41] 69°C (Ethylene Vinyl Acetate Copolymer Resin) [42]		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] 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	910% (TD) and 550% (MD) (C4 Linear Low Density Polyethylene) [39] 990% (TD) and 760% (MD) (C6 Linear Low Density Polyethylene) [40] 640% (TD) and 210% (MD) (Ethylene Vinyl Acetate Coploymer) [41] >800% (Ethylene Vinyl Acetate Copolymer Resin) [42] 590% (TD) and 190% (MD) (Low Density Polyethylene) [45]		90g (Dart drop impact), (C4 Linear Low Density Polyethylene) [39] <60g (Dart drop impact), (C6 Linear Low Density Polyethylene) [40] 400g (Dart drop impact), (Ethylene Vinyl Acetate Copolymer) [41] 120 ft-ib/in² (Tensile impact strength), (High Density Polyethylene) [44]	Readily melt-processible and can be applied as a coating (mPE) [37] Can be injection moulded (Ethylene Vinyl Acetate Copolymer) [41]

	109°C (Low Density Polyethylene) [45] 124°C (C6 Linear Density Polyethylene) [46]								Density Polyethylene)[45] 47Mpa (TD) and 60 (MD) (C6 Linear Low Density Polyethylene) [46]	710% (TD) and 550% (MD) (C6 Linear Low Density 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 temperature) [35] Minimum operating temperature -200°C; Max service temperature in air 80°C (continuously-5000h) and 120°C (short periods, no load) [47]	HB [34, 47]	High chemical resistance [34] High: H, S-H, W [35] Low: sulphuric acid, O, Chlorine [35]		25kV/mm [34] 45 kV/mm [47] 44 kV/mm [48]		0.25 μ (dynamic) [35] 0.29 (friction against hardened and ground steel, P=0.05 N/mm² and v=0.6m/s) [48]	40 MPa (at 23°C) [34]	300% [34] 50% [35] 50% [47]	64 (Shore D) [34] 60-65 (Shore D) [35] 60 (Shore D) [47] 64 (Shore D) [48]	No break (test method:ASTM D256) [34] 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 160°C (intermittent) [50] Max operating temperature 120°C[51]	HB – V0 [50] HB [51]	High: H, S [50] High: H [51] Moderate: weak B [50] Low: strong A, strong B, O [50]	Fairly resistant [50]	10-120 kV/mm [50] 22 kV/mm [51]		Low coefficient of friction [51]	45-90-MPa tensile strength at yield [50] 80 MPa (23°C) [51]	5-150% [50] 40% [51]	80 (Shore D) [51]	3-80 kJ/m² (Izod notched), 3-90 kJ/m² (Charpy notched) [50] 7kJ/m² (ASTM D256) [51]	Easy to manufacture and 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 agents, halogens [57]				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 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] 50 MPa [95]	80% [88] 2.3% [89]			
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/m² [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] -35°C to + 160°C [64] -30 to 150 ºC [65] -30 to 150 ºC [66]							=>23 MPa [63] 100 kg/cm² [64] > 102 Kg/cm² [65] 15 MPA Minimum [66]	=>240% [63] 200% [64] > 250% [65] 200% Minimum [66]	75 (+/- 5), Shore A [63] 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]		

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.

Sources: Please note source numbering was attributed to all sources for both table A9 and A10 before assessment via the credibility matrix. This may cause source numbering to appear out of order.

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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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
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	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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					carcinogenic (17) *PVDF is generally 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	Hazard class not classified (13) Relatively few studies have been conducted on environmental hazards (14)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					carcinogenic (17) Lack of data available for many aspects of 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)	Fluoropolymers are practically insoluble in water and not subject 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	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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					and eyes. Inhalation of fumes from burning polymer may cause temporary lung 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	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

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					endocrine disrupting properties [28]	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, 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	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]

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					dangerous to humans (38)	
Ultra-high molecular weight polyethylene (UHMWPE)					No data available for toxicological information but the product does not contain any known or suspected endocrine disruptors (36)	Contains no substances known to be hazardous to the environment or that are not degradable in wate water 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

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
						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 burns and damage, may cause an allergic skin reaction, harmful if inhaled, may cause respiratory irritation. (53)	No data available on toxicity, persistence and degradability, bioaccumulative potential, mobility in soil. Substance does not have components considered to be either persistent, bioaccumulative and toxic or very persistent and very bioaccumulative at levels of 0.1% or higher. (49) Recyclability: Nylon PA6 is recyclable and commonly reused in many industrial applications. Environmental Impact:

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
						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)
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	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)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					sensitising for inhalation or skin or respiratory system. No test data available for Mutagenicity or Carcinogenicity. (57)	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 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	PMMA is considered environmentally safe and inert under normal usage. It resists UV degradation and is often long-life applications. (82) No data available on toxicity, persistence and degradability or mobility in soil. (85)

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					critical hazards in relation to skin contact or ingestion. Data not available on endocrine disrupting properties. (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 irritate the respiratory tract. (103) Eye: Lacrimation. Eye: Ptosis. Convulsions or effect on seizure threshold. Tremor. Body temperature decrease. (104)	This substance/mixture contains no components considered to be either 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

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
						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 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.	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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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 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	

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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. Reddening, itching, swelling, burning and possible permanent damage. (105) High concentrations may cause severe	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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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)	
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	Avoid release to the environment. Prevent entry to sewers and public waters. The product is not considered harmful to aquatic organisms nor

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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 effects Inhalation: Inhalation of hot fumes may cause lung irritation. [108] Symptoms/effects after inhalation: None	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 (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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. Ingestion: Irritating to mouth, throat, and stomach. This product contains methylpolysiloxanes,	The product components are not classified as environmentally hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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)	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)
Ethylene propylene diene terpolymer (EPDM)					Skin Contact: May cause mild skin irritation with repeated contact.	Persistence and degradability: This product is not

	Cost per tonne of raw material (€/kg)	Cost increase over XX (%)	European market volume (tonnes/year)	Global market volume (tonnes/year)	Human health hazards (EU CLP Classification/SDS hazard statements)	Environmental hazards (EU CLP Classification/SDS hazard statements)
					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)	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.

Sources: Please note source numbering was attributed to all sources for both table A9 and A10 before assessment via the credibility matrix. This may cause source numbering to appear out of order.

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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, the study finds that substitution is often unfeasible, particularly in aerospace, defence and semiconductors. Substantial economic losses and employment impacts are expected under both restriction options, with associated risks to Europe's global competitiveness. Amongst other recommended policy steps, the study recommends time unlimited derogations for critical sectors, the extension of transition periods for green technologies, and the exclusion of F-gases from the restriction. Further research and the creation of an innovation fund to support the development of alternatives are also recommended. Overall, the study proposes a balanced approach that protects the environment while preserving industrial and technological capability.

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