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Food Chain Safety
Environment

PFAS in Belgian industry – market study

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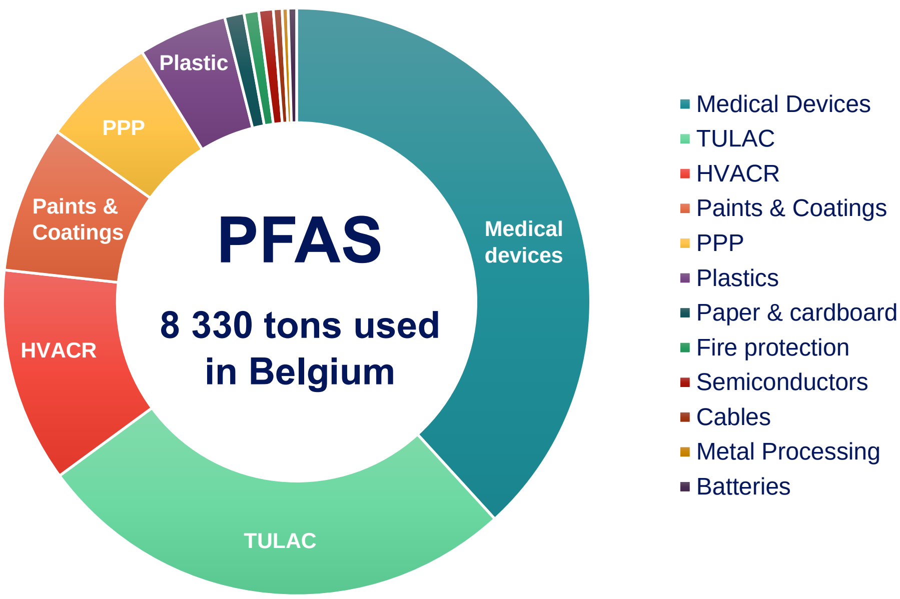
EXECUTIVE SUMMARY

The environmental and health toxicity of PFAS (per- and poly-fluoroalkyl) substances has been proven for several years. Due to their high chemical, thermal and weathering stabilities these "forever chemicals" accumulate in the environment (water, soil and subsoil). For the same reasons, PFAS are still widely used in highly diverse applications covering almost all industrial sector in Europe and in Belgium. As part of the National Recovery Plan, FPS Economy & FPS Public Health requested an in-depth technical and economic study on the PFAS market in Belgium to develop a strategy and targeted means of public support for the development of sustainable alternatives in the territory.

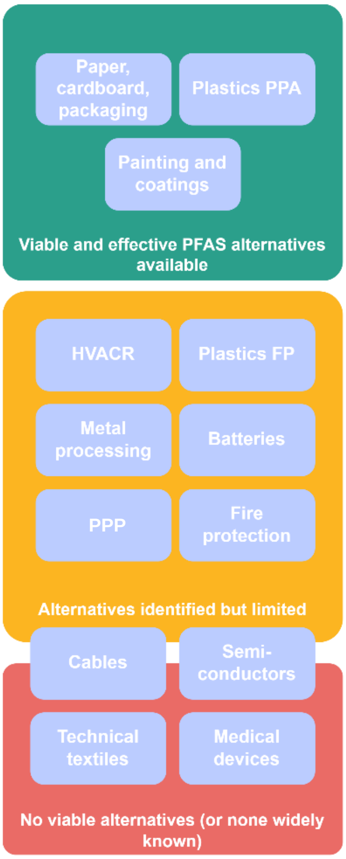
The market study of the use of PFAS in Belgium was based on literature and interviews. A workshop was organised for each of the three priority sectors (medical devices, technical textiles and HVACR).

In this study, the Belgian PFAS market was broken down into 12 different segments. Almost all PFAS uses and applications are supposed to be covered. The review of the 12 different markets revealed heterogeneous contexts with different awareness on PFAS uses, penetration of alternatives or economic importance. Volumes of PFAS also largely differ, with three segments (Medical, TULAC & HVACR) gathering more than 75% of all the estimated PFAS volume used in Belgium (i.e., 8 330 t/y).



Some industrial companies and R&D laboratories have already invested in the development of PFAS alternatives since many years. In most cases the developed or tested alternatives lead to products with shorter lifespan and/or inferior performances. However, in some cases, successful substitution has been achieved. Substitution is well underway in some industries such as paints & coatings, packaging or polymer processing ais, but in others (medical devices, personal protective equipment) it has further to go. This is due to unawareness of PFAS in the supply chain, lack of current knowledge of viable alternatives, or lack of viable alternatives even at low maturity.

The barriers to the development of alternatives varies by industry and application. While PFAS-free solutions may be found at the Belgian level, they are more often more likely to come from European (or even global) efforts. Consequently, there is no one-size fits-all policy that can help the acceleration of substitution away from all PFAS. The proposed public policies that would promote the phase-out of PFAS in Belgium are directly linked to the alternative maturity.



Proposed public policies include (i) increasing consumer / producer information on PFAS content, (ii) short term subsidisation to encourage users to switch system, (iii) ensuring the easy availability of technical information on the alternatives for users, (iv) ensuring that there is sufficient competent and trained staff to install and maintain these systems and (v) placing increasing restrictions on PFAS use by way of environmental permits.

Proposed public policies include (i) subsidies to R&D to accelerate innovation, promote collaborative R&D, facilitating (antitrust-compliant) information exchange (ii) subsidies to encourage switching to alternative products providing a similar function and (iii) subsides to CAPEX (investments to buy, maintain, or improve fixed assets).

Proposed public policies include (i) support measures to reduce emissions of existing PFAS systems until they can be replaced. (ii) establishment of priority alternative substances for R&D for certain applications and (iii) subsidies to R&D.

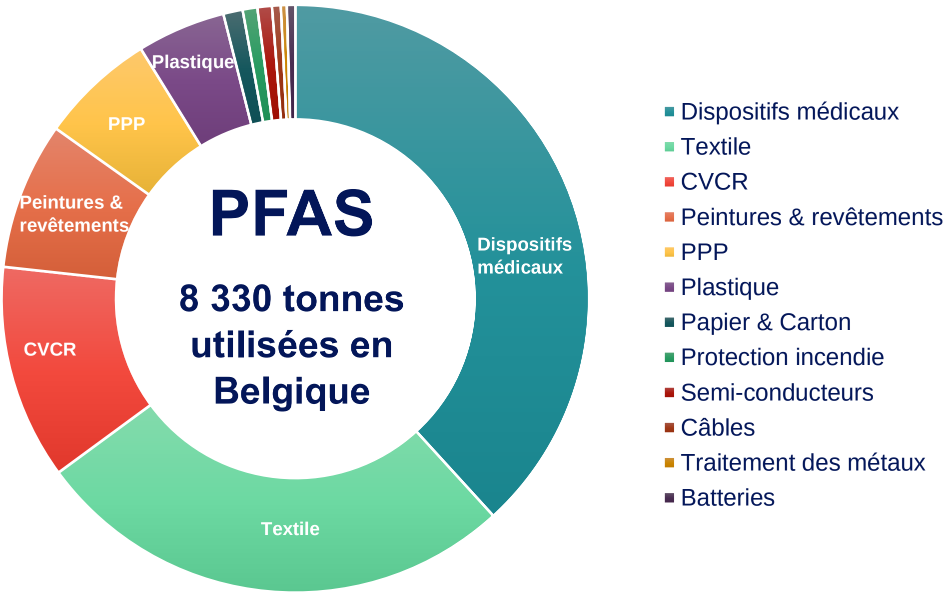
Depending on the case, different public policies can be rolled out accelerate substitution away from PFAS. In some cases, the process for finding viable alternatives will be a long-term task, even with the aid of these policies. Specific public policies are proposed for the priority sectors in the report.

RÉSUMÉ EXÉCUTIF

La toxicité environnementale et sanitaire des substances PFAS (per- et poly-fluoroalkyles) est prouvée depuis plusieurs années. En raison de leur grande stabilité chimique, thermique et climatique, ces « produits chimiques éternels » s'accumulent dans l'environnement (eau, sol et sous-sol). Pour les mêmes raisons, les PFAS sont encore largement utilisés dans des applications très diverses couvrant presque tous les secteurs industriels en Europe et en Belgique. Dans le cadre du Plan de relance national, le SPF Economie et le SPF Santé publique ont demandé une étude technique et économique approfondie sur le marché des PFAS en Belgique afin de développer une stratégie et des moyens ciblés de soutien public pour le développement d'alternatives durables sur le territoire.

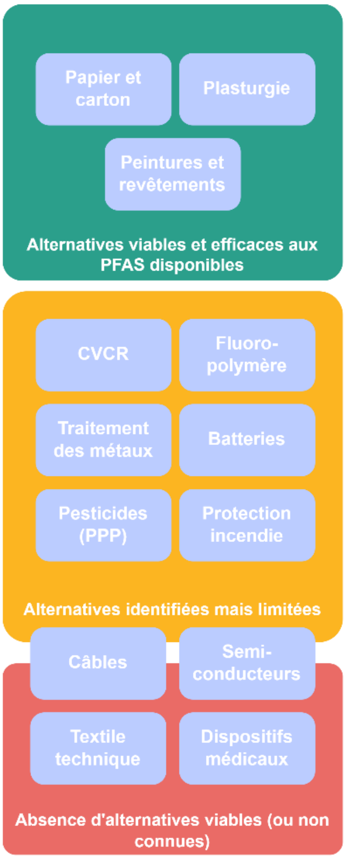
L'étude de marché sur l'utilisation des PFAS en Belgique est basée sur des fonds documentaires publics ainsi que la réalisation d'entretiens avec des acteurs industriels belges. Un atelier a été organisé pour chacun des trois secteurs prioritaires (dispositifs médicaux, textiles techniques et HVACR – chauffage, ventilation, conditionnement d'air et réfrigération).

Le marché belge des PFAS a été divisé en 12 segments, couvrant la quasi-totalité des utilisations industrielles et applications des PFAS en Belgique. L'examen de ces 12 « sous-marchés » révèle des contextes industriels hétérogènes, des applications plus ou moins critiques, des marchés associés plus ou moins importants, des niveaux de sensibilisation différents ainsi que des alternatives plus ou moins matures. Les volumes de PFAS diffèrent aussi largement : trois segments - Médical, Textile, et HVACR - rassemblent plus de 75 % de du volume total PFAS utilisé en Belgique (c'est-à-dire 8 330 t/an).



Certaines entreprises industrielles et certains laboratoires de R&D ont déjà investi dans le développement d'alternatives aux PFAS depuis de nombreuses années. Dans la plupart des cas, les alternatives développées ou testées conduisent à des produits ayant une durée de vie plus courte et/ou des performances inférieures. Toutefois, dans certains cas, des substitutions ont été réalisées avec succès. La substitution est bien avancée dans certaines industries telles que les peintures et revêtements, l'emballage ou le traitement des polymères, mais dans d'autres (dispositifs médicaux, équipements de protection individuelle), il reste encore du chemin à parcourir. Cela est dû à la méconnaissance des PFAS dans la chaîne d'approvisionnement, au manque de connaissances actuelles sur les alternatives viables, ou à l'absence d'alternatives viables même à un faible niveau de maturité.

Les obstacles au développement d'alternatives varient en fonction de l'industrie et de l'application. Si des solutions sans PFAS peuvent être trouvées au niveau belge, elles sont plus souvent susceptibles de provenir d'efforts européens (voire mondiaux). Par conséquent, il n'existe pas de politique unique susceptible d'accélérer la substitution de tous les PFAS. Les politiques publiques proposées pour promouvoir l'élimination progressive des PFAS en Belgique sont directement liées à la maturité alternative.



Les politiques publiques proposées comprennent (i) une meilleure compréhension et communication auprès des consommateurs et des producteurs sur la teneur en PFAS, (ii) des subventions à court terme pour encourager les utilisateurs à changer de système, (iii) la mise à disposition d'informations techniques sur les alternatives pour les utilisateurs, (iv) la garantie d'un personnel compétent et formé en nombre suffisant pour installer et entretenir ces systèmes et (v) la mise en place de restrictions croissantes sur l'utilisation des PFAS par le biais de permis environnementaux.

Les politiques publiques proposées comprennent (i) des subventions à la R&D pour accélérer l'innovation, promouvoir la R&D collaborative, faciliter l'échange d'informations (dans le respect des règles antitrust), (ii) des subventions pour encourager le passage à des produits alternatifs offrant une fonction similaire et (iii) des subventions pour les dépenses d'investissement (CAPEX (investissements destinés à l'achat, à l'entretien ou à l'amélioration des actifs fixes)..

Les politiques publiques proposées comprennent (i) des mesures de soutien pour réduire les émissions des systèmes PFAS existants jusqu'à ce qu'ils puissent être remplacés, (ii) l'établissement de substances alternatives prioritaires pour la R&D pour certaines applications et (iii) des subventions à la R&D.

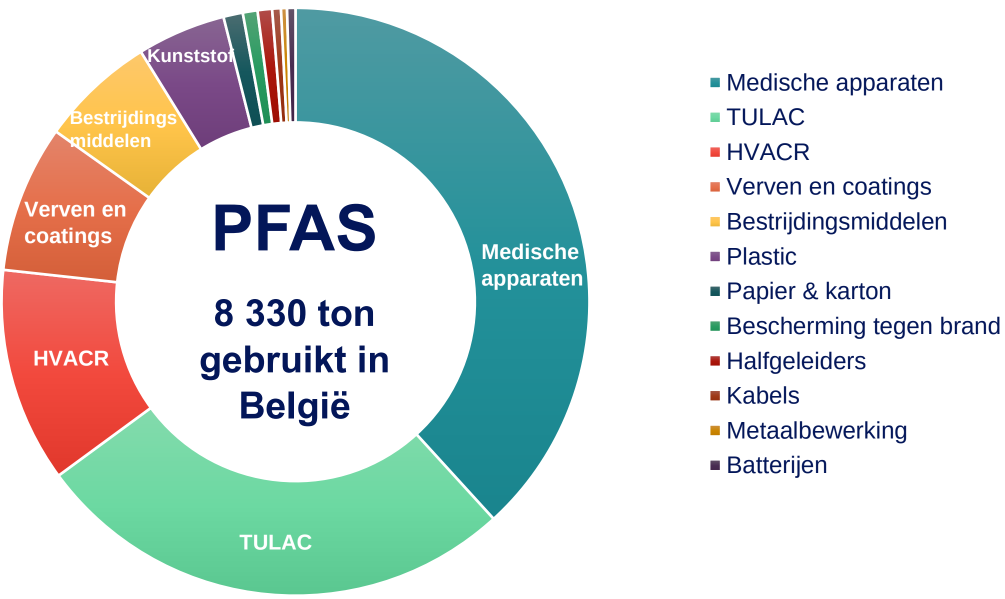
Selon le cas, différentes politiques publiques peuvent être mises en œuvre pour accélérer la substitution des PFAS. Dans certains cas, le processus de recherche d'alternatives viables sera une tâche de longue haleine, même avec l'aide de ces politiques. Des politiques publiques spécifiques sont proposées pour les secteurs prioritaires dans le rapport.

SAMENVATTING

De milieu- en gezondheidstoxiciteit van PFAS-stoffen (per- en polyfluoralkyl) is al jaren bewezen. Door hun hoge chemische, thermische en verweringsbestendigheid hopen deze "voor altijd chemische stoffen" zich op in het milieu (water, bodem en ondergrond). Om dezelfde redenen worden PFAS nog steeds op grote schaal gebruikt in zeer diverse toepassingen in bijna alle industriële sectoren in Europa en België. Als onderdeel van het Nationaal Herstelplan vroeg de FOD Economie een diepgaande technische en economische studie over de PFAS-markt in België om een strategie en gerichte middelen voor overheidssteun voor de ontwikkeling van duurzame alternatieven op het grondgebied te ontwikkelen.

De marktstudie van het gebruik van PFAS in België was gebaseerd op literatuur en interviews. Voor elk van de drie prioritaire sectoren (medische apparaten, technisch textiel en HVACR) werd een workshop georganiseerd.

In deze studie werd de Belgische PFAS-markt onderverdeeld in 12 verschillende segmenten. Bijna alle PFAS-gebruiken en -toepassingen worden verondersteld aan bod te komen. Het onderzoek van de 12 verschillende markten bracht heterogene contexten aan het licht met een verschillend bewustzijn van de PFAS-toepassingen, de penetratie van alternatieven of het economisch belang. De volumes van PFAS lopen ook sterk uiteen, waarbij drie segmenten (medisch, TULAC & HVACR) meer dan 75% van het geschatte PFAS-volume dat in België wordt gebruikt (d.w.z. 8 330 ton/jaar) vertegenwoordigen.



Sommige industriële bedrijven en R&D-laboratoria investeren al jaren in de ontwikkeling van PFAS-alternatieven. In de meeste gevallen leiden de ontwikkelde of geteste alternatieven tot producten met een kortere levensduur en/of slechtere prestaties. In sommige gevallen is vervanging echter succesvol gebleken. In sommige industrieën, zoals verven en coatings, verpakkingen of polymeerverwerking, is de vervanging al goed gevorderd, maar in andere (medische apparaten, persoonlijke beschermingsmiddelen) moet er nog veel gebeuren. Dit is te wijten aan onbekendheid met PFAS in de toeleveringsketen, gebrek aan huidige kennis over haalbare alternatieven, of het ontbreken van haalbare alternatieven, zelfs bij een lage maturiteit.

De barrières voor de ontwikkeling van alternatieven verschillen per industrie en toepassing. Hoewel PFAS-vrije oplossingen kunnen worden gevonden op Belgisch niveau, zullen ze eerder voortkomen uit Europese (of zelfs wereldwijde) inspanningen. Bijgevolg is er geen pasklaar beleid dat de vervanging van alle PFAS kan versnellen. Het voorgestelde overheidsbeleid dat de uitfasering van PFAS in België zou bevorderen, houdt rechtstreeks verband met de alternatieve rijpheid.

Voorgesteld overheidsbeleid omvat (i) meer informatie voor consumenten/producenten over het PFAS-gehalte, (ii) kortetermijnsubsidies om gebruikers aan te moedigen over te schakelen op een ander systeem, (iii) ervoor zorgen dat technische informatie over de alternatieven gemakkelijk beschikbaar is voor gebruikers, (iv) ervoor zorgen dat er voldoende bekwaam en opgeleid personeel is om deze systemen te installeren en te onderhouden en (v) het opleggen van steeds meer beperkingen aan het gebruik van PFAS door middel van milieuvergunningen.

Voorgesteld overheidsbeleid omvat (i) subsidies voor R&D om innovatie te versnellen, gezamenlijke R&D te bevorderen en (antitrustconforme) informatie-uitwisseling te vergemakkelijken (ii) subsidies om de overstap naar alternatieve producten met een gelijkaardige functie aan te moedigen en (iii) subsidies voor kapitaaluitgaven (CAPEX, kosten voor ontwikkeling of levering van niet-verbruikbare onderdelen van een product of systeem).

Voorgesteld overheidsbeleid omvat (i) ondersteunende maatregelen om de emissies van bestaande PFAS-systemen te verminderen totdat ze kunnen worden vervangen. (ii) vaststelling van prioritaire alternatieve stoffen voor R&D voor bepaalde toepassingen en (iii) subsidies voor R&D.

Afhankelijk van het geval kunnen verschillende overheidsmaatregelen worden genomen om de vervanging van PFAS te versnellen. In sommige gevallen zal het vinden van levensvatbare alternatieven een zaak van lange adem zijn, zelfs met behulp van dit beleid. In het verslag wordt specifiek overheidsbeleid voorgesteld voor de prioritaire sectoren.

Table of content

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1 \ INTRODUCTION

1.1 \ Context

The environmental and health toxicity of PFAS (per- and poly-fluoroalkyl substances), a family of highly persistent and bioaccumulative compounds, has been proven for several years. The production, use and end-of-life of these substances generate diffuse pollution at the global level in water, soil and subsoil. One of the most well-known and emblematic examples of pollution and contamination is that of the area surrounding the 3M Group's Zwijndrecht plant in Belgium.

All uses of these substances are sources of contamination and potential health threats on a large scale due to the diffuse nature of the applications (firefighting foams, coatings for textiles, production of fluoropolymers such as PTFE or PVDF, end-of-life impacts, etc.). Due to the high stability of these PFAS molecules, totally safe management of PFAS-containing products along their life cycle is not achievable. Thus, the substitution of uses is at the heart of the subject of the mission.

To address the risks to public health and the environment, some of these subfamilies of compounds have already been banned in the European Union, such as PFOS and PFOA, since 2020. Several other PFAS compounds are on the REACH – SVHC (Substances of Very High Concern) candidate list, some of which are already covered by the Stockholm Convention on Persistent Organic Pollutants (POPs). A proposal for a general restriction was recently published by ECHA (Annex XV)[1], supported by several EU Member States including Belgium. This text targets 14 sectors of activity and aims to eventually ban the production, use, import and placing on the market of around 10,000 PFAS compounds in the EU and EE. However, at the time this report is written, the European Commission did not plan to work on REACH revision.[2]

There are some more sustainable and safer alternatives to some of these substances that are often specific to a particular application. However, for uses still considered "essential" for reasons of performance/cost and need, the future of PFAS use is still uncertain. To illustrate, let's take the case of PVDF, a fluoropolymer widely used in Li-ion batteries as a binder or in coatings of materials requiring high durability. On this point, the Belgian chemist Solvay announced in 2022 the investment of € 300 million of its site in Tavaux (Jura, France) to increase the production capacity of PVDF to 35 000 t/year.[3]

In Belgium, there are many industrial uses of PFAS in the primary processing, subcontracting and manufacture of fluorinated products in the plastics and rubber industry, in formulations such as firefighting foams, for textile finishing, refrigerants, etc. These uses still play a central role in the supply of these value chains, so it is essential to support their future in this regulatory and health context.

This is why the development of sustainable alternatives to these substances is a major economic and environmental challenge for the coming years, with potential development opportunities for the players in the Belgian innovation ecosystem: companies, universities, institutes, clusters, etc.

As part of the National Recovery Plan, and in particular the Belgium Builds Back Circular project, FPS Economy and FPS Public Health wish to commission an in-depth technical and economic study on the PFAS market in Belgium in order to develop a strategy and targeted means of public support for the development of sustainable alternatives in the territory.

[1] https://echa.europa.eu/documents/10162/1c480180-ece9-1bdd-1eb8-0f3f8e7c0c49
[2] https://www.lemonde.fr/planete/article/2023/10/17/la-commission-europeenne-s-apprete-a-renoncer-a-son-plan-d-interdiction-des-produits-chimiques-dangereux_6194944_3244.html
[3] https://www.usinenouvelle.com/article/solvay-injecte-300-m-a-tavaux-pour-en-faire-le-plus-grand-site-de-pvdf-d-europe.N1779947?recommended_by=dynamic&recommended_code=348c7400b4e9d1f934529cc98e4715df

1.2 \ Objectives

The purpose of this study is to carry out a market study of perfluoroalkyl and polyfluoroalkyl substances (PFAS) with the aim of supporting and encouraging the development of health- and environmentally safer alternatives necessary for the construction of a more sustainable economy in Belgium. In this scope, this report addresses two main objectives:

1. Characterisation of the PFAS market in Belgium (section 3)

2. Propose policy measures to accelerate the substitution of PFAS in Belgium (section 4)

This first objective is dedicated to the characterisation of the PFAS market in Belgium. The aim is to get an overview of the use and/or presence of PFAS in the Belgian industry, in particular those considered “essential”, and to identify the highest priority areas where government action is needed to enable the replacement of PFAS with safer alternatives. This analysis should serve as a scientific basis to enable the policy level to implement evidence-based strategies according to policy priorities and accelerate the substitution of PFAS in Belgium.

2 \ METHODOLOGY

2.1 \ Chemical scope

The scope of the study comes out from the OECD definition of PFAS, that includes (i) PFAAs and PFAA precursors, (ii) fluorinated gases and (iii) polymeric PFAS. Due to their different properties and environmental impact on soil, water, air and human health, the distinction between these three PFAS groups have been kept as far as possible in the characterisation of the Belgian PFAS market.

2.2 \ Segmentation

Many of these PFAS are used in a wide range of applications that concern all industrial sectors. In this study, the Belgian PFAS market was initially broken down into 14 different segments. Almost all PFAS uses and applications are supposed to be covered.

First investigations revealed highly inequal segments in terms of PFAS usefulness and alternative development. Two segments, Cookware and Cosmetics were excluded from the scope: they are associated with non-critical uses of PFAS and PFAS-free alternatives are commercially available. Conversely, three high priority segments were identified: TULAC (mostly technical textile), HVACR and Medical Devices, where significant, critical uses of PFAS with no or limited alternatives is reported. For these three high priority segments, workshops have been organised with Belgian industrial companies.

This selection is the first step towards targeting useful public policies. Below is the initial list of the 14 segments:

- Batteries
- Cables
- (Cookware) - Excluded
- (Cosmetics) - Excluded
- Fire protection
- **HVACR: Heating, Ventilation, Air Conditioning and Refrigeration**
- **Medical Devices**
- Metal Processing
- Paints & Coatings
- Paper & cardboard, including packaging
- PPP: Plant Protection Products
- Plastics
- Semiconductors
- **TULAC: Textile, Upholstery, Leather, Apparel & Carpet**

2.3 \ Sources

Information was collected from numerous public reports from ECHA (Annex XV of the Restriction report on PFAS, result of the public consultation), OECD, industrial or environmental associations, the « Forever Pollution Project », etc. Additionally, 24 interviews were conducted with Belgian federations (Fedustria, BeMedTech, Essenscia), other associations (Pesticide Action Network, Recharge, Eurometaux) or industrial companies active in Belgium.

RDC Environment conducted three workshops, one for each high priority sector of concern identified (technical textiles, medical devices, HVACR). The attendees were a mix of representatives of companies and federations active in each sector in Belgium (see Annex for more details).

2.4 \ Comparative analysis

In order to evaluate the relevance of public action and to orient the selection of instruments, all market segments were reviewed and characterised through a series of criteria:

- PFAS role in the final product: functional importance and technical complexity

There are numerous uses of PFAS in processes and products, which are more or less technically complex. In some cases, PFAS play only a secondary role in the final application; alternately, they may play a fundamental role in a complex product. Technology intensive sectors tend to invest more in R&D, and thus are more likely to spontaneously investigate alternative solutions.

- Final function considered as “essential”

A function associated with a product may be considered as “essential” when evaluating the consequences of failures, i.e. when the function is not properly performed. Various aspects may be at stake: sanitary (impacts on health), safety (impacts on working conditions), economy (impacts on employment), etc. PFAS are associated with various functions, which are more or less “essential”.

- Maturity of alternatives

The availability and maturity of alternatives is analysed in the ECHA Restriction report. This criterion is here evaluated from a strictly technical point of view: the question of cost is not taken into account.

- Industrial awareness

The extent to which PFAS are, nowadays, actually used may vary according to the industry concerned. This knowledge is a prerequisite before considering the awareness of the availability of alternatives.

- Volumes

This criterion refers to the quantities of PFAS (all types) used annually by the Belgian industry. Its evaluation is based on the estimations detailed in the respective monographies (see Section 3.2); a simplified scale is used (see below), taking into account the various uncertainties affecting these estimations.

It must be emphasised that these criteria are not intended to prioritise the different segments – which are inherently heterogeneous –, but rather to characterise their profiles, using a systematic, common analysis grid. The way these criteria are applied is detailed in the table below.

Table 1: Criteria definition for the comparative analysis

Criterion	1	2	3	4
PFAS role in the final product: functional importance and technical complexity	PFAS plays a key role in the final application, which is technically complex	PFAS is a secondary component in a technically complex product	PFAS plays a key role in a rather basic, mature application	PFAS is a secondary component in the final product, its role is not central
Final function considered as “essential”	The PFAS added value is basically classified as “comfort”	A deficiency in the final function associated with PFAS would have limited impacts	A deficiency in the final function associated with PFAS would have significant but manageable impacts	PFAS is associated with a function of the final product considered as “essential”
Maturity of alternatives	Some alternatives, tested in an industrial context, meet basic requirements	Some alternatives, partially satisfactory, need adaptations or further developments	Several potential alternatives are identified, none of which is technically satisfactory	No satisfying alternative is available, previous attempts were unsuccessful
Industrial awareness	PFAS uses are well identified by the industry, some alternatives are tested	PFAS uses are well identified by the industry, debates about alternatives are emerging	PFAS uses are identified by the industry, which has a limited knowledge of alternatives	The extent to which PFAS are used is not well known, and knowledge of alternatives is limited
Volumes (Belgium)	Less than 100 t/y	Between 100 and 500 t/y	Between 500 and 1000 t/y	More than 1000 t/y

3 \ PFAS MARKET ANALYSIS

3.1 \ Overview of the PFAS market

In 2023, AECOM established that the global PFAS issue, that includes PFAS alternatives development & manufacturing, waste management and environmental mitigation, represents a global market of about €250 billion.[4] This market is ten times larger than the global PFAS market, estimated at €26 billion.[5] Furthermore, in Europe, the European Commission estimates that a total ban of PFAS substances would lead to a health benefit of €11-31 billion annually.[6] The Nordic Council of Minister evaluated this same health cost at €52-84 billon.[7] The development of alternative to PFAS would necessarily lead to both health and economic benefits. However, identification of a technically and economically relevant substitute is not straightforward.

Compared to other chemistries, PFAS show extreme durability in harsh environment due to their chemical inertness, mechanical strength, high temperature stability, oil & water repellency or low coefficient of friction. PFAS are costly to manufacture and their uses are generally limited to applications when no other chemistry could address the technical requirements. Nevertheless, PFAS are found in almost all sectors. For instance, sealings made of fluoropolymers are used in the oil & gas industry, energy production, all kinds of transportation equipment, materials & food processing and to a lower extent in the building industry. Some industrial companies and

[4] https://investors.aecom.com/static-files/2dfcf5c0-ab90-4e1c-a53d-3138f669f54e
[5] https://chemsec.org/reports/the-top-12-pfas-producers-in-the-world-and-the-staggering-societal-costs-of-pfas-pollution/
[6] https://www.lemonde.fr/planete/article/2023/07/11/l-exposition-des-europeens-aux-produits-chimiques-dangereux-est-generalisee-et-alarmante_6181390_3244.html
[7] http://norden.diva-portal.org/smash/get/diva2:1295959/FULLTEXT01.pdf

R&D laboratories have already invested in the development of PFAS alternatives, with in some cases successful substitution. In most cases, however, the developed or tested alternatives lead to products with shorter lifespan and/or inferior performances.

The ECHA Annex XV listed 20 PFAS major production sites in Europe, including 2 in Belgium: the 3M plant at Zwijndrecht and the Chemours plant at Mechelen. The European PFAS production is estimated at 257 kt/y with similar share (w:w) of PFAAs, fluorinated gas and polymeric PFAS. Available data on import and export from Eurostat, literature or the ECHA stakeholder consultation differ but volumes reach about 100 000-200 000 t/y, with significant exports of PFAAs and imports of fluoropolymers.

ECHA also estimated the total PFAS uses in the manufacture of product in EEA (European Economic Area) in 2020, with larger volumes for 5 applications/segments: HVACR, TULAC, Medical devices, food contact packaging and transport. The table below summarises the PFAS uses for the three PFAS families. A first estimate of Belgian volumes is added, assuming similar industries and considering relative industrial GDP of Belgium and the EEA (3%).

Table 2: First and global estimate of the PFAS uses in Belgium

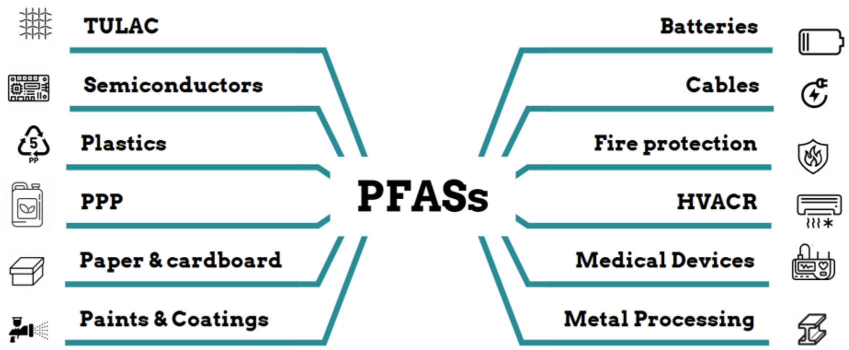
PFAS group	EEA (t/y)	Belgium (t/y)
PFAA and PFAA precursors	32 540	976
Fluorinated gases	64 001	1 920
Polymeric PFASs	128 504	3 855
All groups	225 045	6 751

Assuming similar industries, 6 751 tons of PFAS would be used in Belgium annually, with a higher share of polymeric PFAS. A deeper analysis of the Belgian PFAS industry, segmented in 12 major sectors is proposed below.

3.2 \ Market segmentation

3.2.1 \ Introduction

Excluding limited PFAS uses in cookware and cosmetics, the 12 segments (see below) have been characterised, almost all PFAS uses and applications are supposed to be covered. Characterisation includes the identification of PFAS uses, applications, molecules, industrial actors, economic aspects, estimation of PFAS volumes in Belgium and their related emissions, and finally existing alternatives and/or relevant R&D substitution projects and initiatives.



3.2.2 \ Batteries

Applications/products scope

PFAS are conventionally used in alkaline batteries as surfactants. More recently, PFAS such as PVDF, PTFE or fluoroelastomers are used in binders, membranes, separators, etc., in new generation batteries, such as flow and lithium-ion batteries.[8,9] Lithium-ion batteries are widely used and the growth due to the electrification of transport is strong. These batteries contain PVDF (a binder) at a proportion of about 1-1.4%.[10,11]

Table 3: List of PFAS application in battery with the associated molecules

Applications	PFAS (sub)family involved
Anti-drip agent	PTFE, 1,1-difluoroethene, TFE
Lithium batteries (seals, electrode binders, separator films/coatings, electrolyte additives, thermal management pack/module, coatings for the separator film, ion-permeable separators, gel polymer electrolytes)	Fluoroelastomer (FKM), PVDF, PTFE, FEP
Flow batteries & vanadium redox batteries (ionomer membranes, ion exchange membrane)	Fluoropolymers, PVDF, PTFE
HVACR-systems to cool down/heat traction batteries of electric vehicles	Fluorinated gases
Zinc batteries (formation of dendrites prevention, hydrogen evolution and electrode corrosion due to adsorption to electrode, binders)	Fluorinated gases and surfactants, perfluorooctanoic acid (PFOA), perfluorosulfonic acid (PFSA) polymers, PTFE, PVDF
Alkaline batteries (surfactant, binders)	Fluorinated surfactants (Forafac 1110, potassium perfluoroalkylcarboxylate), PVDF
Alkaline manganese batteries (cathodes surface treatment)	Fluorinated surfactants

[8] An overview of the uses of per- and polyfluoroalkyl substances (PFAS), 2021, Env. Sci. Process Impacts (DOI: 10.1039/d0em00291g)
[9] Annex XV restriction report, ECHA, Per- and polyfluoroalkyl substances (PFASs), 2023
[10] Per- and Polyfluoroalkyl Substance (PFAS) Emissions from Recycling Processes of Lithium-Ion Batteries, Amanda Rensmo, Uppsla Universitet, 2022
[11] Position statement by RECHARGE on the proposal for a restriction on per- and polyfluoroalkyl substances (PFASs)

Belgian industry

The Belgian industry represents around 10 companies active in the battery value chain, mainly in upstream activities such as materials and components. None of them produces complete products, except for one company.

According to Eurostat (NACE code C272), Belgium represents a proportion of 2.4% in the battery industry in EU in term of turnover (€339 million for a total of €13.8 billion for EU in 2018).[12]

Volumes (in Belgium)

The ECHA Restriction report uses data from the Urban Mine Platform for the volume of lithium-ion batteries (157 000 t/y) used in EEA and estimations from stakeholders that the PFAS content (PTFE and PVDF) in batteries is around 1%.[13] The volume of polymeric PFAS in batteries was thus estimated at 1 600 t/y in EU.

As explained above, the Belgian industry is specialised in upstream products such as binders, seals and separators. The volume of PFAS products for batteries is not known. In order to calculate an estimation of these quantities, an extrapolation based on the estimated volume of PFAS at the European level and the ratio from Eurostat data (battery industry) – 2.4% – may be used as a proxy: this leads to a volume of **38.4 t/y** for Belgium.[14]

It must be emphasised that:

(i) This volume does not include PFAS used for thermal control (cooling), which are associated with the vehicle system as a whole,

(ii) The volume of PFAS for the production of alkaline batteries is not known, even at the European level.

Environmental impacts

Human exposure to PFAS in batteries primarily occurs during the manufacturing and waste treatment (including recycling) stages. According to the ECHA Restriction report, no significant release of or exposure to PFAS is expected during use.

Estimated annual EEA emissions in the energy sector (in which batteries are included) of PFAA and PFAA precursors, fluorinated gases, polymeric PFASs and total PFASs were estimated in 2020 (average baseline). An estimation of emissions associated with batteries may be extrapolated from their proportion (PFAS volumes) in the energy sector.

Table 4: Estimates of PFAS volume emissions in EEA for the battery market

All values in t/y	C2- C3 subst.	PFAA ≥C4	Sc-FP	PFAAs & PFAA precursors	FP	PFPE	Polymeric PFASs	Total PFASs	Total PFASs (Battery)
Total volume	233	20	40.5	293	2 753	2.5	2 756	3 049	1 600
Production stage	12	10	20.5	42	8.5	1.5	9.5	51.5	27
Use stage	0	0.1	0.2	0.03	2.5	0	3	3	1.57
Total emissions	12	10	20.5	42	11	1.5	12.5	54.5	28.6

[12] https://bestat.statbel.fgov.be/bestat/crosstable.xhtml?view=1b8e35b2-3d1f-4094-8413-ed392671a381
[13] http://www.urbanmineplatform.eu/homepage
[14] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_IND_R2__custom_7248533/default/table?lang=en

As mentioned above, these estimations only take into account the contribution of lithium-ion batteries, which mainly contain PVDF as a binder. When treating end-of-life products, risks related to toxicity and toxic emissions become apparent. In this case, PFAS emissions are of high risks since chemical transformation processes are not well understood. As stated in the ECHA Restriction report, "*incomplete combustion (temperatures <850°C) of fluoropolymer cathode materials but also fluorinated ingredients in the electrolyte can lead to the formation of various persistent PFASs. Potential products of the thermolysis of fluoropolymer binder (often PVDF or FEP) are short and long chain perfluoroalkyl acids (PFAAs) and CF_4*". However, current PFAS emissions associated with lithium-ion battery waste treatment, which currently represents limited but growing waste streams, are not known.

Considering the estimated PFAS quantities for Belgium (38.4 t/y), a rough estimation of the total PFAS emissions would be **0.686 t/y, with:**

- 0.648 t/y for the production stage
- 0.038 t/y for the use stage

It must be emphasised that the contribution of PFAS emissions from end-of-life management (mainly recycling), not included in this estimation, is likely to become more significant in the coming years.

Existing alternatives

Currently, no alternative is available for the use of PTFE and of PVDF in primary lithium and lithium-ion battery technologies.[15]

Hydrocarbon elastomers (seals) are currently tested for solid state and lead acid batteries, but failed to deliver the same performances, because of several issues (failure of the seal material to maintain a tight seal due to deterioration, lack of heat resistance, chemical resistance, water vapour barrier and flame-retardant properties).

For flow batteries components (ionomer membranes and ion exchange membranes), alternatives such as solid-state batteries are still investigated, but it would take a while before flow batteries replacement, and industrials inform that there is no viable PFAS alternatives for flow batteries components at this moment. Battery fluid, compounds for separator films, binders are not studied or no specific alternative is known.

In general, no alternative battery technologies, or PFAS-free solid-state batteries, can as of today be used as a substitute for lithium-ion and flow batteries. But the feasibility of using such batteries as a replacement for flow batteries is still investigated.

Some alternatives may exist for PTFE and PVDF in coatings for separators in Li-ion rechargeable batteries and for PTFE, FEP, PFA, FKM in valves, gaskets, washers in Li-ion rechargeable batteries, like the use of hydrocarbon elastomers, PEEK, ionomers/sulfonated polymers (for seals), but they are still in development and could necessitate a 6.5-year transition time (as requested by the Recharge association).

3.2.3 \ Cables

Applications/products scope

Cables are widely used in several sectors (electric and electronic equipments and components, medical devices, HVACR for transportation vehicles, lifesaving and fire protection, communications and data cables, renewable energy, architectural parts for building industry, in

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

oil & gas and mining, etc.).[16,17,18] PFAS incorporated in cables are mainly composed of fluoropolymers and fluoroelastomers and essentially used in coatings and insulations for precise and constant transmission, moldability and flexibility, temperature, chemical/radiative resistance, corrosion resistance, stress crack resistance, longevity/durability, light weight, and fire retardancy.

Table 5: List of PFAS application in cables with the associated molecules

Applications	PFAS (sub)family involved
Electronic cables	ECTFE
Insulation of wires and cables (including downhole cables) in electrical, energy/O&G and semiconductor applications (automotive parts, medical, sub-sea, aerospace, clean room production, ...)	PTFE (Polytetrafluoroethylene, Perfluoroalkoxy), PFA, PTFE/PFA, ETFE, FEP, FEPM, PFPE, PCTFE, PVDF, PFC
Insulation of wires and cables in data cable/5G, LAN	FEP
Cables and wires of medical equipments	Fluoroelastomers
Coating of cables in the selective catalytic reduction system for diesel engines	PTFE, ETFE, PFA, FEVE
Electric vehicle charging cables	Fluorinated gases
Wind energy cables	FEVE, ETFE, Perfluorobutane sulphonamide
Plastic or a fibreglass-based tapes for electrical applications (wrapping bundles of wires) and gasket hoses	PTFE, PCTFE, ETFE, FEP, PVDF
Capacitive sensors and connecting cables in petroleum industry, and drilling	Fluoropolymers, PTFE
Orthodontic wires for aligning teeth	Fluoropolymers
Guidewires and vascular guidewires	PTFE (Polytetrafluoroethylene, Perfluoroalkoxy), PFA, PTFE/PFA

Belgian industry

Only few industrial companies are producing cables in Belgium, representing approximatively 12 producing sites for a total of 51 companies working in the cable sector in Belgium.[19]

According to Eurostat (NACE code C273), the total turnover value of Belgium represents a proportion of 2.0% in the cable and wiring industry in EU (€1 067 billion for a total of €53 billion for EU).[20,21]

Volumes (in Belgium)

Fluoropolymers are widely used for in the cable Industry. 40 000 t/y of fluoropolymers are produced in the EU, of which 5% are dedicated to cable & wiring. Thus, it is estimated that 2 000 t/y of fluoropolymers are used in the cable industry in the EU.[22] Considering that the Belgian cable industry represents 2% of the European industry, a volume of 40 t/y may be extrapolated for Belgium. This quantity mainly consists in fluoropolymers.

[16] https://www.rsc.org/suppdata/d0/em/d0em00291g/d0em00291g1.pdf
[17] https://europump.net/uploads/EUROPUMP_Position%20Paper%20PFAS.pdf
[18] ECHA restriction report
[19] https://www.cablebel.be/fr/adherents
[20] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_IND_R2__custom_7248439/default/table?lang=en
[21] https://bestat.statbel.fgov.be/bestat/crosstable.xhtml?view=1b8e35b2-3d1f-4094-8413-ed392671a381
[22] Fluoropolymer waste in Europe 2020, Conversio company, 2022

Environmental impacts

Due to a lack of viable data on emissions as volumes, we cannot provide relevant information on that topic. PFAS volume uses in cables and wires are relatively marginal and only a few actors give quantitative information.

Existing alternatives

There are no technically feasible alternatives (PEEK, PC, EPDM were studied) existing for wire insulation replacing the fluoropolymers used in the examples listed below.

For cables and their use in O&G industry, PEEK could replace PTFE thanks to its comparable temperature resistance, better mechanical and tensile strength, but has lower chemical resistance (in presence of H_2S and other acids), so such uses are still under development. Moreover, PEEK cannot be readily coloured for cable identification.

Another alternative for cables could be crosslinked (or XL) PE (which is widely used in consumer goods), but much more development related to its lower chemical resistance is necessary, and it is not compatible with temperature ranges needed (maximum temperature handling: 150°C) for single cables.

Silicone materials, polyether ether ketone (PEEK), perfluoroalkyl silyl mica (or mica), EPDM, polyvinyl chloride (PVC), polyethylene (PE), or ceramic based materials are alternatives for wire insulation in the electronic industry. Alternatives available might not fulfil the thermal/chemical resistance or durability requirements. ECHA reported that it is likely that alternatives can be found for a lot of smaller components used in many categories.

3.2.4 \ Fire protection

Applications/products scope

Fluorinated gases (HFCs) are used for fire protection purposes where their main advantage is that they are non-conductive to electricity (good dielectric properties) and are considered safe for humans to breathe at the concentrations used. In this context, the ability of fire suppressants not to leave non-volatile residues after discharge avoids the potential damage caused by conventional extinguishing agents. This means that fluorinated gas fire suppressants occupy small quantities, when there is a need to protect items that otherwise would be damaged by a fire extinguishing agent, and in enclosed spaces where some other fire suppressants would pose a risk to human health.[23,24]

Fire suppressants may be divided into total flooding agents and local streaming agents. Areas of use include portable and fixed aircraft fire protection systems (engine, auxiliary power units and cargo compartments), as well as specific risk situations (clean-room protection, electronic-, IT- and control room installations mainly in critical infrastructures) including the defence sector.

PFAS are used as flame retardants and anti-dripping additives in polymers in interiors of transportation vehicles. They are also used for fluorine-based firefighting foams formulated and placed on the market in the EU. The different functions (film-forming, surfactants, solvents) are provided by different components of firefighting foams.

[23] Opinion on the Annex XV dossier proposing restrictions on Per- and polyfluoroalkyl substances (PFAS) in firefighting foams, Committee for Risk Assessment (RAC)
[24] Committee for Socio-economic Analysis (SEAC), ECHA, 2023

Table 6: List of PFAS application in fire protection with associated molecules

Applications	PFAS (sub)family involved
Fire retardant coatings and additives in polymers	PTFE, PFA, ETFE, FEP, FEPM, PFPE, PVDF, PFBS, (non-)polymeric PFAS
Fire protection fluids	HCFCs
Semiconductor product/component photoresistance to avoid fire	Fluorotelomer-related compounds
Fire suppressants	Fluorinated gases (Pentafluoroethane, 1,1,1,2,3,3,3-Heptafluoropropane, 1,1,1,3,3,3-Hexafluoropropane, 1-Chloro-1,2,2,2-tetrafluoroethane), HCFCs, 2-Bromo-3,3,3-trifluoroprop-1-ene, Dodecafluoro-2-methyl-3-pentanone, HFCs, HCFCs
Personal protective equipment (PPE) *(see section 3.2.13 \ for details)*	PFAAs including PFAA precursors (side-chain fluorinated polymers) and fluoropolymers (in particular PTFE)
Machinery for production of oxidising chemicals - PFAS-based lubricants to avoid fire / auto ignition / explosion	PTFE
Diving equipment with O2 contact - PFAS-based lubricants to avoid fire / auto ignition / explosion	PTFE
Firefighting foams	C-6 fluorinated substances, 1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-N-[[(gamma-omega-perfluoro-C6-C16-alkyl)thio]acetyl] derivatives, 1-Propanaminium, N-(carboxymethyl)-N,N-dimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino] derivatives, 2-Propenamide, telomer with 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanethiol

Belgian industry

According to Eurostat[25] and StatBe[26] (NACE code C8020), there are approximatively 276 companies in security system and service activities for fire protection on the Belgian territory, with 11 000 in the EU. This information has to be taken regarding the imprecision of subcategory in the security part of report used by ECHA for their inquiry. It is mentioned that the breakdown of the data in these sources is not sufficiently detailed to distinguish specific types of fire-fighting foams (or even foams from other fire-fighting preparations).

Some of the producers of firefighting foams have developed PFAS-free alternatives such as Orchidee Fire, Uniteq, and Dehon.[27]

Volumes (in Belgium)

The estimated volumes of fluorinated gases including HFCs, PFCs and HFOs (and normally HFEs, but their use seems confidential) are classified by type of use (products contained in new manufactured products, stocks and decommissioning) in 2019 for fire-protection (firefighting foams excluded, they are detailed thereafter the table below). The information provided below were used by ECHA and coming from United Nations Framework Convention on Climate

[25] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_1A_SE_R2__custom_7495062/default/table?lang=en
[26] https://bestat.statbel.fgov.be/bestat/crosstable.xhtml?datasource=b9eca8ea-cdbe-4b07-b8ee-6928c406d146
[27] https://echa.europa.eu/documents/10162/28801697/pfas_flourine-free_alternatives_fire_fighting_en.pdf/d5b24e2a-d027-0168-cdd8-f723c675fa98

Change (UNFCCC) report[28] and the F-gas report[29]. We have to mention that aerosols are used through automatic projection of firefighting solution in buildings in case of fire departure.

Table 7: Estimates of PFAS volume used in EEA for the fire protection market

In t/y	Fire protection	Aerosols (non-MDI - Metered Dose Inhalers)	Total fluorinated gases
Manufactured products	863	504	**1 367**
Stocks	20 201	907	**21 108**
Decommissioning	208	N/A	**208**
Total fluorinated gases	21 272	1 411	**23 183**

It has to be noted that 130 tons of fluorinated gases were imported in EU in 2019 for the fire-protection activity and could bring the total fluorinated gases used in fire-protection to 23 313 tons in 2019. No further information was provided for other PFAS compounds used in fire protection, nor their volume in Belgium.

For firefighting foams, concerning the total tonnage of foam used in firefighting foams in the EEA, it is estimated that 14 000-20 000 t/y are produced, and that between 480-560 t/y PFAS are manufactured in EEA for this application[30]; we took 560 t/y as a high estimation in calculations.

The estimated volumes based on Wood and F-gases reports in 2020 used for the fire protection industry for the ECHA inquiry led to 1 367 t/y of PFAS in manufactured products in EEA.

Belgium has a proportion of 3.5% of GDP in EU (€549 billion for a total of €15 700 billion for EU).[31] Using this ratio for extrapolation leads to **67.4 t/y of PFAS in the fire protection industry**, with the following repartition below:

- Fire protection (FG, manufactured products): **30.2 t/y**
- Aerosols (non-MDI): **17.6 t/y**
- Firefighting foams: **16.8-19.6 t/y**

Environmental impacts

Data on emissions of fluorinated gases from different applications have primarily been collected from the GHG Inventory data, estimated based on UN methodology (EEA, 2022). It is to be noted that the GHG Inventory data include HFCs and PFCs, while HFOs, HFEs, fluoroketones, etc. are not considered.

Estimates for HFO emissions have been derived by combining market volumes from the F-gas report and Implied Emission Factors (IEF) derived from the GHG Inventory based on data for market volumes and emissions for HFCs in similar applications. Stock emissions are to be understood as emissions from products and equipment currently in service life.

[28] United Nations Framework Convention on Climate Change, UNFCCC (EEA, 2022), PFAS inventory of 2018
[29] F-Gas Report (EEA, 2020)
[30] Annex XV restriction report, ECHA, Per- and polyfluoroalkyl substances (PFASs), 2023
[31] SPF Economy

Table 8: Estimates of PFAS volume emissions in EEA for the fire protection market

In t/y	Manufactured products	Stocks	Total fluorinated gases
Fire suppressing Agents	1	702	**703**
Propellants (non-MDI)	2	699	**701**
Cover gas	23	N/A	**23**
Total fluorinated gases	26	1 401	**1 427**

For EEA, a volume of PFAS of 1 367 t/y of PFAS in manufactured products in fire protection emits 26 t/y. Emissions extrapolated to Belgium leads to **0.9 t/y of PFAS** in the fire protection industry, as detailed below (production and thus emissions are essentially based on fluorinated gases, other PFAS compounds are marginal):

- Fire suppressing agents: **0.035 t/y**
- Propellants (MDI): **0.07 t/y**
- Cover-gas: **0.8 t/y**

Existing alternatives

(i) For fire suppressants, alternatives have been studied, as water or CO_2, but they suffer from a range of drawbacks, like risk of asphyxiation in the case of CO_2 use, or potential damages to protected assets in the case of water use, and both provided a slower speed of action than fluorinated gases.[32,33]

Price already provides a mechanism favouring alternatives to fluorinated gases and has led to a significant shift in the market where they are not considered necessary. Remaining users include safety critical applications such as fire prevention on aircraft and in military vehicles, and protection of cultural assets, considering the benefits of fluorinated gases sufficient to accept higher prices. Thus, a derogation would be proposed due to the lack of functional alternatives, with a ban and a transition period of 18 months and a 12-year derogation to research and introduce cost-effective alternatives.

Another potential derogation refers to all parts of vehicles where fluoropolymers and perfluoropolyethers are needed to ensure the safety of the vehicles, as no alternatives are currently available (e.g. actuator or engine compartment, fuel system or safety features like airbags, ABS, or fire protection).

(ii) For firefighting foams, alternatives are available. Responses to the ECHA consultation suggest that the main alternatives used could be based on hydrocarbon surfactants, siloxanes and detergents, without providing any precise chemical names or CAS numbers.

Other relevant regulations

For firefighting foams, PFOAs salts (as perfluorooctanoic acid) or PFOA-related compounds (class B fires) will benefit of a 5-years derogation before ban in 2025 and a transition period is still under discussion.[34,35,36]

[32] Appendices to Annex XV Restriction Report: Per- and polyfluoroalkyl substances (PFASs) in firefighting foams.
[33] The use of PFAS and fluorine-free alternatives in fire-fighting foams. Final report, Specific contracts No 07.0203/2018/791749/ENV.B.2 and ECHA/2018/561, Wood
[34] https://www.saval.be/en/news/tightened-eu-regulations-pfas-in-extinguishing-foam/
[35] https://echa.europa.eu/fr/-/proposal-to-ban-forever-chemicals-in-firefighting-foams-throughout-the-eu
[36] https://www.belgielex.be/fr/legislation

3.2.5 \ HVACR: Heating, Ventilation, Air Conditioning and Refrigeration

Applications/products scope

Fluorinated gases are essentially produced for the HVACR sector and used in multiple sub-categories (domestic/commercial/industrial/transport refrigeration, mobile air conditioning (MAC), stationary air conditioning (SAC), heat pumps, domestic/commercial air conditioning and domestic heat pumps for space heating, etc.).

Refrigeration is used in the chemical, pharmaceutical and food processing industries, throughout the supply chain, including manufacturing, storage and transportation. Fluorinated gases are often used in refrigeration equipment where extreme controlled temperatures are required (below -40°C), more specifically in vaccines and biopharmaceuticals manufacturing. Blood banks, medical examination, tissue and cell diagnostics may also rely on the use of fluorinated gas refrigerants. Furthermore, such gases are used in refrigerated laboratory equipment that require precise temperature control over a large temperature range. However, this equipment is usually designed with hermetically sealed systems to avoid leakage, and at end of life, the fluorinated gas is normally collected under controlled circumstances to avoid releases. Low temperature refrigeration also has applications within commercial refrigeration.

HFC-125 and HFC-134a are used as component in refrigerant blends, when HFOs may be used in organic rankine cycle (ORC) technology to generate electricity by recovering waste heat from industrial processes such as glass/ceramics factory and using geothermal energy and biomass. The same technology is also used for cooling purposes in data centres to minimise energy consumption by half compared to current systems and thus enhance energy efficiency.

Foam blowing agents are widely used in household, commercial and industrial settings often to provide thermal insulation, to keep heat out of refrigerated areas, or to prevent pipes from freezing and cracking in cold weather conditions. Foams are also used to fill gaps in buildings to prevent excessive air movements and can be used as a protective and cushioning cover, such as for seat covers or vehicle steering wheels.

Table 9: List of PFAS application in HVACR with associated molecules

Applications	PFAS (sub)family involved
Refrigeration (in blend)	Fluorinated gases (Fluoroform (trifluoromethane), 1,1,1-Trifluoroethane, 1,1,-Difluoroethylene), 3-Ethoxyperfluoro(2-methylhexane), HFC/CO2 blend, HFC/HFO/CO2 Blend, HFC/PFC Blend
Refrigeration and heat pumps (domestic & commercial air conditioning, domestic, industrial, transport refrigeration, electronics cooling, water and space heating heat pumps)	Fluorinated gases (1,1,1,2-Tetrafluoroethane, Difluoromethane, 1,1,1,3,3-Pentafluoropropane, 2,3,3,3-Tetrafluoropropene, Trans-1,3,3,3-Tetrafluoroprop-1-ene, Trans-1,1,1,4,4,4-hexafluorobut-2-ene), 1-Chloro-2,3,3,3-tetrafluoropropene, (Z)-1-Chloro-2,3,3,3-tetrafluoropropene, Trans-1-chloro-3,3,3-trifluoropropene, HFC Blend, HFC/HFO Blend, HFO-1336mzz(Z) / trans-1,2 dichloroethene (1130(E))
Solvents (precision & electronics cleaning, commercial & industrial cleaning and carrier solvent & lubricants), immersion cooling of electronics	1,1,1,2,2,3,4,5,5,5- Decafluoropentane
Fire suppressants	Fluorinated gases (Pentafluoroethane, 1,1,1,2,3,3,3-Heptafluoropropane, 1,1,1,3,3,3-Hexafluoropropane, 1-Chloro-1,2,2,2-tetrafluoroethane), 2-Bromo-3,3,3-trifluoroprop-1-

	ene, Dodecafluoro-2-methyl-3-pentanone, HFCs, HCFCs
Foam-blowing agents, propellants	Fluorinated gases (1,1,1,2-Tetrafluoroethane, 1,1-Difluoroethane, 1,1,1,2,3,3,3-Heptafluoropropane, 1,1,1,3,3-Pentafluoropropane, 1,1,1,3,3-Pentafluorobutane, 1,1-Dichloro-1-fluoroethane, 1,3,3,3-Tetrafluoropropene, Cis-1,1,1,4,4,4-Hexafluoro-2-butene), (Z)-1-Chloro-2,3,3,3-tetrafluoropropene, Trans-1-chloro-3,3,3-trifluoropropene, (E)-1,1,1,2,3,4,5,5,5-nonafluoro-4-(trifluoromethyl)- 2-pentene, (E)-1,1,1,2,3,4,5,5,5-nonafluoro-4-(trifluoromethyl)- 2-pentene, Perfluoro-2-methylpentane
Insulating gas	2,3,3,3-tetrafluoro-2-(trifluoromethyl)-propanenitrile, 1,1,1,3,4,4,4-heptafluoro-3-(trifluoromethyl)-2-butanone
Air conditioning	HFC/HFO Blend

Belgian industry

There are numerous industrial companies in HVACR organised through several professional federations in Belgium: FRIXIS (Royal Belgian Association for Refrigeration and Air Treatment) for cooling and air conditioning, ATIC (Royal Association for Heating, Ventilation and Air Conditioning Technology) for HVAC professionals, ATTB (Association for Thermal Techniques in Belgium) for heat pumps & hot water. They represent about 832 companies in Belgium.

Table 10: Companies active in the HVACR sector in Belgium

FRIXIS[37]	ATIC[38]	ATTB[39]
• Installation and/or service companies: 584 • Suppliers, importers, manufacturers: 47 • WPAC (Warmpac, heat pump model supplier), heat pump suppliers: 9	• 91 actors in the federation of HVAC professionals	• Heating boilers: 18 • System components: 17 (hydraulic), 11 (thermal wall modules), 6 (technical and removal materials) • Heat pump, cogeneration, biomass: 25 (heat pump), 5 (cogeneration) • Solar water heaters: 19

Belgium represents a proportion of 5.5% in the non-domestic cooling and ventilation equipment industry in EU in terms of turnover (€2.92 billion in Belgium for a total of €52.9 billion for EU).[40] For domestic refrigeration, this proportion is estimated to be between 4-4.5% (according to Frixis interview) of the €33.1 billion European market (i.e., €1.41 billon).[41] The Belgian HVACR market is therefore estimated at €4.32 billon.

Volumes (in Belgium)

HFC and HCFC production in Europe is low compared to China and USA, and the HFO production in Europe appears to be hardly existing. Fluorinated gases for the European market are mainly manufactured outside of the EU and imported.

The following table details estimated volumes of fluorinated gases including HFCs, PFCs and HFOs (and normally HFEs, but it seems confidential) by type of use (contained in new

[37] https://www.frixis.be/fr/nos-membres
[38] https://www.atic.be/fr/membres/societe-membres
[39] https://www.attb.be/fr/a-propos-de-attb/
[40] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_IND_R2__custom_7250019/default/table?lang=en
[41] https://www.arizton.com/market-reports/europe-hvac-market

manufactured products, stocks and decommissioning) in 2019 for HVACR. The data provided below were used by ECHA and comes from the United Nations Framework Convention on Climate Change (UNFCCC) report and the F-gas report.

Table 11: Estimate of the PFAS volume used for the HVCAR sector in EEA

In t/y	Manufactured products	Stocks	Decommissioning	Total fluorinated gases
Commercial refrigeration	7 915	90 992	5 717	**104 624**
Domestic refrigeration	122	4 496	671	**5 289**
Industrial refrigeration	2 360	34 358	1 219	**37 937**
Transport refrigeration	1 010	9 915	226	**11 151**
Mobile air conditioning	5 221	115 763	4 647	**125 631**
Stationary air conditioning	7 465	148 791	6 865	**163 121**
Foam blowing agent (closed cell)	4 940	57 635	170	**62 745**
Foam blowing agent (open cell)	271	9 848	N/A	**10 119**
Solvents	N/A	0	N/A	**0**
Other	N/A	267	N/A	**267**
Total fluorinated gases	29 304	472 065	19 346	**520 445**

For PFAS in HVACR systems, according to stakeholder information gathered by ECHA in EU, the following amounts of PFAS containing heat exchange media are used in the HVACR-systems of road vehicles to cool/heat the passenger cabins (ECHA estimation):

- 0.6 kg/personal vehicle
- 1 kg/unit per truck
- 6 kg/unit per bus

For Mobile air conditioning (MACs), considering these ratios, combined with Belgian statistics of new vehicles[42], PFAS in HVACR systems of road vehicles could contain **53.2 t/y PFAS in Belgium**:

- 35 428 new passenger vehicles → 21.3 t/y for Belgium
- 417 new buses → 2.5 t/y for Belgium
- 29 391 new trucks or equivalent → 29.4 t/y for Belgium

The estimation of PFAS quantities in HVACR in Belgium in new products (based on the Belgian share in HVACR in EU as mentioned above and 4.5% share for domestic refrigeration) are decomposed as below, for a total of **984 t/y of PFAS**:

- Commercial refrigeration: **435 t/y**
- Industrial refrigeration: **130 t/y**
- Transport refrigeration: **55.6 t/y**

[42] https://statbel.fgov.be/en/themes/mobility/traffic/vehicle-stock#news

- Domestic refrigeration: **5.5 t/y**
- Mobile air conditioning (MAC): **53.2 t/y**
- Stationary air conditioning: N/A
- Foam blowing agents (closed cell): **272 t/y**
- Foam blowing agents (open cell): **14.9 t/y**

As mentioned above, foam blowing agents are mainly used for commercial refrigeration, but are considered as a separate category.

Environmental impacts

Data on emissions of fluorinated gases from different applications have primarily been collected from the GHG Inventory data, with estimations based on UN methodology (EEA, 2022). It is to be noted that the GHG Inventory data include HFCs and PFCs, while HFOs, HFEs, fluoroketones etc. are not considered.

Estimates for HFO emissions have been derived by combining market volumes from the F-gas report and Implied Emission Factors (IEF) derived from the GHG Inventory based on data for market volumes and emissions for HFCs in similar applications. Stock emissions are to be understood as emissions from products and equipment currently in service life.

Table 12: Estimates of PFAS volume emissions in EEA for the HVCAR sector

In t/y	Manufactured products	Stocks	Total fluorinated gases
Commercial refrigeration	121	9 426	**9 547**
Domestic refrigeration	1	16	**17**
Industrial refrigeration	77	3 603	**3 680**
Transport refrigeration	29	1 312	**1 341**
Mobile air conditioning	78	1 1648	**11 726**
Stationary air conditioning	47	7 411	**7 458**
Foam blowing agent (closed cell)	1 272	2 914	**4 186**
Foam blowing agent (open cell)	45	1 029	**1 074**
Solvents	N/A	11	**11**
Other	0	35	**35**
Total fluorinated gases	1 670	37 405	**39 075**

Manufactured products in HVACR emit 1 670 t/y of PFAS. Extrapolating from the estimation of PFAS quantities in HVACR in Belgium (based on the Belgian share in HVACR in EU mentioned above and 4.5% share for domestic refrigeration) leads to the following estimations:

- Commercial refrigeration: **6.7 t/y**
- Industrial refrigeration: **4.2 t/y**
- Transport refrigeration: **1.6 t/y**
- Domestic refrigeration: **0.045 t/y**
- Mobile air conditioning (MAC): **0.79 t/y**

- Stationary air conditioning: N/A
- Foam blowing agent (closed cell): **70 t/y**
- Foam blowing agent (open cell): **2.5 t/y**

For Belgium, this leads to an **estimated emission of 85.9 t/y** (not including emissions from SAC, for which estimates are not available).

Existing alternatives

In the HVACR domestic sector and heat pumps, R&D is already ongoing, for example by using hydrocarbons for heat pump clothes dryers and refrigerators, and by some manufacturers of AC systems. Shifting to such alternatives would bring an increasing cost of 6-10% for ACs. Propane is cheaper than the fluorinated gases that it would replace, offsetting any price differences for refrigerants.

In the HVACR commercial sector, R&D for using hydrocarbons, CO_2 and NH_3 has already been investigated by some manufacturers of commercial equipments, with a growing acceptance of the use of such alternatives (particularly CO_2 and hydrocarbons).

For industrial heating and cooling, efficient systems based on ammonia (NH_3) have been in place for many years. Other alternatives to F-gases are also practicable for some industrial applications. Three specific types of equipment where identification of alternatives is problematic are identified by ECHA through their enquiry: low temperature refrigeration around - 40 °C for vaccines and biopharmaceuticals manufacturing, laboratory test and measurement equipment and refrigerated centrifuges.

In electronics cooling, large & isolated data centres could be able to use alternative refrigerants such as ammonia without problems. Small systems may be cooled using basic ventilation or small-scale AC systems for which hydrocarbon charge size (C5 - C6 max) would not be problematic.

In HVACR systems in transport vehicles, several alternatives exist (air, water, ethylene glycol, mineral oils, silicone oils, alcohols, natural gases (n-butane, ammonia, CO_2)), but require more developments and adaptation of equipments with a substitution estimated time of 5-11 years.

For foam blowing agents, fluorinated gases are used, alternatives exist but are disadvantaged because of performance constraints linked to fire performance, energy efficiency and durability. Hydrofluoroolefins (HFOs) provide the best level of insulation (the gases contained within the foam themselves providing an effective barrier to heat transfer), other chemicals such as PFCAs, PFSAs, and fluorotelomer-based derivatives could be used; all belong to the PFAS family.

In some applications (e.g. spraying on-site) the use of hydrocarbons would not be permitted given the risk of flammability. According to ECHA, stakeholders claim that low-pressure spray polyurethane foams in self-contained cylinders is a niche reliant on fluorinated gases as blowing agents.

For current derogation proposals:

A 12-year derogation would be reconsidered and was submitted by ECHA in 2020 with a ban and a transition period of 18 months for maintenance and refilling of existing HVACR equipment. Without functional alternatives, the alternative to permitting maintenance including topping up of systems would be to require system replacement. Due to insufficient capacity in the market to carry out this work on a short or medium timescale, drop-in alternatives are not available.

A time-unlimited derogation for refrigerants in HVACR-equipment was submitted by ECHA the same year in buildings, where national safety standards and building codes prohibit the use of alternatives (limiting the use of hydrocarbons, ammonia, or CO_2 as alternatives).

A 5-year derogation is proposed after EiF of the restriction and the 18 months transition period for refrigerants in mobile air conditioning (MAC) systems in combustion engine vehicles with mechanical compressors.

A 12-year derogation is proposed after entry into force of the restriction and the 18 months transition period for potential derogation marked for refrigerants and for mobile air conditioning (MAC) in vehicles in military applications.

A derogation is proposed for a period of 5 years after entry in force of the restriction and the 18 months transition period for refrigerants in transport refrigeration other than in marine applications.

Other relevant regulations

As announced in October 2023, HFCs should be banned in the EU by 2050 (Amendment Directive 2019/1937 2018/0106(COD)).[43] They will be banned in refrigerators from 2026, in certain small heat pumps and certain air conditioning systems from 2027, then in all air conditioners and heat pumps between 2032 and 2035. They will be prohibited in technical aerosols after 2030, and in foams after 2032. It will also be prohibited to export the products concerned outside of Europe.

Additionally, the production of HFCs in the EU will also be completely banned after 2050 (except for the production of semiconductors, considered strategic). It will be drastically reduced from 2036, via a quota system.[44]

3.2.6 \ Medical Devices

Products and application scope

Due to their durability, biocompatibility, thermal, electrical, and chemical stability, PFAS play a critical role in the medical devices industry, serving diverse applications.

PFAS are used in vascular grafts, stent-grafts, and surgical meshes to minimise failure risks and infections while extending implant lifetimes. In heart patches, fluoropolymers reduce complications related to tissue attachment and equipment failure. Low-friction and clot-resistant coatings made from fluoropolymers enhance patient safety and comfort in catheters.[45] Additionally, PFAS enables the production of high-dielectric insulators used in defibrillators, pacemakers, and imaging devices like CRT (Cardiac resynchronisation therapy), PET (Positron emission tomography), and MRI (Magnetic resonance imaging) machines. They also contribute to 3D printing, addressing supply chain disruptions for essential personal protective equipment like certified face masks, and play a crucial role in producing ventilators and COVID-19 test kits.

In the medical technologies sector, PFAS are valued for their properties, including chemical and heat resistance, lubrication, and biocompatibility. PFAS are utilised as components in final medical devices, IVDs (In Vitro Diagnostics)[46], and integral drug-devices combinations, or as processing aids during manufacturing.[47] They play a vital role in achieving high performance and durability in various medical uses, such as gas-permeable lens (RGP) contact lenses, blood contact invasive devices, medication contact components, surgical sutures, treatment of acute and chronic diseases, hernia meshes, medical devices cleaning, surgical drapes, gowns, ophthalmic products, medical tapes, wound dressings, and medical imaging devices. In the realm of IVD reagents and instruments, PFAS are crucial in testing kits for detecting blood

[43] https://oeil.secure.europarl.europa.eu/oeil/popups/ficheprocedure.do?reference=2022%2F0099(COD)&l=fr
[44] https://www.europarl.europa.eu/news/fr/press-room/20230717IPR03026/accord-sur-la-reduction-des-emissions-de-gaz-fluores-dans-l-ue
[45] https://www.fostercomp.com/fluoropolymers-in-medical-catheters/
[46] https://www.satra.com/bulletin/article.php?id=2895
[47] https://news.3m.com/PFAS-in-the-Medical-Industry

coagulation, acting as heat-transfer agents, facilitating in vitro diagnostic assays' surfactant properties, and is used in analytical instruments. Additionally, PFAS serve as coatings on various medical components like dispense tips, tubing connectors, distributors, seals, gaskets, syringe pump valves, O-rings, and sealants.

Below is a table featuring a non-exhaustive list of PFAS that can be used in the manufacturing of medical devices.[48] The corresponding nomenclature and regulatory restrictions are also provided.[49]

Table 13: Per- and polyfluoroalkyl substances (PFAS) used in medical devices area

PFAS	Nomenclature and classification	Application areas	Regulation/restriction program
PVDF	Polyvinylideifluoride *Class:* Polymer *Subclass:* Fluoropolymers, backbone fluorinated polymers	*As coating:* Packaging, hoses, and seals *As material:* Membranes in cochlear implants, handle parts, connectors	Highly monitored and currently not directly regulated, PVDF is influenced by emerging regulations concerning perfluorooctanoic acid (PFOA) and substances related to C9 to C14 perfluorocarboxylic acids (PFCA).
PTFE	Polytetrafluoroethylene Class: Polymer Subclass: Fluoropolymers, backbone fluorinated polymers	*As coating:* guide wires, catheter, stone catcher, polypectomy loops, anti-adhesion coating, handles specular, obturator rods. *As material:* multi-lumen catheter, high purity transfer line, Introducer, working channels in flexible endoscopes, seals heat shrink tubing, insulation of wires, cables and complex electronic components, stents, prostheses, filters.	Highly monitored and currently not directly regulated, PTFE is influenced by emerging regulations concerning perfluorooctanoic acid (PFOA) and substances related to C9 to C14 perfluorocarboxylic acids (PFCA).
PFA	Perfluoroalkoxy Class: Polymer Subclass: Fluoropolymers, backbone fluorinated polymers	The application areas of these polymers are like those of PTFE. Compared to PTFE, PFA has better anti-stick properties and higher chemical resistance, at the expense of lesser scratch resistance.	No specific restrictions
ECTFE	Ethylene Chlorotrifluoroethylene Class: Polymers Subclass: Fluoropolymers	*As coating*: Electrosurgery/ monopolar and bipolar high-frequency surgery, biopsy forceps with high-frequency connection, coagulation probes, papillotomies for use in the high-frequency surgery.	No specific restrictions
PCTFE	Polychlorotrifluoroethylene Class: Nonpolymers Subclass: Polyfluoroalkyl substances	Generally used in IVD reagents & instruments Sealing components, valves and fittings, tubing and catheters, pump components, cryogenic applications, electrical insulation, diagnostic instruments, surgical instruments, implantable devices.	No specific restrictions
ETFE	Ethylene tetrafluoroethylene Class: Polymer Subclass: Fluoropolymers, thermoplastic	Biomedical and labware equipment, including oxygen respirator components, blood analyser valves, evaporating dishes, and centrifuge tubes	No specific restrictions: ETFE is composed of carbon, hydrogen, and fluorine. As for PTFE, it is PolyTetraFluoroEthylene, also consisting of fluorine, but it is made up of long chains of carbon atoms.

[48] An overview of the uses of per- and polyfluoroalkyl substances (PFAS), 2021, Env. Sci. Process Impacts (DOI: 10.1039/d0em00291g)
[49] https://substitution-perfluores.ineris.fr/fr/reglementation-pmtvpvm

FEP	Fluorinated ethylene propylene Class: Polymer Subclass: Fluoropolymers	Commonly used for heat shrink tubes	No specific restrictions
PBSF (PFBS)	Perfluorobutanesulfonyl fluoride Class: Nonpolymer Subclass: perfluoroalkane sulfonyl fluoride (PASF)	Used as surfactant to provide dirt repellence, durability, and moisture resistance, e.g., mixed with silicone: balloon catheters; tubing for feeding, drainage, and use with peristaltic pumps; compression bars; infusion sleeves and test chambers; introducer tips and flexible sheaths. Surgical staples use a PBSF surfactant as a coating to approximate skin for surgical	No specific restrictions (C4-based PFAS) Identified as SVHC (Substance of Very High Concern, candidates for inclusion on the REACH Authorisation List).
FKM/FPM	Fluoroelastomers Class: Polymer Subclass: Fluoropolymers	Seals and gaskets, membranes (resistant to chemicals and harsh environmental conditions), tubing and hoses, diaphragms, fluid reservoirs, valves	No specific restrictions FKM/FFKMs are chemically stable, non-toxic, biologically available, non-water-soluble, non-mobile substances that are judged to have no significant impact on the environment and human health. PFAS REACH regulations should result in the exemption of FKM from any regulatory action.
PFPE (PFEP1, PFEP3, PFEP4, PFEP5)	Perfluoropolyethers Class: Polymer Subclass: Fluoropolymers	Lubricants, oils and water repellents	No specific restrictions
FP ionomer	Fluoropolymer ionomer Class: Polymer Subclass: Fluoropolymers	Dry or humidify breath for anaesthesia and respiratory care as well as for biomedical inserts.	No specific restrictions

Other groups of non-polymeric PFAS, mainly belonging to the perfluoroalkane or perfluoralkyl family, are also utilised in the medical domain as reagents or reaction solvents. Examples include hexafluoropropanol, trifluoroacetic acid, trifluoroacetic acid anhydride, trifluoromethane-sulfonic acid anhydride, trifluorotoluene, and methyl trifluoromethanesulfonate. Additionally, hydrophobic surface treatments involving surface-bound or reacted fluoropolymers of undisclosed composition are used. These products are currently not subject to REACH restrictions.

In addition to PFAS in liquid and solid forms, PFAS in gaseous form are also used in the healthcare sector. Fluorinated gases (F-gases) are a category of chemical solutions composed of very low GWP (Global Warming Potential) hydrofluoroolefins (HFOs) and blends of hydrofluoroolefins. They enable efficient cooling in various healthcare settings, from laboratories to pharmaceutical production facilities, at every stage of the cold chain. Fluorinated gases are used in fixed refrigeration and transportation systems that facilitate the distribution of medicines and vaccines, including in areas where the existing cold chain infrastructure fails to provide alternative solutions. It is essential to define specific temperature set points for medical equipment and vaccine integrity. Refrigeration equipment provides this capability, being able to maintain temperatures ranging from -80°C to +10°C in any ambient conditions. This equipment uses fluorinated refrigeration gases to deliver the performance and reliability levels indispensable to the pharmaceutical industry.

In response to the increasing threat of climate change, innovative alternatives based on hydrofluorocarbons (HFCs) and HFOs have been developed to replace older hydrochlorofluorocarbons (HCFCs) with relatively high Ozone Depleting Potential (ODP) and high-GWP HFCs.

Other instances of fluorinated gases include perfluorocarbons and perfluorotributylamine (non-polymeric PFAS), which were previously utilised in the vapour sterilisation of laboratory and medical equipment. According to the Belgian Federation of the Medical Technology Industry (beMedTech), these PFAS are no longer employed for such purposes. Here are some examples of other PFAS that have historically been used in the vapour sterilisation of laboratory and medical equipment: perfluorodecalin, perfluoromethyldecalin, perfluorotetradecahydrophenanthrene, perfluoroperhydrofluoranthene, perfluoroperhydrofluorene, and perfluorotrialkylamine.

Belgian industry

The Belgian medical technology industry has more than 200 affiliated companies.[50] Manufacturers and/or distributors are divided into five product segments: in-vitro diagnostics (IVD), consumables, implants, medical investment goods (MES), and Extra Muros solutions, including Digital Health. Together they represent over 500 000 technologies (it refers to the diversity and range of medical devices, equipment, and diagnostic tools produced by the industry) for an annual turnover of €2.4 billion (total yearly turnover in Belgium of medical devices/IVD excluding exports).[51]

The total medical technology sector in Belgium including the (made-to-measure) devices that are custom-made (by dental labs, orthotists, prosthetists, …) or sold directly to end-users (such as hearing aids, eyewear, …) represents a total yearly turnover of around €3.5 billion. 38% of companies active in Belgium in medical devices/IVD export one or more of these products outside of Belgium.

Product portfolio (percentage of participating companies indicating that they have at least one product of this category of products in portfolio): 6.6% Para-pharmaceuticals/beauty products, 12.7% Pharmaceutical products, 15.1% IVD, 30.2% Services (inside or outside the hospital walls), 43.4% Medical devices software and/or Digital Health Applications, 67.9% Medical devices – consumables, 45.3% Medical Equipment and systems (medical investment goods), 40.6% Implants.

The table below indicates the percentage of companies active in medical device products per type of activity (headquarters services, manufacturing, distribution, and research and development). It is established that 28% of medical device companies, 10% of in vitro diagnostic (IVD) companies, and 23% of pharmaceutical product companies are engaged in manufacturing activities in Belgium. Additionally, many of these companies operate as distributors, while 10% to 33% of them maintain research and development (R&D) laboratories within the country.

Table 14: Percentage of companies active in medical devices products per type of activity

	Headquarter services (regional or global)	Manufacturing	Distribution	R&D
Activities of the medical device companies	30.0%	28.0%	90.0%.	33.0%
Activities of the IVD companies	15.8%	10.5%	94.7%	10.5%
Activities of the companies active in pharmaceutical products	30.8%	23.1%	100%	23.1%

A significant volume of PFAS-containing products is found in the following categories: IVD (In Vitro Diagnostic), consumable medical devices, medical equipment, and systems (medical

[50] The belgian medical technology industry facts & figures, 2018, BeMedTech
[51] Belgium Medical Devices Report, 2022, BMI

investment goods), and implants. Some wall and floor coverings employ fluoropolymers to allow for aggressive cleaning to help reduce potential sources of infection.

Several industrial sites in Belgium host companies - either Belgian or non-Belgian - manufacturing various products based on PFAS for the medical market, including fabric-supported wipes, and coated fabrics. These companies are in industrial sites in Brussels, Mechelen, Zwijndrecht or Ghent regions with confirmed PFAS pollution (reported PFAS concentration >10 000 ng/kg). The significant use of fluoropolymers in the healthcare industry is proven, and the properties offered by PFAS-based products are currently unmatched. The table below list the activities for which PFAS used have been demonstrated and for which PFAS used is suspected.

Table 15: Activity related to PFAS uses and the manufacture of medical devices in Belgium

PFAS use	Activity
Evidence of PFAS use	Production of high performance chemicals, polymers and plastics (PTFE, PCTFE, …)
	Production of high-end rubber & silicone hoses
	Manufacture of medical devices (IVDs)
	Production and use of consumables and hygiene solutions for the medical and pharmaceutical industry
Suspected PFAS use	Production of packaging for the healthcare industry
	Production of window profiles, flooring tiles, roofing, cladding & sidings, skirting board, pipes & fittings
	Tissue engineering polymers
	Coated textile for medical industry

Volumes (Europe, focus Belgium)

(i) Fluoropolymer used in the manufacturing of medical devices (Europe):

The most used PFAS in the manufacturing of medical devices are fluoropolymers (PFAS polymers). The global medical fluoropolymers market size was valued at $475 million in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 9.2% from 2023 to 2030 ($962 million).[52] The rising interest in cutting-edge medical technology and devices, coupled with increasing healthcare investments in developing economies, is anticipated to boost the market for medical fluoropolymers in the coming years.

The polytetrafluoroethylene (PTFE) product segment leads the market and accounts for more than 65% share of the global revenue (PVDF 21.3%, ETFE 9.6%, Fluoroelastomers ~8%, Others 2%).[53] The PTFE market size is expected to grow from 197 kt in 2023 to 251 kt by 2028, at a CAGR of 4.93% during the forecast period (2023-2028). Europe accounted for 22.6% of total consumption volume in 2023.[54] Approximately €20-35 million in revenue were generated from the sales of fluoropolymer materials and products exclusively used in medical applications in 2020. This revenue corresponds to approximately 5-6 ktons of fluoropolymers sold in the medical sector during that year.

Medical applications such as syringes, tubing, pipes, milled & drilled lab equipment, diaphragms, or microinvasive surgery applications, such as stents, account for around 2-3 ktons of FP materials used for manufacturing.

(ii) Fluoropolymer materials used in the manufacturing of medical devices (Belgium):

[52] https://www.grandviewresearch.com/industry-analysis/medical-fluoropolymers-market-report
[53] https://www.mordorintelligence.com/industry-reports/polytetrafluoroethylene-ptfe-market
[54] https://www.mordorintelligence.com/industry-reports/europe-fluoropolymer-market

Polymers containing fluorine are strongly favored in the medical devices field in Belgium, with PTFE accounting for approximately 65% of the PFAS used.

(iii) PFAS quantities used in processes/products in medical devices manufacturing (Belgium):

Based on information from the Belgium Federal Agency for Medicines, Health Products (FAMHP), the Belgian Medical Technology Industry (beMedTech), and the European Chemicals Agency (ECHA), it is estimated that PFAS, primarily perfluoroalkyl precursors, are employed at a rate of approximately 110 tons per year in Belgium. In addition, fluorinated gases account for a considerably higher volume, totaling an estimated 2 500 tons annually, while fluoropolymers, particularly PTFE, play a significant role with an estimated usage ranging from 500 to 650 tons per year. This last data reflects an estimation derived from ECHA analysis; the information regarding Belgium's PFAS volume lacks official validation. It should be regarded with caution. This corresponds to approximately 10-11% of the ECHA-reported estimated annual PFAS production volumes used in the medical devices industry across Europe. All EU and Belgium PFAS volumes are gathered in Table 16.

Environmental impacts

Based on the amounts of PFAS used in the manufacturing of medical devices, the corresponding emissions were calculated using emission data for PFAS employed in medical device manufacturing in Europe (Table 16). The emissions resulting from the use of PFAS in Belgium were calculated based on the data collected regarding the quantities used. As for the emissions related to the use of PFAS in Europe, they have been recorded by the ECHA.

Table 16: Estimated annual tonnage and emissions from the use phase for PFAS manufacture and major PFAS medical devices use sectors in 2020

Medical devices manufacturing	Estimated annual tonnages		Estimated annual emissions	
	Europe	Belgium	Europe	Belgium
Perfluoroalkyl precursors (t/y)	2 387	110	239	11
Fluorinated gases (t/y)	33 080	2 500	11 825	894
Polymeric PFAS (t/y)	7 633	575	76	6
Total PFAS (t/y)	**43 100**	**3 175**	**5 901**	**515**

In Europe, approximately 23.5 ktons of fluoropolymer waste were collected from various sources, including residential, commercial, and industrial waste. This accounted for nearly 60% of the total fluoropolymer production for the same year. Additionally, 2 300 tons of this waste were generated by the medical device manufacturing sector.[55]

Other relevant regulations

PVDF (polyvinylidene fluoride) in general and PTFE (polytetrafluoroethylene) in particular stand out as two of the most widely utilised fluoropolymers in medical device manufacturing due to their extensive volume usage. Their blend of properties renders them as preferred materials for a diverse array of applications. While they currently lack direct regulatory scrutiny, PTFE faces new regulations pertaining to perfluorooctanoic acid (PFOA), primarily stemming from the irradiation process used to create fine PTFE particles for the coatings industry, which has been found to generate PFOA emissions.[56] Consequently, conventional PTFE will necessitate replacement with low-PFOA content PTFE or PTFE-free alternatives, employing novel low-PFOA PVDF or PVDF-free resins. Furthermore, commencing on July 4, 2023, limitations

[55] Fluoropolymer waste in Europe, 2020, Converso
[56] https://www.lubrizol.com/Coatings/Blog/2020/07/New-PFOA-Regulations-Will-Impact-PTFE

concerning C9 to C14 perfluorocarboxylic acids (PFCAs) will be enforced in textiles employed for oil and water repellency to safeguard workers from hazardous liquids posing health and safety risks. These restrictions will similarly extend to the production of high-performance medical textiles employing PTFE and PVDF.

Existing alternatives

PFAS are used in medical technologies as they have a combination of properties that no other materials/chemicals have enabling strength, flexibility, durability, lubricity, biocompatibility, chemical compatibility (with other device materials, processing chemicals, and sterilant/sterilisation methods), and processability which all allow minimally invasive surgeries. There is currently no viable alternative to the use of PFAS in many medical technologies and their packaging that would deliver similar functionalities or deliver equivalent safety or quality requirements.[57] Certain polymers have been considered as alternatives (Table 17); however, their use remains very limited and falls short of meeting all the specific requirements currently fulfilled by fluoropolymers.

Table 17: PFAS alternatives in medical devices (very limited use, do not fulfil all these special requirements)

Polymer	Application	Description
PEEK	Tubes, catheters, and other hospital material	PEEK catheters are commercially available. PEEK is a stiffer material than PTFE or fluorothermoplastics. PEEK is an alternative for specialty catheter applications. It is biocompatible but it is generally not suitable for uses where longer term (30+ day) contact with tissue or blood is required. As a result, they are inferior to FPs for solutions such as heart patches. Some publicly available evidence suggests that PEEK may eventually be suitable for long-term solutions but is currently comparatively expensive. The sector has particularly strict quality testing and approval procedures, which would delay the appearance of alternatives in the market for the applications where FPs are used
Polyurethane	Tubes and catheters	It is not suitable for steam sterilisation. Higher costs than current solutions. Concerns with clogging are highlighted by users

Replacing PFAS with alternatives will require extensive research, rigorous testing, clinical validations, and regulatory approvals. These processes can take years, if not decades, for each specific device. The time required by the medical technology sector for a transition to PFAS-free materials depends on various factors.

The sector relies on a multi-tier supply chain and often serves as a downstream user of components. Given the absence of a mandatory disclosure requirement for PFAS in the supply chain, the medical technology sector may not yet be fully aware of all PFAS uses in the components they utilise, their manufacturing processes, or their own production activities.

Lastly, the complexity of products incorporating PFAS components and the substantial number of products that may require simultaneous substitution pose additional challenges for companies in this sector.

Therefore, the medical device sector requests sufficient derogation time for the medical technology sector, as no possible alternatives exist for the time being, and the identification of alternatives up until the confirmation of their feasibility and approval of the related changes may take a long time.

[57] Position statement by MedicalMountains GmbH on the proposal for a restriction on per- and polyfluoroalkyl substances (PFASs)

A restriction of PFAS-containing substances within the EU may cause suppliers to terminate their production and hence disrupt the distribution of medical technologies within the EU.[58] Additionally, a shortage of possible alternative materials may arise due to a sudden high demand from several manufacturers.

To illustrate the complexity of the process of identifying and validating alternatives, here are some examples of case studies conducted on various PFAS applications in the medical sector. These case studies were conducted by MedTech Europe[59]:

> **(i) Implantable medical devices.** Fluoropolymer-containing medical devices have been implanted in patients for +45 years safely and effectively. Currently, there are no available alternatives that can match the full spectrum of properties offered by fluoropolymers or boast the successful clinical history that fluoropolymers have achieved. According to case studies conducted on this subject by MedTech Europe, the organisation concludes that introducing new, yet-to-be-discovered alternatives may not adequately meet the diverse needs of the patient population currently benefiting from fluoropolymers. This could potentially lead to unforeseen adverse effects, given the limited historical data available for reference. Replacing materials used in implantable medical devices is an exceedingly complex and resource-intensive effort, particularly when compared to most other applications and industries. The estimated timeline for the development, validation, clinical trials, and regulatory approval of a material substitution in implantable medical devices is approximately 20 years for a single device. Therefore, members of MedTech emphasise the imperative need to obtain exemptions for fluorinated polymer processing aids (PPAs) and the upstream supply chain to ensure the continued production of medical devices containing fluoropolymers.

To illustrate these points, MedTech announced that a high-level materials transition plan has been created to outline what would be necessary to replace fluoropolymer films in peripheral stent graft (endoprosthesis) with an appropriate polymer, including an assessment of the technical feasibility of this substitution. The assumptions embedded in this model include that the facilities currently have the capacity to prototype using current facilities, equipment, and personnel. The model also assumes that there will be no change in product indications, specifications, or performance requirements. Design modifications may be necessary to account for changes in film properties. It should be noted that these assumptions likely underestimate the amount of work required for success. There for the key takeaways from this model are as follows: polymer development (6 years), manufacturing (2 years), and commercialisation (10 years - overlapping with manufacturing) would require a minimum total of 16 years (best-case scenario).

> **(ii) Equipment for organ replacement (active medical devices).** The challenge of addressing PFAS concerns in complex medical equipment is exemplified in devices that serve as life-support systems for patients experiencing acute or chronic organ failure. A spot-check conducted by a single manufacturer unveiled the presence of over a hundred distinct components, many of which consist of various fluoropolymers, including biocompatible elements like valve components. Moreover, industry-standard components such as O-rings, batteries, and electronic parts are likely to be impacted, further compounding the intricacies. Beyond active medical devices, PFAS play an indispensable role in the production and packaging of essential single-use disposables. The evaluation of potential alternatives necessitates a meticulous examination of each component, accounting for specific technical and regulatory requirements. Material alterations frequently affect production tools, significantly extending the requisite time and effort. It is imperative to consider even discontinued products, as these devices have a lengthy operational lifespan and must be maintained for approximately a decade after production ceases. MedTech emphasises the fact that substituting PFAS, if feasible, is a time-intensive endeavour, with past experiences

[58] Regulatory management option analysis for fluoropolymers, 2021, PlasticsEurope
[59] MedTech Europe, PFAS Briefing, 27 February 2023

indicating a timeline of over six years. The resources necessary for technical qualification, biocompatibility assessments, and regulatory affairs for numerous parallel substitution projects within this short timeframe are currently inadequate, an argument on which this organisation relies to advocate for an exemption regarding the use of PFAS in active medical devices). Furthermore, the analysis of potential alternative materials, design modifications, and tool changes can only commence after identifying a component as PFAS-relevant. The complexity of active medical devices, composed of thousands of components and materials, further complicates matters, especially when components are designed and manufactured in-house or sourced through multi-tier supply chains. The extent of the issue and the low PFAS restriction thresholds have resulted in incomplete PFAS disclosure and limited data availability, primarily evident in cases where fluoropolymers are explicitly specified.

(iii) In-vitro devices (IVDs). IVD analytical equipment: polymeric PFAS materials, including PTFE, Kynar, FFKM, PVDF, FEP, Viton, etc., have essential use applications in IVD analytical equipment. These primarily are within the fluidic pathway of the analysers. Specific examples include tubing and O-rings. One example is for dispensing accurate volumes of liquid reagents. Referring to a case study presented by MedTech, while using non-PFAS materials, the coefficient of friction of the dispensing material was so high that it would wick away the liquid reagent and an inaccurate volume would be dispensed for the reaction, leading to inaccuracies in diagnostic test results. Another example is the use of tubing and O-rings in the fluid pathway of the diagnostic instrument. Previous use of non PFAS materials have led to premature failure of the components, leading to increased downtime which ultimately result in delayed patient results. For both of these presented use cases, there are no known alternative materials that can perform the same task by providing the same properties. According to the medical technology sector, a substantial period (>13 years) is essential for identifying a suitable replacement material and completing the replacement process, including the necessary validations and regulatory approvals, where applicable, for each PFAS use case in the IVD instrument. Any necessary modifications to tubing or electronic components currently containing PFAS would have a cascading impact, potentially affecting over 100 IVD laboratory diagnostic devices and the entire laboratory systems portfolio. These devices collectively account for over 650 million tests conducted annually in the EU.

(iv) IVD reagents: PFAS are used in hemostasis testing kits (at extremely low concentrations and volumes) for detecting blood coagulation. They are also utilised as heat-transfer agents in IVD clinical chemistry diagnostic testing instruments, a critical component for the proper functioning of these instruments. The presence of PFAS in these instruments is essential for maintaining the optimal temperature of the reaction cuvette, ensuring that the detection reactions for diseases or conditions occur under the ideal conditions to produce accurate patient results. Manufacturers of IVD reagents and system fluids are bound by regulatory design change procedures, which can take anywhere from 3 to 12 years to complete to ensure compliance with safety and performance standards. Furthermore, these changes must undergo regulatory approvals in each country where the products are sold, a process that can extend up to 42 months for a single substance, the time estimation is only for one PFAS compound. According to MedTech, in the event of a potential ban on a group of PFAS compounds, which could encompass thousands of substances, the redesign process could span beyond 12 years when applied to multiple products. The minimum approval time for materials in contact with blood or similar critical applications is approximately 3 years and may even exceed this timeframe, especially if local registration updates necessitate additional clinical studies.

Other examples of IVD devices, such as Blood Glucose Meters (IVD) for diabetes treatments, face similar substitution limitations, indeed, the extensive and lengthy design change processes required for material replacement can be particularly time-consuming, even if a material with comparable properties is identified.

(v) Prefilled syringe stopper - A device constituent of an integral drug-device combination: glass prefilled syringes are widely utilised with approximately +200 drugs in prefilled syringes sold annually in the European Union. Many of these drugs utilise PFAS (ETFE) coated stoppers due to their sensitivity, serving as a vital barrier against extractables from rubber stoppers and reducing the risk of interactions between the rubber and drugs during shelf-life. A non-coated stopper led to health issues due to interactions with rubber extractables. For sensitive drugs, immediate substitution of PFAS-coated stoppers with PFAS-free alternatives is not feasible. There are currently no PFAS-free stoppers on the market with equivalent properties, particularly regarding extractable impurities. MedTech asserts that without a derogation, European citizens' health could be severely impacted, leading to shortages of key drugs (+200 biologics with PFAS-coated stoppers on the EU market). It would also hinder innovation and the launch of new drugs in Europe, with an estimated +100 biologic drugs in clinical trials expected to use PFAS-coated stoppers in prefilled syringes. According to MedTech Europe a minimum 12-year derogation is necessary due to the mandatory redesign. It is estimated that 240 to 480 million units of PFAS-coated stoppers are used in the EU market for marketed drugs and clinical trials. The transition to PFAS-free stoppers will require significant time and investment, involving the conversion of manufacturing equipment for rubber stoppers and pharmaceutical filling drug lines. Redesign efforts are underway, but the substitution process is expected to take more than 12 years, including an unknown redesign timeline (estimated at a minimum of 4 years), stability studies (3 to 5 years), manufacturing qualification (9 months), regulatory approvals from both the device and drug sides (2 years), and industrial ramp-up (6 months).

(vi) Immunoassay cartridges: the present packaging of the immunoassay cartridges utilises a transparent, molded container made of PCTFE. These devices exhibit a significant susceptibility to moisture, and it will be essential to conduct a thorough assessment of their prolonged exposure to moisture before proceeding with the implementation. The complete process, including selection, characterisation, and validation, is anticipated to span a timeframe ranging from 5 to 10 years.

(vii) Intensive care devices and systems: intensive care ventilators, anaesthesia machines, incubators, patient monitoring systems, medical media supply systems, and hospital gas management systems will be affected by the PFAS restriction. In these products, fluoropolymers like PTFE, PVDF, PFA, and FKM are key materials within components such as hoses, seals, and other gas-carrying parts, electrochemical sensors, lubricants, and valve coatings. These materials are useful primarily due to their resistance to aggressive media. Given the current state of knowledge, it is uncertain whether alternative materials that fulfil all necessary requirements will emerge, as this is subject to the constraints of chemical-physical laws. Due to the high cost, fluoropolymer materials are only used where necessary. In addition, medical technologies are strictly regulated under sectorial legislation and where changes in the chemical or material composition occur, long validation processes are triggered. Currently, there are no alternatives that meet all these properties and/or have a successful clinical history.

Despite efforts to find alternatives, there are currently no suitable replacements that can meet the specific needs of the medical industry as effectively as fluoropolymers. Substituting PFAS with other materials is a complicated and time-consuming process, involving extensive research, thorough testing, clinical trials, and regulatory approvals. The medical technology sector faces difficulties in identifying and adopting alternatives because of the complex supply chains, strict regulations, and the intricate nature of products that use PFAS components. As a result, the medical device industry is requesting an extended transition period, recognising the current lack of viable alternatives and the lengthy process required to confirm feasibility and gain approval.

3.2.7 \ Metal Processing

Applications/products scope

PFASs are used in (i) metal plating processes and (ii) in the manufacture of metal products, both ferrous and non-ferrous. Applications and PFAS molecules are summarised in the table below.[60,61]

Table 18: Application and uses of PFAS in metal processing with the associated molecules

Process	Applications	PFAS
Metal plating	- Mist suppressants, lowering surface tension or non-foaming surfactants in plating solutions (chromium, nickel, copper coatings or platings) - Fluoropolymers onto steels for surface protection	6:2 FTS (mostly) Fluoro-based sulfonates: derivates of PFBS, F-53, F-53B, PFOS Perfluoroalkyl phosphinic acids Perfluorohexanesulfonamides
Manufacture of metal products	- Inhibit the formation of acid mist - Treatment of coatings of metal surfaces - Processing of aluminium - Cleaning of metal surfaces - Anti-stick coating and anti-stick parts in silicone moulding processes	Perfluoroalkyl and derivates Trifluoromethyl and derivates 6:2 FTS PTFE, PVDF, HFP, PCTFE, ETFE

Metal plating (e.g. electroplating) is used for corrosion inhibition and radiation shielding; to harden, reduce friction, alter conductivity, and decorate metallic structures and objects. PFAS are used to lower the surface tension of the plating mixture (wetting agent) and to decrease aerosol emissions (mist suppressing agent). Their benefits come from their high stability in acidic or basic solutions.

Chrome plating, which comprises functional/hard plating and decorative plating, is one of the most widely used industrial process. In chrome plating, PFOS was commonly used at a concentration of 5–10% to limit the development of bubbles and the emission of hexavalent chromium (i.e., Cr (VI)) aerosols into workplace air.[62,63] The ban of PFOS led to the substitution with 6:2 fluorotelomer sulfonate (6:2 FTS also known as H4-PFOS) at concentration usually between 1% and 3%.[64] However, the use of PFOS as a mist suppressant for non-decorative hard chromium plating in closed loop systems is still allowed (POP Regulation, EU 2019/1021) but remains marginally used.

Hard chrome plating is specially driving the demand for PFAS uses in the treatment of metal surfaces. Thickness of hard chrome plating ranges from 2 to 250µm, and provides very high hardness, up to 1 100 HV (Vickers hardness).[65,66] Hard chrome plating is used to protect structural parts and machinery (e.g., cylinders, rollers, cutting tools) for the aircraft, shipbuilding and automotive industries, papermaking industry, or for defence purposes.

According to the FPG survey, fluoropolymers are not sold into the chrome plating industry[67]. A survey conducted by the German Environment Agency in 2022 showed that chrome plating and plastic electroplating are achieved with 6:2 FTS-containing wetting agents, with no other PFAA

[60] https://www.haleyaldrich.com/wp-content/uploads/2020/08/HA-Technical-Update-PFAS-in-the-plating-industry.pdf
[61] Annex XV restriction report, ECHA, Per- and polyfluoroalkyl substances (PFASs), 2023
[62] https://pfas-1.itrcweb.org/2-6-pfas-releases-to-the-environment/
[63] https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2022-03-02_texte_13-2022_best-available-techniques-pfos-substitution.pdf
[64] Best available techniques for PFOS substitution in the surface treatment of metals and plastics and analysis of alternative substances to PFOS when used in equipment for chromium plating and plastic etching, 2022, German Environment Agency
[65] https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-hard-chrome-plating
[66] https://www.icdacr.com/wp-content/uploads/2022/10/ICDA_The_strategic_importance_of_Cr_plating.pdf
[67] The fluoropolymer industry in europe a socio-economic perspective, 2018, PlasticsEurope

or PFAS used (see footnote 64). Information on the use of fluorinated substances in tin, copper and nickel-plating processes is limited.

In the manufacture of metal products, fluoropolymers are used to lower the surface tension, to promote the flow of metal coatings or to inhibit the formation of acid mist, to inhibit corrosion on steel and to improve the life of baths.

Belgian industry

VOM, the Belgian association for the surface treatment of materials, brings together around 260 companies. The association has only very limited knowledge on PFAS and seems unaware of its uses. According to VOM there are currently no uses of PFAS during metal plating or hard chrome plating. According to Eurometaux (the European non-ferrous metals association), the metal surface treatment companies in Belgium are about a hundred; almost all of them are small businesses and are indeed using PFAS. Electroplating is the process using the largest amount of PFAS, but Eurometaux estimates that "*95% of the industrial companies do not know they are using it*" which is in accordance with VOM statement.

The Forever Pollution Project and the European Environment Agency E-PRTR database list 31 locations in the Belgian territory were PFAS are probably used in the treatment and coating of metals. Most of the industrial sites are specialised in the automotive market. Other companies are specialised in firearms production, aerospace, steel manufacturing and surface treatment. The activity of these companies suggests they are achieving hard chromium plating. They are rather mid-market or large enterprises, suggesting a larger number of companies involved in the treatment of metal surfaces. According to Eurostat, the treatment and coating of metals gathers 494 companies in Belgium.

The Forever Pollution Project and the European Environment Agency E-PRTR database also lists 5 locations in the Belgian territory were PFAS are probably used in the manufacture of metal products.

Table 19: List of activity suspected to require PFAS in Belgium

Activity
Recycling of nickel, copper, lead and antimony containing products
Refining of secondary zinc feed materials
Production of molybdenum-based material
Refining and recycling of precious metal

Volumes (in Belgium)

Eurometaux suggests that PFAS uses are widespread in metal processing, with most of companies using PFAS without knowing. Therefore, a worst-case scenario and volume have been adopted. According to ECHA, approximately 57 tons of PFAS (worst-case scenario) are used in metal plating in the EEA per year and 960 tons of PFAS are used in the manufacture of metal products. At the European scale, information on the concentration of PFAS, the production volume or import and export of these PFAS are not available. To estimate the Belgian production volumes, an industrial turn-over ratio has been applied (see Table 20 below).

Table 20: Estimate of the PFASs volume used in metal plating and manufacture of metal product in Belgium

Activity	Europe		Belgium	
	Turn-over (million €)[68]	PFAS volume (t/y)	Turn-over (million €)[68]	PFAS volume (t/y)
Treatment and coating of metals (2020)	31 700	57	921	1.7
Manufacture of fabricated metal products (2019)	500 000	960	13 401	25.7
Total				27.4

In Belgium, the metal plating processes uses approximatively 2 tons of PFAA per year (6:2 FTS) and the manufacture of metal products requires 25 tons of FPs.

Environmental impacts

Chromate solutions containing mist suppressing agents have a limited usage lifetime and have to be regularly changed. Emissions of PFAS during metal plating processes originate from the rinsing steps, de-chroming plating and replacement & management of used solutions containing 6:2 FTS (i.e., sludge). PFAS, alongside with heavy metals (e.g., Cr(VI)) and other toxic compounds, are removed from the used electrolytic solution via ion exchange membranes. About 20% of this solution is lost during its lifetime, causing release of PFASs into the environment: 50-85% via wastewater, 0.1-24% via waste and <0.1% via exhaust air (ECHA). The Belgian emissions of PFAS during the chrome plating process are summarised in the following table.

Table 21: PFAS emissions during the chrome plating process, according to the ECHA ratio

	Wastewater	Solid waste	Air	Total
Emissions of PFAS (t/y)	0.17-0.28	0.01-0.08	< 0.01	0.33

Emissions of the Belgium chromium plating industry reaches 330 kg of PFAA per year, mostly through 6:2 FTS releases in wastewater. Information on emission of fluoropolymers during production and use of metal products is not available.

Existing alternatives

The study from the German Environment Agency reviews the different PFAS alternatives and their market shares in the chromium plating industry in Germany. The use of PFOS have been established as currently non-significant (<0.1 t) and the use 6:2 FTS is the standard procedure for hard chrome plating.

Three main categories of alternatives exist:

(i) Fluorine-free mist suppressants

They are based on oleylamine ethoxylate only or mixture containing oleylamine ethoxylate and derivatives. Fluorine-free agents are exclusively used in decorative chromium plating solution and represent more than 75% of volume of mist-suppressants. Meanwhile, Atotech recently claimed to commercialise the "*First fluorine-free, non-PFOS, non-PFAS fume suppressant*" for both hard and decorative chrome plating.[69]

[68] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_IND_R2__custom_7428077/default/table?lang=en
[69] https://www.atotech.com/products/general-metal-finishing/wear-resistance/functional-chrome-coatings/fumalock/

(ii) Other wet-chemical processes.

The main wet process alternative rely on the use of Cr(III) electrolyte solution - instead of Cr(VI) – in which PFAS can be dispensed with. The trivalent chromium plating is far more complex (maintenance-intensive and personal-intensive process, complex wastewater management). Once again, in hard chromium plating, the state of development in replacing chromium VI processes with chromium III processes is significantly less advanced. However, in various applications, hard chromium coatings can be replaced by nickel-based wet coatings.[70]

(iii) Other physical processes.

Among them are (i) high-velocity flame spraying for coating rotationally symmetrical or flat component, (ii) PVD of hard coatings based on titanium nitride, titanium carbonitride, titanium aluminium nitrite for aerospace industry or plasma nitriding for complex geometry.

Despite these known alternatives, according to Eurometaux, there is no technically fully acceptable alternatives for hard chromium plating. Main difficulties are raising from the toxicity of the fluorine-free alternatives (GHS05 - Corrosive, GHS07 - Harmful, GHS08 – Health hazard and GHS09 - Environmental hazard), the high concentration of fluorine-free alternatives and challenging wastewater management. Obviously, phasing out PFAS in chrome plating is not straightforward, especially for hard chrome plating. However, alternatives can be implemented on a case-by-case basis for various applications.

Other relevant regulations

Hexavalent chromium, often referred to as Cr(VI), has harmful effects on human health and the environment (GHS07, GHS08 and GHS09).[71] Under REACH, hexavalent chromium is considered a Substance of Very High Concern (SVHC) and its uses are subject to separated authorisation. By May 2021, the European Commission granted authorisations to over 1,000 industrial sites for functional chrome plating and surface treatment.[72] There is currently no full restrictions on Cr(VI) use for surface treatment. However, year after year, authorisations are harder to obtain with (i) a limited scope for the authorisations and (ii) more evidence of safe use required.[73] With more stringent regulations on Cr(VI), it is likely that PFAS containing mist-suppressant would have more confined use with limited associated volumes.

3.2.8 \ Paints & Coatings

Applications/products scope

PFAS-containing paints, coatings, varnishes, lacquers or inks are widely used in the construction, industrial, transport and energy sectors. All these products will later be referred to as paints & coatings (i.e., P&Cs). Products out of this scope include anti-reflective coatings and cable and wiring coatings (see *Semiconductors* and *Cables* sections).

The majority of PFAS used in P&Cs are fluoropolymers (FPs) such as polytetrafluoroethylene (PTFE), polyvinylidene difluoride (PVDF) and fluoroethylene vinyl ether (FEVE). FPs are added in various coatings to provide resistance to corrosion, weathering, abrasion, scratching, and overall provide high durability. There are a few exceptions: (i) short-chain PFAS (perfluoroalkane sulphonic acids (PFSAs)) and pefluorocarboxylic acids (PFCAs)) used in paints and acting as

[70] https://www.imts.com/read/article-details/Chrome-VI-Ban-Offers-Challenges-and-Opportunities/1674/type/Read/1
[71] Substance information on Cr(VI) from ECHA
[72] https://echa.europa.eu/sv/-/chromium-trioxide-widely-used-in-plating-and-surface-treatment
[73] https://curia.europa.eu/juris/document/document.jsf?text=&docid=272682&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=456092

levelling, wetting and anti-blocking agents and (ii) side-chain fluorinated polymers (SCFP) mostly based on siloxane chemistry.[74,75,76]

Harsh environments, typically outdoors protective applications, are more likely to involve PFAS-based coatings. The different uses of PFAS, along with the molecules involved are summarised in Table 22.

Table 22: PFASs application ans uses in the paint & coating sector with associated molecules

Industrial sector	PFAS uses	PFAS
Construction	- Architectural paints (ensure long lasting and weathering resistance of buildings) - Wetting agent for wood substrate coatings, varnishes and lacquers - Glass surface treatment (windows, mirror) for non-stick properties and durability - Decorative paints - Anti-graffiti coatings	-PTFE, PVDF, ETFE. Those FPs account for 97% of the reported total usage of polymeric PFAS in the construction sector. -Acrylate-, urethane- and siloxane-based SCFP -Fluorosurfactants
Industrial	- Anti-corrosion or anti-sticky coatings for industrial production equipment (food, feed, chemical or pharmaceutical products). One of the main uses for PFAS in industrial applications is in food and feed processing lines where PFAS (polymers) provides non-stick properties to conveyor belts. -Protective coatings for the power and mining industries	- PTFE or PVDF.
Transport	- Coatings of automotive filters and braking hoses. - Aircraft interior and exterior coatings - Glass surface treatment of windows or windscreens for non-stick properties (water, stain, dirt repellency). - Vehicle painting and brightness enhancement.	-PFPE, PTFE, ETFE -Fluoroalkylsilanes,
Energy	- Glass surface treatment of solar panels and photovoltaic cells for non-stick properties (water, stain, dirt repellency). - Protection of wind turbine blades and off-shore structures	- PVDF, ETFE, FEVE, PFPE - Perfluorobutane sulphonamide
Packaging	-Ink	- PTFE

Belgian industry

At the European scale, P&Cs with or without PFAS are mainly used in the construction (58%), industrial (19%) and automotive (9%) sectors.[77] The European P&C market is estimated to be €39.4 billion.[78]

According to different sources, the Belgian paints and coatings sector is valued at €2.1 billion (5.2% of the European market), employing around 3 300 people in 100 companies, representing

[74] Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs), Report on the Commercial Availability and Current Uses, 2022, OECD
[75] Fluoropolymer Product Group of PlasticsEurope Update of market data for the socioeconomic analysis (SEA) of the European fluoropolymer industry, 2022, Wood
[76] https://www.chemours.com/en/-/media/files/corporate/pfas/fluoropolymers-aerospace-fact-sheet.pdf?rev=c22fa007b13a48a5b313483fc9c04a33&hash=5DF429038AAA9F87801EAC6A4D303BDE
[77] https://ceresana.com/en/produkt/paints-and-coatings-market-report-europe
[78] https://www.european-coatings.com/news/markets-companies/tough-times-at-the-european-coatings-market/

approximately 25 production sites. This market is ranked 7th in Europe in 2023 and has declined 1.8% (in value) per year on average between 2018 and 2023.[79,80,81]

The Belgium IVP Coatings Federation distinguishes 6 main applications and sub-sectors for the Belgian industry. Description of the sub-sectors and examples of production sites are detailed in the following table.

Table 23: Belgium P&Cs sector segmentation with application and example of companies and estimated PFAS uses according to IVP Coatings

Sub-sector	Description	Belgian industry size	PFAS uses
Car refinishes	Bodywork protective coatings and paints for damaged vehicles	++	Presumably not
Decorative coatings	Architectural paints, including anti-graffiti coatings	++++	Known
Liquid waterproofing systems	Protective construction coatings, roof-coatings	+	Presumably not
Industrial & transportation protective coatings	Coatings dedicated to automotive industry, chemical and food production plants, boat and offshore structures, bridges and engineering structures, port facilities and wind turbines.	+++	Known – Prevailing PFAS uses for the Belgian P&C industry
External Thermal Insulation Composite System	Thermal insulation systems for external walls that incorporate decorative and/or protective coatings	+	Presumably not
Printing Inks	Flexography, screen printing, gravure	+	Known – PTFE

According to IVP Coatings, PFAS are mainly used in industrial protective coatings. IVP estimates that PFAS-containing P&Cs represents less than 10% of the Belgian turnover. In Belgium, PFAS are being used by about 5-10 companies. PFAS uses have been reported for the following applications:

- Aeronautical coatings to reduce wind friction
- Wind turbine blade coatings to reduce wind friction
- Interior coatings of paint containers to ease the product removal and limit losses
- Inks: PFAS protects the printed surface when manipulated

PTFE is the only PFAS used in Belgium for the production of ink. No other Belgian-specific information on the molecules used was found. For car refinishes, thermal insulation and liquid waterproofing systems, no evidence of PFAS uses in Belgium have been reported. Nevertheless, PFAS could be used in these P&Cs as it is the case at the European scale. Indeed, architectural paints or automotive coatings are known to incorporate significant amounts of FPs, alongside with SCFPs and non-polymeric PFASs.

A study by BlueQuark Research and Consulting estimates that the Belgium paints & coatings imports and exports are valued at €133 million and €85 million in 2020, respectively.[82] However,

[79] IVP Coatings
[80] https://www.ibisworld.com/belgium/industry-statistics/paint-coatings-printing-ink-manufacturing/14589/
[81] https://www.statista.com/forecasts/389486/manufacture-of-paints-varnishes-and-similar-coatings-revenue-in-belgium
[82] https://www.bluequarkresearch.com/reports/belgium-paints-and-coatings-industry

IVP-Coatings and its 61 members claim to export 75% of the production with no available importation value. Finally, data on Belgium from the Observatory of Economic Complexity (OEC) indicate that paints, dyes and varnishes import and export reach €2.64 and €2.81 billion. For the following P&Cs and PFAS volume estimates, we supposed that both import and export are valued at 75% of the Belgium production.

Volumes (in Belgium)

No estimates of the volume of paint and coating production in Belgium are available. The European consumption amounted to 9.23 million tons in 2021.[83] With 5.2% of market share and assuming similar industry and products, the Belgium P&Cs consumption can be established at 478 000 tons. The estimates have been calculated independently for the 5 different industrial sectors.

Table 24: Estimate of the PFAS volumes of the Belgian P&Cs market

Sector	Estimation method	PFAS volume estimate in P&Cs	Approximation
Construction	ECHA estimates that construction products use 8 939 tons of PFAS per year. Plastic Europe indicates that the most common uses of fluoropolymers in the construction sector are coating applications with an estimation that 81% of the FPs are used for the formulation of "construction liquid mixture" such as paints. Therefore 7 242 tons of PFAS are supposed to be used for construction P&C production at the European scale. Belgium volumes have been estimated assuming that Belgian P&C market represent 5.2% of European market	376 t/y	-Mismatch between Europe and Belgium construction sectors. *Overestimation* -No PFAS reported uses have been identified for the production of liquid waterproofing and external thermal insulation system
Industrial	The ECHA proposal for PFAS restriction estimates that "Industrial food production and pharmaceuticals, drinking water and beverage production" leads to a volume of 3 000 tons of PFAS. Those kinds of protective industrial coatings are produced in Belgium. Belgium volume have been estimated assuming that Belgian P&C market represent 5.2% of European market	156 t/y	-Mismatch between Europe and Belgium industry *Underestimaton* -Missing contribution of the chemical, material production equipments -Missing contribution of the protective coatings applied in transportation infrastructures.
Transport Automotive	According to ECHA, about 500 t/y of PTFE are used for automotive interior protective coatings (e.g. hoses coating). Belgium volume have been estimated assuming that Belgian P&C market represent 5.2% of European market	26 t/y	-Mismatch between Europe and Belgium aerospace sector. *Underestimation:* -Missing volume destinated to automotive paints and glass surface treatment -Missing volume destinated to glass surface treatment
Transport Aerospace	According to the European FP product manufacturers, 2% of the FPs are used by the aerospace industry. Assuming ECHA volume of 277 684 t FPs uses, the European aerospace industry accounts for 5 554 tons. This volume also includes wires, cables, electronics	72 t/y	-No information on the relative volume of P&Cs in the aerospace sectors -Mismatch between Europe and Belgium aerospace sectors.

[83] https://ceresana.com/en/produkt/paints-and-coatings-market-report-europe

	systems, sealing and gasket. No information on relative uses quantity was found. Belgium volume have been estimated assuming that Belgian P&C market represent 5.2% of European market		
Energy	ECHA estimates that 3 049 tons of PFAS are used in this sector, including 1 600 tons for the battery production. 1 449 t/y are used for coating of PV cells and wind blades, alongside with several out of the scope uses: filters and gasket in power plants, fuel cells membranes, pipes, tubes, lubricants for wind turbines, switchgears… No information on relative uses quantity was found. We hypothesised that 25% of this quantity (362t) is used in coatings of PV cells and wind blades. Belgium volume have been estimated assuming that Belgian P&C market represent 5.2% of European market	19 t/y	-Mismatch between Europe and Belgium energy sectors. -Missing information on the relative volume of P&Cs in the energy sector
Packaging	According to the ECHA stakeholder's surveys, about 500 t/y of PTFE wax or micro-powder are used. Belgium volume have been estimated assuming that Belgian P&C market represent 5.2% of European market	26 t/y	-Mismatch between Europe and Belgium packaging sectors.
Total		675 t/y	- Overestimation of the PFAS volumes of construction sector - Missing volume of the ink Belgian production

The Belgium industry of P&Cs is supporting the production and import of PFAS, with an estimated volume of 675 tons. Since the construction volume might be overestimated, this PFAS use is likely to be a high-volume scenario. Without the construction input (low-volume scenario), the estimated PFAS volume only reaches 299 t/y.

According to the European FPs producers, 12% of the FPs are used to produce coatings. ECHA and the European FPs producers have both estimated the total FPs uses in 2020 at 277 684 and 40 000 tons respectively, suggesting Belgian volumes of 1 733 and 250 tons of FPs. Therefore, **the estimate of 675 tons per year seems more likely.**

With 478 000 tons of P&Cs consumed in Belgium, it can be assumed that the Belgium P&Cs contain an average of 0.14% PFAS. A more realistic approach is to consider that most of the decorative paints are PFAS-free when other specific protective coatings contain a few percents of PFAS.

Main contributions are coming from the construction, industrial and transport sectors, and to a lower extent from the energy sector. The construction contribution is probably overestimated, since only a few elements indicate that PFAS are indeed used.

As the import and export shares are considered as equivalent, the Belgian production and use quantities are supposed to be the same. Differences between imported and exported P&Cs could not be taken into account.

Environmental impacts

Four basic life-cycle stages are considered in which emissions may occur: formulation/production, application, service life and waste management. Very high emissions are coming from PFAS releases during the application stage (e.g. by spray, roller, cloth, brush, dipping, etc.). The production and application stages are considered as non-significantly different for the 3 sectors (construction, industrial and transport). On the other hand, the service life of the coating and related emissions undergoing during abrasion, erosion or weathering are considered separately. Emissions are summarised in Table 27.

(i) Production & application stages

ECHA proposed a methodology to estimate the emissions rate during the production and application stages of "*construction liquid mixture*". This same methodology and ERC are applied to the Belgian volume (675 tons).

Table 25: Estimate of the PFAS emissions during the production and application stage of paint & coating in Belgium

Production stage	PFAA (t/y)	SCFP (t/y)	FP (t/y)	Total (t/y)
Formulation	0.76	0.05	11.8	12.6
Application	10.1	0.76	189	200
Total	10.2	0.8	201	213

The PFAS emissions during the production and application stages of P&Cs reach 213 tons, most of them are FPs emissions during the application stage (> 90%).

(ii) Service life

1.Construction

According to the ECHA methods and ERC, 2.5 tons of PFAS are emitted during the use stage of paints & coatings in Belgium.

Table 26: Estimate of the PFAS emissions during the service life of paint & coating used in construction in Belgium

Production stage	PFAA (t/y)	SCFP (t/y)	FP (t/y)	Total (t/y)
Service life	0.09	0.01	2.43	2.5

2.Industry

According to ECHA, European emissions during use of food, feed and pharmaceutical industrial equipment are very low and could be negligible (<1 ton). Emissions in the use stage are expected to be low unless equipment is improperly used, for example scratched or overheated.[84,85]

3.Transport (Automotive)

Emissions were estimated based on the ECHA methodology. With an average service life of 11.9 years and 556 000 new automobile registration in Belgium, emission during life and waste stage is 5 tons of FPs per year.

4.Transport (Aerospace)

No data was found on the emission of PFAS during aircraft uses. Emissions are estimated as very low and calculation pointless.

[84] Raman imaging for the identification of Teflon microplastics and nanoplastics released from non-stick cookware, Science of The Total Environment, 2022 (DOI: 10.1016/j.scitotenv.2022.158293).
[85] Emission of perfluoroalkyl carboxylic acids (PFCA) from heated surfaces made of polytetrafluoroethylene (PTFE) applied in food contact materials and consumer products, Chemosphere, 2015, (DOI: 10.1016/j.chemosphere.2014.11.036).

(iii) Total emissions

Table 27: Emission of PFAS to the environment during production, application and service life of P&Cs in Belgium

Production stage	PFAA (t/y)	SCFP (t/y)	FP (t/y)	Total (t/y)
Formulation	0.76	0.05	11.8	12.6
Application	10.1	0.76	189	200
Transport service life	-	-	5.0	5.0
Construction service life	0.09	0.01	2.4	2.5
Industrial service life	-	-	-	-
Total	**10.9**	**0.8**	**209**	**220**

The total emissions during the production, application and service life of P&Cs are estimated to be approximately 220 tons / years. Most of the emissions consist in FPs, such as PTFE, PVDF, ETFE. A dozen tons of PFAS precursors are also emitted.

Direct human exposure:

Polymeric PFASs which make up the greatest share of PFAS used in paints and coatings are stable up to 300°C. Exposure of workers or consumers is assumed to be low during the service life of transportation vehicles and industrial equipment. Worker exposure during production of articles could occur through inhalation of vapors or of dust generated during mechanical manipulation of materials or mixing.

The highest human exposures will likely occur during the application stage of Do-It-Yourself (DIY) decorative paints or varnishes in the construction sector. PFAS-based mixtures are applied by spraying, rolling, or brushing onto walls, roofs & floors, shutters or furniture; this may occur both indoors and outdoors. Products for DIY durable water repellent impregnation of stone, glass, tiles and aftermarket floor protection can contain between 0.5% and 2% PFAS. If applied as an aerosol spray, high exposure can occur, and cases of acute intoxication have been observed.

Existing alternatives

The report « Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs) » from OECD published in 2022 provides an overview of the PFAS alternatives and the market penetration.

PU-based, siloxane-based, epoxy-based or HDPE-based paints, with or without incorporation of inorganic micro-particles, are the most widely used alternatives for FPs-based paints, achieving acceptable durability and repellency. FPs-based paints remain more efficient but are significantly more expensive; the PFAS-based paints are dedicated to specific applications with a very low market share. Non-PFAS alternatives also exist for fluorosurfactants such as silicone-based coatings.

Targeting challenging specifications and properties, the mentioned study specifically indicates existing PFAS alternative chemistries.

Table 28: Existing PFAS alternatives for the formulation of P&Cs

PFAS Function	Alternatives
Thermal stability	Epoxy, polyolefin, polymethylmethacrylate
Flame resistance	PVC
Corrosion resistance	Epoxy, polyurethane, polyolefin, polymethylmethacrylate; galvanisation and anodization (for metallic surface only)
Weather resistance	Polyurethane, polyester, silicone modified polyester, polysiloxane, epoxy;
Mechanical resistance (abrasion, scratch)	Polyurethane, polyester, polysiloxane, polymethylmethacrylate, polysilozane, aliphatic diisocynates-based polyurethane
Smudge resistance	Silica-based coatings
Anti-graffiti effect	Polyurethane, polyester.
Levelling and wetting agent	Silica based and sulfosuccinates
UV 'cool roof' property	None identified
Oil & dirt repellency	None identified

The report indicates that most of the applications do have available PFAS-alternatives, those alternatives having high market share (typically > 90%). This is not the case for very harsh environments and for some specific market segments such as coatings conferring anti-dirt and anti-fingerprint properties to touch screens. Fluoropolymer-based roofing coatings also suffer from limited opportunity to phase out PFAS. These coatings enhance thermal insulation, limiting heat transfer and acting as reflective coatings. Due to an increased focus on energy and material efficiency of buildings, it is therefore expected that fluoropolymers will continue to play an important role in 'cool roof' (reflective white coatings) construction.

In Belgium, Materia Nova (Mons) is especially working on the development of PFAS-free coatings, coordinating the BIO-SUSHY European project (2023-2026, €4.8 million).[86] The project is targeting the development of durable water & oil repellent coatings based on thermoplastic powder and hybrid sol-gel process for the textile, food packaging, and cosmetic markets.

According to IVP Coatings, very few Belgium industrial companies are still using PFAS. If PFAS are of importance for the P&C Belgian industry, "*the use of PFAS is probably not critical*".

3.2.9 \ Paper & cardboard, including packaging

Applications/products scope

The paper & cardboard sector gathers any product based on sheets of cellulose-derived substances, including paper and board packaging for food or non-food contact. Most of paper & cardboard do not basically contain PFAS. However, PFAS are used in packaging to confer oil and grease resistance and water or vapour repellency. They can be added to the pulp but they are mostly applied as part of a coating formulation. Different studies point out that oil-repellent paper and board packaging contain PFAS at concentrations around 500 mg/kg, with higher concentration for the 6:2 fluorotelomer alcohol (6:2 FTOH).[87,88] The application of side-chain fluorinated polymers (SCFP) is among the most efficient way to introduce such surface properties. Perfluoropolyether (PFPE) based oil and grease repellent products are also used.

[86] https://www.bio-sushy.eu/
[87] Forever chemicals in the food aisle: PFAS content of UK supermarket and takeaway food packaging, FIDRA, 2020
[88] Throwaway Packaging, Forever Chemicals European wide survey of PFAS in disposable food packaging and tableware, Arnika, 2020

This repellency function is especially important in the food packaging sector in which oils, greases and water may migrate from food during transport and storage.

The product scope includes the following items that are subject to PFAS incorporation:

- Food packaging:
  - Greaseproof paper (bakery bags, fast-food containers, cupcake cups, microwave popcorn bags, disposable tableware…)
  - Baking paper
  - Heat resistant packaging
- Other food packaging (milk containers, pouches, etc.):
  - Generic packaging
  - Paper and board for non-food applications
  - Folding packaging cartons
  - Masking papers

Belgian industry

The Belgian paper sector (forest management, pulp fabrication, papermaking, printing, waste management) represents €10 billion of turn-over with more than 6 000 compagnies and 30 000 employees.[89] According to InDUfed, the paper and cardboard post-processing sub-sector represented €3.8 billion in 2019.[90] Almost 2 million tons of paper and cardboard are produced in Belgium by more than a hundred of companies including large European companies.

As a highly internationalised market, the imports and exports reach respectively €3.4 billion (3.59 million tons) and €2.9 billion (3.60 million tons). The total quantity of packaging (including glass, plastic or metallic packaging) introduced on the Belgian market increased by 4.6% in 2020 and amounts to just over 1.9 million tons. Paper and cardboard account for 39% of the total weight of packaging introduced in the Belgian market (741 000 tons).[91]

The paper & cardboard Belgian industry in specialised in corrugated cardboard, a widely used material for the transport of food and non-food products. Other products made in Belgium are bags, supplies for school & office, envelopes, playing cards, wall coverings, cigarette papers, paper products for hospitals, napkins, or self-adhesive materials.

According to InDUfed, there is no production of food-contact packaging in Belgium, and there is no intended introduction of PFAS in the production process of paper and cardboard. Nevertheless, dozens of manufacturers of pulp, paper and paperboard have been cited as presumptive users of PFAS in Belgium by the Forever Pollution Project. However, no evidence of a company currently using PFAS in Belgium was found, and the Belgian industry is not specialised in products that would require oil & water repellency properties.

Volumes (in Belgium)

With a significant import of paper and cardboard packaging and import of fresh products in their paper and cardboard packagings, PFAS are easily found in Belgium. A recent study, involving the Health and Environment Alliance in Belgium, points out that 38% of food-contact packagings

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[89] Papier.be
[90] Indufed, Annual repport, 2019
[91] https://statbel.fgov.be/en/themes/environment/waste-and-pollution/packaging-waste

collected in 6 different countries in Europe are suspected to have been treated with PFAS chemicals for oil repellency (see footnote 88). Analysis shows that “the highest PFAS concentrations were consistently found in moulded fibre products (e.g. bowls, plates, and food boxes)”; those paper-based products being advertised as biodegradable or compostable disposable. Another study, conducted on the Belgian territory revealed that 18 of 20 paper drinking straws collected in Belgian supermarkets, toy stores, e-commerce or fast-food contain PFAS. In this case, PFOA was the most frequently detected component because of the water-repellency properties. 75% of the identified countries of origin of the straws are in Asia.[92]

Considering the Belgian paper & cardboard industry, it could be reasonably assumed that the production only involves limited volumes of side-chain fluorinated polymers (SCFP). PFAS volumes and emissions during the production stage are considered as non-significant. The limited PFAS volume would unintentionally have been introduced by paper recycling. Data show that in Europe, 82% of paper and board packaging is recycled.[93]

Conversely the imported papers & cardboards used in food-contact application are known to contain PFAS. Therefore, it seems relevant to only consider the service life and waste stage emissions of the imported paper and cardboard packaging (741 000 tons).

According to ECHA methodology:

- Between 0.5 and 1% of paper and board packaging contain PFAS
- The concentration of PFAS is between 0.4 and 1.2% (wt.)

Low-end and high-end estimates indicate that 14.8-88.8 tons of SCFP are introduced in the Belgian market every year. Nevertheless, significant amount of paper and cardboard are introduced into the Belgian territory through packaged product imports. Realistic PFAS volumes would rather be values approaching the high-end estimate (88.8 tons).

Environmental impacts

Service life outdoor emissions of food contact material and (food/feed) packaging is of lesser relevance than manufacturing emissions. Applying the ECHA methodology and based on the PFAS volumes, emissions to air, water and land would reach 47.7-286 kg / year.

If the outdoor emissions during the service life of the paper and cardboard product seems very limited, available literature data suggest that diet is the major human exposure pathway for non-polymeric PFAS. Human exposure occurs from wear and tear and PFAS migration to food and drinks from paper and board.

The end-of-life stage is the most important source of PFAS emissions in water and land, occurring during recycling, landfill and composting. For paper and board, it is observed that increased recycling leads to spreading PFAS throughout all the paper and board market. The Single Use Plastic Directive could lead to more moulded fibre food packaging being used, most of which contains PFAS for water and grease resistance. As PFAS containing products are advertised as biodegradable and are indeed intentionally composted, a very high rate of land and water emissions occurs during composting.

Existing alternatives

There is sufficiently strong evidence that technically and economically feasible alternatives are widely available on the market for an extensive range of paper and board packaging. A study carried out by the OECD/UNEP indicates that ten alternatives to long-chain PFAS for paper and

[92] Assessment of poly- and perfluoroalkyl substances (PFAS) in commercially available drinking straws using targeted and suspect screening approaches, Food Additives & Contaminants, 2023 (DOI: 10.1080/19440049.2023.2240908)
[93] European Paper Packaging Alliance

paperboard food packagings have been classified by authorities.[94] According to InDUfed, these alternatives have been available for 10 or 15 years.

Alternatives to PFAS-containing paper and board are divided into two categories to achieve the same performance: physical or chemical barriers. Physical barriers are where the paper itself serves as barrier, by means of lamination and subsequent microstructure (e.g. lotus effect). Chemical barriers are achieved by either adding chemicals during the paper production, or by applying a surface treatment consisting of waxes, silicone oils & resins or polysiloxanes.

Another alternative consists in the substitution of paper & cardboard by other materials (metal, glass).

Other relevant regulations

In November 2022, the Belgian government notified the EU of a draft Royal Decree to limit the placing on the market of single-use plastic products. The draft was open for comments until March 1st, 2023, and shall enter into force on January 1st, 2024. Article 10 of the draft Belgian Royal Decree imposes a ban on placing for the first time on the market packaging containing PFAS, namely Perfluoroalkyl and Polyfluoroalkyl substances.

3.2.10 \ PPP: Plant Protection Products

Applications/products scope

Within agrochemical products, two primary categories are considered: active ingredients responsible for pest control and inert ingredients or co-formulants, typically considered non-toxic, that facilitate formulation.[95,96,97] Active substances meeting the PFAS definition are often characterised by the presence of CF3-groups in their molecular structure. Over the past two decades, fluorinated pesticides have surged, making them a key trend in modern agriculture, frequently ranking among the top-selling pesticides with anticipated future growth. These pesticides are referred to as plant protection products (PPP) under ECHA terminology, and the recent PFAS restriction proposal by ECHA includes an option to exempt PFAS used as active ingredients in PPP, as they are governed by separate EU regulations (EC. 1107/2009). However, a general restriction on PFAS in PPPs would render at least 48 active substances in over 200 products unusable, impacting the availability of fungicides, pesticides, and herbicides across various crops.[98]

Table 29: Non-exhaustive list of active substance approved by the EU and covered by the current definition of PFAS

Active pesticide substance		PFAS classification	Regulation/ restriction program
Triflumuron/tritosulfuron Isoxaflutole Triflusulfuron-méthyle Trifloxystrobin Tefluthrin Pyroxsulam Pyridalyle Picolinafen Penthiopyrade Fluopyram Flonicamide	Fluopicolide Flazasulfuron Diflufénican Cyflumétofen Benfluraline Sulfoxaflor Fluazinam Tembotrione Metaflumizone Oxathiapiproline Méfentrifluconazole	**Class: non-polymer PFAS** Aromatic CF3 structure	No specific restrictions The PFAS restriction proposal recently published (22.03.2023) by the European Chemical Agency (ECHA) has an option to exempt PFAS used as active ingredients in plant protection products, as these products and their uses are covered under separate EU regulations (EC. 1107/2009). This regulation aims to ensure a high level of protection for

[94] PFAS and Alternatives in Food Packaging (Paper and Paperboard): Hazard Profile, OECD, 2022
[95] https://www.pfasfree.org.uk/uncategorised/pfas_in_pesticides
[96] Pesticide Action Network, PFAS in pesticides, 2022
[97] https://www.scientificamerican.com/article/pesticides-are-spreading-toxic-lsquo-forever-chemicals-rsquo-scientists-warn/
[98] https://www.ewg.org/news-insights/news-release/2023/06/maine-data-unveils-troubling-trend-55-pfas-related-chemicals

Flutolanil, Flufenacet* Flutianile Flurochloridone Haloxyfop-P Gamma-Cyhalothrine lambda-Cyhalothrine Tau-Fluvalinate Tetraconazole Flufénacet Flumetralin Fluométuron Oxyfluorfène	Bifenthrine Fipronil Flufenoxuron Picoxystrobine Triflumizole Prosulfuron Beflubutamide Penoxsulame Cyflufenamid Acrinathrine Fluazifop-P Flubendiamide		both human and animal health, as well as the environment.

Flufénacet degradation product, trifluoroacetic acid (TFA), can contaminate groundwater.

PFAS can serve an additional role as co-formulants, being integral components of pesticide and other product mixtures. Their inclusion in these formulations enhances the overall efficacy and usability of the product. Introducing fluorine into pesticides increases their most advantageous attributes, such as improved product dispersion and stability, rapid action, extended residual activity, heightened selectivity, and specificity, all while preserving their potency and intended biological activity. It is noteworthy that these co-formulants are not disclosed on the ingredient labels of PPPs.

A recent study conducted by the United States Department of Agriculture (USDA) exemplifies this utilisation of PFAS in pesticides.[99] Upon detecting PFAS in plants cultivated within their research laboratory greenhouse, the USDA embarked on a comprehensive analysis of PFAS presence in the potting soil, water, fertiliser, pesticides, and other vegetation. The investigation pinpointed the source of PFAS contamination to the pesticides themselves, even though PFAS were not the primary active ingredients in these formulations. Consequently, these findings suggest an unrecognised route for PFAS introduction into the environment through inert pesticide components. While an alternate source could be PFAS leaching from plastic storage containers into the pesticides, it is important to note that the PFAS compounds detected differed from those typically found in plastic containers. This study encompassed an examination of 24 distinct members of the extensive PFAS family, comprising over 4 000 substances, within 10 pesticide formulations that are readily available in Europe.

Table 30: Average concentration of PFOS in the analysed PPP formulations

Pesticides*	PFOS concentration (mg/kg)	Regulation/ restriction program
Beauveria Bassiana	0	Since 2009, perfluorooctane sulfonic acid and its derivatives (PFOS) have been included in the international Stockholm Convention to eliminate their use. PFOS has been restricted in the EU for more than 10 years already, under the EU's Persistent Organic Pollutants (POPs) Regulation.
Pyridalyl	0	
Spinosad	0	
Spinetoram, Sulfoxaflor	0	
Abamectin	3.92 ± 0.51	
Novaluron	9.18 ± 0.34	
Mineral Oil (Petroleum oil)	8.64 ± 0.67	
Imidacloprid	13.3 ± 1.4	
Spiromesifen	19.2 ± 1.2	
Malathion	17.8 ± 0.7	

**All pesticides tested are still in production under the same brand names, though the formulations tested should not be assumed to be the same as the ones currently in production, as the sampled product was not new. However, PFAS are known to be incredibly environmentally stable, consequently, historic use of those containing PFAS or PFAS precursors can translate into persistent soil contamination.*

[99] Targeted analysis and Total Oxidizable Precursor assay of several insecticides for PFAS, 2022, Journal of Hazardous Materials Letters (DOI:10.2139/ssrn.4144035)

Additionally, the analysis reveals contamination in both soil and plants, with multiple PFAS species detected in soil and plant grab samples, surpassing the levels observed in the tested pesticide (PFOS). Notably, PFOS was found to be the PFAS species with the highest concentration. The study concludes that these PFAS likely originate from pesticides historically used on these agricultural sites.

Table 31: Per- and poly-fluoroalkyl substances presumably used in pesticide formulation

PFAS *Presumed to be integrated as an inert ingredient in pesticide formulations*	**Nomenclature and classification**	**Regulation/ restriction program**
PFOS	Perfluorooctane sulfonate Class: nonpolymer Subclass: Perfluoroalkyl acids (PFAAs) Group: Perfluoroalkane sulfonic acids (PFSAs)	Since 2009, perfluorooctane sulfonic acid and its derivatives (PFOS) have been included in the international Stockholm Convention to eliminate their use
PFOA	Perfluorooctanoic acid Class: nonpolymer Subclass: Perfluoroalkyl acids (PFAAs) Group: Perfluoroalkyl carboxylic acids (PFCAs)	Suspected carcinogens Since 4 July 2020, PFOA (perfluorooctanoic acid), its salts and other compounds related to PFOA have been banned in the EU
n:2 FTS (n = 4, 8) n = number of perfluorinated carbons	Fluorotelomer sulfonic acids Class: nonpolymer Subclass: Polyfluoroalkyl acids Group: Fluorotelomer acids (potential PFCA precursors)	No specific restrictions FTS acids and salts have been adopted as PFOA, PFOS alternative products. 6:2 FTS under investigation
PFNA	Perfluorononanoic acid Class: nonpolymer Subclass: Polyfluoroalkyl acids (PFAAs) Group: Perfluoroalkyl carboxylic acids (C9-PFCAs)	In the Candidate List of substances of very high concern (SVHCs) Shall not be manufactured, used or placed on the market as substances on their own, 25 February 2023
PFBA	Perfluorobutanoic acid Class: nonpolymer Subclass: Polyfluoroalkyl acids (PFAAs) Group: Perfluoroalkyl carboxylic acids	No specific restrictions
PFUdA	Perfluoroundecanoic acid Class: nonpolymer Subclass: Perfluoroalkyl acids (PFAAs) Group: Perfluoroalkyl carboxylic acids (C11-PFCAs)	In the Candidate List of substances of very high concern (SVHCs) Shall not be manufactured, used or placed on the market as substances on their own, 25 February 2023
PFHxA	Perfluorohexanoic acid Class: nonpolymer Subclass: Perfluoroalkyl acids (PFAAs) Group: Perfluoroalkyl carboxylic acids (PFCAs)	14 Jul 2023, The European Commission (EC) has proposed a Union-wide restriction: ban the manufacturing, placing on the market, and use of PFHxA and PFHxA-related substances after a transitional period of 18 months from the entry coming into force. The restriction will cover PFHxA, its salts and PFHxA-related substances on their own

Based on the compelling evidence presented in the USDA study and further pesticides ban[100], the PAN (Pesticide Action Network) took an initiative to address the European Commissioner for Health and Consumer, urging the mandating of the European Food Safety Authority (EFSA) to conduct independent sampling and analysis of PFAS residues. The aim is to suspend the use of the pesticides under scrutiny based on EFSA's findings, while simultaneously seeking EFSA's expert opinion. Comprehensive testing of not only the formulations but also representative soil, water, and crops in areas where these formulations have been employed was deemed necessary.

Currently, there is no proper regulation for pesticide formulations. ECHA does not consider the use of PFAS as co-formulants or so-called inert ingredients. It is also unclear whether the predominant concern for ECHA's PFAS restriction proposal – persistence – is adequately taken into account in these separate regulations.

Belgian industry

The European crop protection pesticides market has been estimated at $27.7 Billion in 2021 and is projected to reach $31.6 Billion by 2026, at a CAGR of 5.1% during the forecast period from 2022 to 2027.[101] European Union member states uses an average of 3.3 kg of pesticides per hectare of cultivated land (2020). France, Italy, Germany, and Spain reported the highest volumes of pesticide sales in the EU in 2020, as they are the largest agricultural producers in the EU. However, when considering the number of hectares, Germany (4.05 kg/ha) and France (3.44 kg/ha) fall within the European average (3.3 kg/ha). Italy (6.11 kg/ha), on the other hand, surpasses this average, while Spain is the least consumer of the four (2.6 kg/ha). Belgium is among the European countries that use the most pesticides, with more than 7 kg/ha.

The pesticide and other agrochemical industry in Belgium generated a revenue amounting to €682 million and provided employment for 1 067 individuals (2023).[102] On average, a manufacturing business typically employs around 50.8 people. Belgium is tagged as one of the largest consumers and producer of pesticides in Europe.[103]

Volumes (Europe, Focus Belgium)

PPP accounts for 2% of the total EU sales of substances that meet the PFAS definition. ECHA estimates that the annual quantity of PFAS (as an active substance in PPP) used in the European Union is 5 479 tons. According to Eurostat, EU and Belgium turnovers of the activity *Manufacture of pesticides and other agrochemical products* (NACE Rev.2 C202) are evaluated at €7.50 billion and €0.724 billon respectively (2020). Using this ratio (9.65%) and assuming similar PFAS penetration rate, the PFAS volume used in the manufacture of PPP in Belgium is estimated at 529 tons.

The subject of PFAS used as basic ingredients (active substances) in the manufacture of PPP is widely unknown in Europe. Data on the use of PFAS as co-formulants is also absent. However, studies conducted in the United States on these subjects are alarming and have led to initiatives by certain European associations and federations for the protection of agricultural crops. The situation in Belgium mirrors that of the entire Europe, where this issue remains under-documented despite being one of the largest consumers of pesticides.

[100] https://www.federalregister.gov/documents/2022/12/14/2022-27085/pesticides-removal-of-pfas-chemicals-from-approved-inert-ingredient-list-for-pesticide-products
[101] https://www.marketdataforecast.com/market-reports/europe-crop-protection-pesticides-market
[102] https://www.ibisworld.com/belgium/industry-statistics/pesticide-other-agrochemical-manufacturing/14588/
[103] https://www.brusselstimes.com/271193/belgium-must-reduce-pesticide-use-by-58

Existing alternatives

It is worth noting that discussions about alternatives to pesticides have primarily focused on reducing the use of chemical pesticides in general, without specifically targeting PFAS-based pesticides. This approach is partly explained by the complexity of these chemical compounds and the lack of immediate alternatives available. Research and innovation efforts in the field of pesticide alternatives have often aimed to provide more sustainable solutions for the entire agricultural industry, with an emphasis on reducing environmental impact and preserving human health. Many techniques, such as biological control and the cultivation of insect-resistant varieties, have been successfully developed and adopted in various regions. While replacing PFAS-based pesticides may require specific measures, it is part of the broader quest for environmentally friendly agricultural practices that promote food security.

The issue of PPP containing PFAS is a matter of concern due to limited documentation. This necessitates an immediate and thorough investigation involving manufacturers, as highlighted by the Pesticide Action Network (PAN) Europe in 2023. The objective of ECHA is to identify and quantify commonly used pesticides containing PFAS, but the available literature on this subject is scarce. According to PAN, it is important to collaborate with the industry in order to bridge this gap. This involves identifying the pesticides that contain PFAS, determining their quantities sold in Europe, understanding the crops to which they are applied, and pinpointing the regions where they are used.

3.2.11 \ Plastics

Applications/products scope

PFAS are widely used in the plastics industry, either as polymerisation aids, polymer processing aids or as components of a plastic product improving its final property (e.g., fluoroplastics). Various sectors of the plastics industry rely on PFAS: spinning and extrusion processes, injection molding processes, automotive, building and construction, packaging or oil & gas transport.[104,105]

(i) Polymerisation aids for FPs

Polymerisation aids are surfactants or emulsifiers used during the manufacture of fluoropolymers from fluorinated monomers: tetrafluoroethylene (TFE), hexafluoropropylene (HFP), vinylidene fluoride (VDF) and others. According to the ECHA survey, about 50% of fluoropolymers are manufactured with fluorinated polymerisation aids, such as PFNA, PFHxA, 6:2 FTSA, the ammonium salt of hexafluoropropylene oxide dimer acid (HFPO-DA) and dodecafluoro-3H-4,8-dioxanonanoate.

(ii) Polymer processing aids for plastics

Polymer processing aids are lubricants or release-agents that improve the processability of plastics. PFAS are used as mould release agents, foam blowing agents, extrusion aids for the production of plastic articles used in packaging, construction, transport, etc. These articles are based on polyvinyl chloride, polystyrene, polyamide, polypropylene, low density polyethylene, epoxy, polyurethane, polysiloxane epoxy or poly(diethylene glycol diacrylate). The most common PFAS in lubricants are polymeric PFAS like PTFE micro-powder (as a solid additive), PFPE (oil based) and PCTFE (oil based). Other formulations also contain non-polymeric PFAS. All the PFAS used as a processing aid (PA) in the production of these articles are not retained intentionally within the final products.

(iii) FPs-based plastic products

[104] Fluoropolymer waste in Europe 2020, Conversio company, 2022
[105] An overview of the uses of per- and polyfluoroalkyl substances (PFAS), 2021, Env. Sci. Process Impacts (DOI: 10.1039/d0em00291g)

Plastic products containing PFAS are mainly used in the construction, automotive, oil & gas transport and chemical, pharmaceutical of food and beverage industries. Excluded from this chapter are wires and cables, plastic articles for the medical sector or FPs membranes for batteries. In many cases the articles produced are 100% fluoropolymer.[106],[107]

Table 32: PFAS application and uses for the plastic sector with the associated molecules

Market	Application	Molecules
Construction	Architectural membranes, roofing, windows in greenhouses, sealings	Polymeric PFAS (e.g. PTFE, EFTE, PVDF)
Automotive	Sealings (seals in valves and gaskets, O-rings) Car wrapping	Polymeric PFAS (e.g. FKM, PTFE)
Oil & gas transport	Interior lining of pipes and tanks, gaskets, filters & membranes, sealings	Polymeric PFAS (e.g., PTFE, PVDF)
Chemical, Pharmaceutical, and Food & Beverage industries	Sealings, gaskets or diaphragms in pump systems, tubing, linings, conveyor belts	Polymeric PFAS (e.g., PTFE, PVDF)

Belgian industry

The plastic sector is a major player in the Belgian manufacturing industry. In 2018, 2 520 kt of raw material – including plastic waste – have been used to produce plastic.[108] Belgium is a major exporter of plastic raw materials and plastic products in Europe. About 70% of plastic raw materials produced in Belgium are exported. In 2020, 2 310 kt of plastic have been converted to produce plastic articles and more than 1 billion tons have been used in Belgium.[109]

The Belgian plastics converting industry is driven by the packaging (45%; mainly PE, PP, PET, PS), construction (23%; mainly PVC, PU and PP) and automotive sectors (8%; mainly PVC and thermoplastics). According to Eurostat, the production of rubber and plastic products reached €8.77 million in 2020 (3.02% of the EU plastic production), involving 750 companies. In 2018 in Belgium, 200 kt of plastics have been collected for recycling and 80% was reinjected into the manufacture of new plastic products.

Several PFAS users and presumptive PFAS users have been identified by the Forever Pollution Project and during the ECHA consultation. Activities of these companies are gathered in Table 33.

Table 33: Known and presumptive uses of PFAS by plastic producers or transformers in Belgium

Activity of the plant	PFAS use
Production of PTFE gaskets, micropowder and other articles	Known PFAS use
Production of PFAS and PFAS-based articles	Known PFAS use
Production of rubber gaskets for automotive, aeronautical and petrochemical	Known PFAS use
Production of rubber for other application	Presumptive use
Production of military automotive track shoes, pads, bushing and wheels.	Presumptive use

[106] https://www.vaneflon.be/en/industries/
[107] European Sealing Association (ESA) position statement relative to the European proposal for PFAS regulation in relation with the Sealing Industry
[108] https://www.essenscia.be/wp-content/uploads/2019/11/Plast_BROCH_A5_HR.pdf
[109] Plastics - the Facts 2021: An analysis of European plastics production, demand and waste data - Plastic Europe

Volumes (in Belgium)

(i) Polymerisation aids for FPs

Currently, the industry seems to be in transition towards the use of polymerisation aids without PFAS. Indeed, Chemours, Solvay or Arkema have reported the replacement of fluorinated polymerisation aids with nonfluorinated substances. No quantitative data have been founded for Belgium and the 3M production plant in Zwijndrecht.

(ii) Polymer processing aids for plastics

Plastics & rubber production of Sweden, Finland, Norway and Denmark from 2000 to 2017 used 4 700 tons of FPs, or an average of 276 tons / year. With no time shift and according to relative plastics production from 2010, Belgian PFAS use can be estimated at 82 t/y. Considering the Belgian plastics industry, these 82 tons are mostly used in the packaging sector (extrusion of PE & PP thin films) and to a lower extent to the construction sector. This value is in accordance with the estimated volume of PFAS used in the packaging sector derived from the ECHA methodology (87 t/y).

(iii) FPs-based plastics products

Construction, transport, oil & gas sectors and other industries are using PFAS-containing plastics product, either fluoropolymer (PTFE, PVDF) or fluoroelastomer (FKM). Only limited data have been found on the Belgian production of such fluoroplastic articles.

The volume estimate of PFAS used as polymer processing aids (PPA) and fluoroplastics are gathered in the table below.

Table 34: Estimate of the PFAS volume used for the plastic production in Belgium

Market	Method	PFAS use	Approximation
Packaging *Plastic*	PFAS polymer processing aids are used in the manufacturing of thermoplastics packaging (generic and food contact). According to ECHA, 2 910 t/y of PFAS are used. Belgium volume have been estimated assuming that Belgian plastic market represent 3.0% of European market.	87 t/y (Processing aids)	- Mismatch between European and Belgium plastic industry
Packaging / Automotive *Car wrapping*	According to ECHA, 3 950 t/y of PTFE are used for car wrapping. Belgium volume have been estimated assuming that Belgian plastic market represent 3.0% of European market.	118 t/y (FPs articles)	- Mismatch between European and Belgium plastic industry
Construction	ECHA estimates that construction products use 8 939 tons of PFAS per year, which 19% are used for architectural membrane, sealings & adhesives, wires and cables, PPA for PE & PP. Belgium volume have been estimated assuming that Belgian plastic market represent 3.0% of European market.	51 t/y (Processing aids and FPs articles)	- Mismatch between European and Belgium plastic industry *Overestimation* -Cable & Wire have been considered. The contribution could not be isolated.

Transport Automotive *Sealings*	Automotive sealing articles contain between 60 and 100% FPs. ECHA estimates that 5 000 tons of FPs (mid-point) are used in sealing application. Belgium volume have been estimated assuming that Belgian plastic market represent 3.0% of European market.	150 t/y (FPs articles)	- Mismatch between European and Belgium plastic industry
Transport Aerospace	No data found	N/A	*Underestimation* Aerospace materials, tapes, and gaskets have not been considered.
Oil & gas transport	No methodology or pertinent data have been found to identify the PFAS volume correlated to the plastic segment. Considering the Belgium industry, the volume has been estimated as non-significant.	N/A	*Underestimation* -The PFAS of this sector are not considered.
Chemical, Pharmaceutical, and Food & Beverage industries	No methodology or pertinent data have been found to identify the PFAS volume correlated to the plastic segment.	N/A	*Underestimation* -The PFAS of this sector are not considered.
Total		406 t/y	Mostly underestimation

According to the above estimates, 406 t/y of PFASs are used by the Belgian plastic sector. A lot of underestimations were done due to lack of data and complex PFAS uses. Therefore, this estimate is likely to be a low-volume scenario.

Environmental impacts

(i) Polymerisation aids

Due to missing data, emissions related to the use of PFAS-based polymerisation aids have not been quantified.

(ii) Processing aids & FPs product

ECHA provides methods and values to estimate the emission of PFAS during the production stage of FPs articles and plastic articles for the construction sector. Emission occurs during extrusion and manipulation of FPs and losses of processing aids. During the use stage, weathering and abrasion also lead to emissions into environment.

No method or quantitative data on emission rates have been found for the plastic packaging and the transport sectors. For these two sectors, the production emissions have been estimated using the method applied for the construction sector. Emission estimates are summarised in the table below. Emissions in Belgium seems limited to 5 tons per year, nevertheless, missing data leads to several underestimations.

Table 35: Estimate of the PFASs emission during the life cycle of plastic product in Belgium

Stage of the life cycle		PFAAs & PFAA precursors (t/y)	Fluoropolymers (t/y)	Total
Packaging	Production	0.39	0.97	1.36
	Use stage (Fluoroplastic article only)	-	-	-
Construction	Production	0.23	0.42	0.65
	Use stage (Fluoroplastic article only)	0.32	0.66	0.98
Automotive	Production	0.67	1.24	1.91
	Use stage (Fluoroplastic article only)	-	-	-
All sector	All stage			4.89

Existing alternatives

(i) PFAS-free Polymerisation aids

According to the ECHA stakeholder consultation, more than half of the fluoropolymers are already manufactured without fluorinated polymerisation aids. Indeed, several companies commercialise PFAS-free polymerisation aids.[110,111] According to a recent study published in the International Chemical Regulatory and Law Review and dedicated to fluoropolymer manufacturing, "*It is expected that most of the fluoropolymer production will be developed completely free from PFAS polymerization aids in a relatively short time frame*".[112]

(ii) PFAS-free Processing aids

Companies have developed PFAS-free PPA anticipating new regulations, especially a potential ban for food-contact packaging (extruded films).[113] Numerous PFAS-free PPA are already commercially available, some examples are listed in the table below. The composition of these PFAS-free PPAs is often kept confidential; several different chemistries are likely to be used. Flexible Packaging Europe reported difficulties when using boron nitride or PE waxes for the production of flexible polyolefin-based packaging.

No Belgian company or production of PFAS-free PPA in Belgium have been identified.

Table 36: PFASs alternative for the plastic market

Company	Product	Application
Ingenia[114]	IP1170, IP1171	Processing of polyolefin, LDPE
Saint-Gobain[115]	Boron nitride powders	Production of films used for food packaging including polyethylene and m-LLDPE films
Ampacet[116]	1001316-N PFAS-Free PPA	Processing of polyolefin used for packaging

[110] https://www.chemours.com/en/news-media-center/all-news/press-releases/2022/chemours-announces-process-innovation-with-new-viton-fluoroelastomers-advanced-polymer-architecture
[111] https://www.gfl.co.in/assets/pdf/GFL%20Announcement%2030.11.22_new.pdf
[112] Developments in Fluoropolymer Manufacturing Technology to Remove Intentional Use of PFAS as Polymerization Aids, International Chemical Regulatory and Law Review, 2023
[113] https://www.linkedin.com/pulse/polymer-processing-aids-without-fluorinated-molecules-pierre-sarazin/
[114] https://polymer-additives.specialchem.com/selectors/s-ingenia/c-additives-processing-aids-polymeric-processing-aids?q=PFAS-free
[115] https://www.bn.saint-gobain.com/blog/how-boron-nitride-polymer-processing-aids-enable-pfas-free-food-packaging
[116] https://www.ampacet.com/ampacet-introduces-pfas-free-polymer-processing-aid-enhanced-performance-in-a-non-fluoro-based-formulation/

Techmer PM[117]	HiTerra T5	Processing (blown film or cast film extrusion) of polyolefin
Kafrit Group[118]	PFAS-free PPA	Pipe extrusion and HDPE films
Luvobatch[119]	EverGlide PA45, EverGlide PA49, EverGlide PA41 (functionalised polysiloxanes)	Improve processing of PE, PP and EVA (Ethylene-vinyl acetate)

(iii) FPs product: Sealing applications

Conversely to PA and PPA, PFAS-free sealings appear to be extra-challenging. According to the AESSEAL group, « over 99% of all mechanical seals we and other manufacturers supply contain PFAS materials ».[120] In March 2022, the European Sealing Association (ESA) issued a position statement on the potential ban of PFAS.[121] The association claims that PFAS are « *critical to global industry in their use as sealing element* » and that « *there are very few alternatives that offer the same properties, and if they existed, they would be utilised* ». Many European industrial associations or Belgium companies have reported similar statements.

The statements outline the requirement for sealing materials:

- Flexible materials, even at cryogenic temperatures
- Low permeability versus wide range of gas and liquids
- Chemical stability
- Thermal stability, up to 260-290°C
- Low surface energy

The ESA and Europump point out that combining softness and chemical and thermal stability (vs. hydrocarbons, esters or halide environments) is challenging[122]. Potential alternatives like PEEK (Polyether ether ketone), PPS (Polyphenylene sulfide), PPA (Polyphthalamide), ACM (Acrylic rubber) or nitrile rubber do not fulfill all requirements.

According to different sealing producers, the potential ban of PFAS would lead to the search for alternatives, which will be less effective, increase maintenance costs and provoke earlier failures and frequent leakages.[123,124,125]

Only one pertinent alternative has been identified: sealings made of flexible graphite materials commercialised by SGL Carbon. The sealings are proposed as PFAS-free sealings for the petrochemical industry, power plants and the automotive industry.[126] The European Industrial Gases Association reported that for certain applications alternative solutions to PFAS materials could be available. However, the sealing products are in contact with very diverse chemicals, at different temperatures and are facing specific requirements. Therefore, potential PFAS substitution will require case-by-case developments.

117 https://techmerpm-devsite.azurewebsites.net/wp-content/uploads/2023/01/HiTerra-T5-One-Pager-Final.pdf
118 https://spnews.com/kafrit-group/
119 https://www.luvobatch.de/fileadmin/user_upload/luvobatch/Downloads/LUVOBATCH_Film_Additives_EN_2022.pdf
120 https://www.aesseal.com/en/resources/statements-and-compliance/pfas-materials
121 https://www.europeansealing.com/wp-content/uploads/2022/03/ESA-Position-Statement-on-proposed-PFAS-regulation-March-2022.pdf
122 https://europump.net/uploads/EUROPUMP_Position%20Paper%20PFAS_FINAL.pdf
123 https://www.klinger-international.com/en/news/pfas-regulation-its-impact-on-the-sealing-industry
124 https://www.aesseal.com/en/resources/statements-and-compliance/pfas-materials
125 https://www.trelleborg.com/en/seals/resources/technical-library/tech-talks/polymer-and-sealing-technology/implications-of-pfas-on-sealing-technology
126 https://www.sglcarbon.com/en/markets-solutions/markets/sealing-technology/#

3.2.12 \ Semiconductors

Applications/products scope

Because of their vast range of properties, PFASs are widely used in the electronics and semiconductors industry. ECHA estimates that PFAS are used in products and components to enhance their functionality and in the process to make them. Stakeholders report an estimated annual PFAS use of between 2 500 and 6 300 tons (rounded numbers).

Approximately 65% of the PFAS used are fluoropolymers. The main fluoropolymers used are PTFE, PFA, PVDF, ETFE and FEP; the main non-polymeric ionic PFAS is perfluorobutanesulfonate (PFBS), a surfactant. Non-polymeric non-ionic PFAS are mainly used as solvent cleaners and heat transfer fluids. The semiconductor industry accounts for approximately 45% of the polymeric PFAS and approximately 7% of the non-polymeric PFAS uses.

In the electronics and semiconductors industry, fluorinated gases are used in etching and chamber cleaning processes to form nano-level fine semiconductor integrated circuits, for example. CHF_3, CF_4, perfluoroethane, perfluorinated alkanes and cycloalkanes are examples of fluorinated gases used for these purposes. In most cases, PFAS are used as a solvent. Although the amount used is small, today's electronic products require extremely complicated processing to realise high performance, multi-function, and low power consumption. To achieve this, various gases/liquids are combined to perform processing with advanced and delicate control. Fluorinated gases are also used in Carnot cooling cycles in electronics and switchgear, as well as in industrial process refrigeration in the manufacturing plant, while hydrofluoroethers and perfluoropolyethers are used as high-performance heat transfer fluids.

Table 37: PFAS application and uses for the semiconductor sector with the associated molecules

Category	Applications	PFAS (sub)family involved
Semiconductor manufacturing	Photolithography (photoacid generators, antireflection coatings, topcoats and embedded barrier layers, surfactants, filters)	- Photoacid generators: fluorinated salts - Antireflection coatings: acrylate and methacrylate-based copolymers - Layers & filters: fluoropolymers - Surfactants: non-polymeric PFAS, PFBS
	Plasma etching and wafer cleaning & vapour deposition chamber	PFC, HFC and HFO gases
	Wafers	Fluorinated organic acids
	Heat transfer fluids	HFE, PFPE (including PFPMIE), perfluamine
	Vacuum pumps	HFPO, perfluoroethers
	Thermal testing of semiconductor devices (in-line and end of line)	HFE, PFPE (including PFPMIE), Perfluamine, perfluorotributylamine, fluorinated liquids (perfluoroalkyl morpholines, perfluorinated amines, perfluorotributylamine)
	Advanced semiconductor packaging: encapsulants and thermal interface materials, hydrophobic coating/hermetic seal packages, temporary adhesives	- Encapsulants and thermal interface materials & hydrophobic coating/hermetic seal packages: fluoropolymers - Temporary adhesives: fluorinated tetracarboxylic acid anhydride derivatives, aromatic diamines, acrylate and methacrylate-based copolymers

	Semiconductor manufacturing equipment & infrastructure - Enabling uses of fluoropolymer articles (polymer parts embedded within manufacturing equipment, spare parts and infrastructure, piping, ...)	Fluoropolymers (i.e., Teflon, Viton, PTFE, PFA, FEP, ETFE, PVDF, FFKM, etc.)
	Release sheets for thermocompression bonding process of semiconductor chips	PTFE
	Data centres - Immersion cooling of semiconductor devices/servers	HFE, PFPE (including PFPMIE), PFC, FK, fluorinated liquids (perfluorinated amines, perfluoroalkyl morpholines, perfluamine, Methyl perfluoropropyl Ether
	Production, storage, usage of high-purity chemicals	PVDF
	Semiconductor processing	PCTFE
	Semiconductor wet bench equipment	FEP
Semiconductor Products and components	Plastics such as PC/ABS	Perfluoroalkane sulfonic acids (PFSA), their salts and esters
	Fluoroelastomers, polymers including polyimides, polyamides, polyesters, polycarbonate	Bisphenol AF and its salts
	Adhesives, coatings, lubricants	Perfluoroalkylethers
	Semiconductor product/component photoresistance to avoid fire	Fluorotelomer-related compounds
	Local Area network (LAN) cabling (fire resistance)	FEP
	Semiconductor, electronics, optoelectronic devices	MFA

Belgian industry

According to Eurostat (NACE code C2611), Belgium represents 1.5% in the semiconductor industry in EU in terms of turnover (€981 million for a total of €63.9 billion for EU).[127,128] It is estimated that more than 87 Belgian companies are involved in the semiconductors value chain, including conditioning, packaging, etc.

Volumes (in Belgium)

The estimated European volumes are based on the responses of 27 out of the 30 companies' active in the electronics/semiconductor industry in Europe, as reported by ECHA.

Table 38: Estimate of the volume of PFAS used for the semiconductor market in the EU (from ECHA) and Belgium

PFASs group	Volume used in the EU (t/y)	Volume used in Belgium (t/y)
C2- C3 (non-ionic) PFAS substances	190	2.8
PFAAs ≥C4	993	15
Side-chain fluorinated polymers	12	0.2
Total PFAAs and PFAA precursors	1 195	18
Total fluorinated gases	140	2.1
Fluoropolymers	2 807	42
PFPE	281	4.2
Total polymeric PFASs	3 088	46
Total PFASs	**4 423**	**66**

As mentioned above, according to Eurostat (NACE code C2611), Belgium represents a proportion of 1.5% in the semiconductor industry in EU in term of turnover. Thus, a rough PFAS volume estimation would be **66 t/y in Belgium for the semiconductor industry** and allocated as follows:

- PFAAs and PFAA precursors: **18 t/y**
- Fluorinated gases: **2.1 t/y**
- Polymeric PFAS: **46 t/y**

Environmental impacts

Emissions are calculated for the different life-cycle stages; considering the uncertainties in the estimated volumes and many unspecified actual uses, an emission calculation per substance is not possible. An approach is used with default emission factors corresponding to different calculations described by ECHA (ECHA, 2016a). Default release factors from the REACH environmental release categories (ERC) are used in the emission characterisation. Estimates of product service-life emission to the environment are derived using the latest version of the standard REACH methodology (ECHA, 2016a).[129]

Emissions are calculated for combined values of soil, water and air. The following life cycle stages are considered in the assessment:

[127] https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_IND_R2__custom_7248618/default/table?lang=en
[128] https://bestat.statbel.fgov.be/bestat/crosstable.xhtml?view=1b8e35b2-3d1f-4094-8413-ed392671a381
[129] https://echa.europa.eu/documents/10162/13632/information_requirements_r16_en.pdf/b9f0f406-ff5f-4315-908e-e5f83115d6af

(i) Production: The manufacturers included in this section are mainly companies that specialise in modifying or combining raw materials to create new products.

(ii) Use: In this stage all PFASs that are produced in the production stage are assumed to enter the use stage, except for the solvents (non-ionic non-polymeric PFASs).

For emission calculations, a distinction is made between polymeric PFASs and non-polymeric PFASs. Polymeric PFASs include fluoropolymers and perfluoropolyethers, and non-polymeric PFASs include side-chain fluorinated polymers and ionic and non-ionic PFASs. This is done because the various PFAS groups differ in their uses and emission pathways.

A study by Beu and Raoux (2019), on greenhouse gases in the electronics industry, indicates that 89% to 99% of fluorinated gases is captured, and 1% and 11% is emitted[130]. Based on these results, a calculation factor of 0.05 (5% will be emitted, 95% captured) is used to estimate the total emissions of PFASs used for cleaning or as solvents (non-ionic non-polymers and fluorinated gases).

Other groups have a calculation factor of 1 (100%) as all tonnages not emitted are expected to remain in the products until the use stage.

Table 39: Selected Environmental Release Categories (ERC) for electronics and semiconductors

PFASs group	Production	Use
Fluoropolymers	3	Widespread use of articles with low release (indoor)
Perfluoropolyethers	5	Widespread use of articles with low release (indoor)
Side-chain fluorinated polymers	5	Widespread use of articles with low release (indoor)
Fluorinated gases	4	Widespread use of functional fluid (indoor)
Ionic non-polymeric PFAS	5	Widespread use of articles with low release (indoor)
Non-ionic non-polymeric PFAS	4	Widespread use of functional fluid (indoor)

Table 40: Emission factors (%) to the environment based on a one compartment model, corresponding with emissions scenarios from ERC

PFASs group	Production (%)	Use (%)
Fluoropolymers	0.3	0.1
Perfluoropolyethers	50	0.1
Side-chain fluoropolymers	50	0.1
Fluorinated gases	100	5
Ionic non-polymer	50	0.1
Non-ionic non-polymers	100	5

[130] Electronics industry emissions, Intergovernmental Panel on Climate Change (IPCC), 2019

Table 41: Estimate of the PFAS emissions for EEA (from ECHA) and for Belgium for the different PFAS groups

PFASs group	EEA		Belgium (1.5%)	
	Emission during the production stage (t/y)	Emission during the service life (t/y)	Emission during the production stage (t/y)	Emission during the service life (t/y)
C2- C3 (non-ionic) PFAS substances	9.5	0	< 1	0
PFAAs ≥C4	496	0.65	7.4	< 0.01
Side-chain fluorinated polymers	6	0.006	< 0.1	< 0.01
Total PFAAs and PFAA precursors	512	0.65	7.7	< 0.01
Total fluorinated gases	7	0	0	0
Fluoro polymers	8.5	3	3	< 0.1
PFPE	140	0.15	0.15	< 0.01
Total polymeric PFASs	148	3	2.2	< 0.1
Total PFASs	**667**	**3.5**	**10.0**	**< 0.1**

Applying the 1.5% ratio leads to total PFAS emissions of **10 t/y in Belgium** for the semiconductor industry.

Existing alternatives

No evidence that technically feasible alternatives exist for several uses, such as:

- Photolithography (photoacid generators)
- Fluoroelastomers used for chip manufacturing
- Immersion cooling of semiconductor devices
- Flame retardancy in plastics

The industrial companies interviewed did not provide information on R&D collaborative work, some of them explain that alternatives (if as/more performant than PFAS) could lead to a patent strategic advantage against competition, thus providing a reason not to discuss it.

The chemical properties necessary for semiconductor manufacturing process explain the nonexistence of alternatives for several uses.[131] However, some alternatives are investigated:

(i) For semiconductor manufacturing equipment & infrastructure, HDPE is a possible replacement for tanks, tubing, containers, but more developments are needed. At the international level, the SIA (Semiconductor Industry Association) consortium investigates various materials groups (>15 individual polymers) for PFAS alternatives in piping equipment. EPDM, nitrile butadiene rubber (NBR) and silicone rubber have been evaluated as potential alternatives for FKM and FFKM in O-rings for semiconductors sealings.[132]

[131] Flash update: Echa publishes EU PFAS reach restriction PROPOSAL, PlasticsEurope, February 2023
[132] PFAS-Containing Articles Used in Semiconductor Manufacturing, Semiconductor PFAS Consortium Articles Working Group, July 31, 2023

(ii) Mineral oils and Si-based oil could be an alternative to PFPE or perfluoroalkylethers for lubricants, but their potential seems limited for the moment.[133]

(iii) For etching processes and deposition, NF_3 and F_2 are non PFAS alternatives for CVD/PVD chambers and cleaning processes. But for other techniques (damascene process, 3D NAND, FEOL hard mask patterning), potential alternatives such as NF_3, SF_6, CH_4, and C_2H_4 show poor efficiency in operational environment.[134]

For current derogation proposals:

ECHA considers a 12-year derogation with a ban and a transition period of 18 months, because the information provided suggests considerable transition times (3-10 years or more) are required when alternatives become available.

Assuming a full derogation of all polymeric PFAS, PFAAs including precursors, and fluorinated PFAS for a duration of 12 years would cause additional emission of 9 394 t (maximum additional emission scenario). Given the assumptions and arguments provided above it is reasonable to assume that factual emissions during the production and use phase of semiconductors will be lower.

3.2.13 \ TULAC: Textile, Upholstery, Leather, Apparel & Carpet

Applications/products scope

PFASs have commonly been used across multiple Textiles, Upholstery, Leather, Apparel and Carpets (TULAC) products for the construction, automotive, clothing or medical sectors. Fluoropolymers (FPs) are used as breathable membranes and side-chain fluoropolymers (SCFPs) as long-lasting durable water and oil repellent finishes in apparel. Protection against liquids (water, oil, chemicals) drive the demand for PFHxA-based coatings. The Annex XV Restriction Dossier for PFHxA (ECHA, 2019) estimates that ~78% of the PFHxA used in the EEA is for TULAC. PFAS are also used as (i) polymer processing additives (PPAs) for the extrusion of plastics fibres and as (ii) polymerisation aids (PAs) and production of FP fibres. The report from Wood & the European commission (*The use of PFAS and fluorine-free alternatives in textiles, upholstery, carpets, leather and apparel*, 2020) indicates penetration rates of PFAS for the European production. The table below summarises the PFAS uses and European market penetration.

Table 42: PFAS applications and uses in the TULAC industry with the associated molecules

Product category	Sub-category	Products	Market penetration of PFAS at the EU scale (products containing PFAS)
Interior textiles	Home furniture	Curtains, upholsteries	100%
	Transport furniture	Upholsteries	100%
	Wall & floor covering	Carpet, wall cover	30-80% (Carpet)

[133] PFAS-Containing Lubricants Used in Semiconductor Manufacturing, Semiconductor PFAS Consortium Lubricants Working Group, May 18, 2023
[134] PFAS-Containing Fluorochemicals Used in Semiconductor Manufacturing Plasma-Enabled Etch and Deposition, Semiconductor PFAS Consortium Plasma Etch and Deposition Working Group, June 28, 2023

Technical textiles	Construction textile	Canvas, gear, awnings, tarps	20%
	PPE (Personal Protection Equipment)	Protective gloves, overalls, coats, safety footwear	100%
	Military textile	Antiballistic fabrics, apparel	-
	Medical textile	See section 3.2.6 \	See section 3.2.6 \
	Industrial textile	Filters, membranes	-
Clothing & Apparel	Sportswear	Various	10%
	Indoor and outdoor wear	Various	20%
Other	Aftermarket treatment for textiles		

Belgian industry

The Belgian turnover of the textile sector reached €5.1 billion in 2022.[135] The same year, the total imports and exports of textile materials and articles made of textile materials reached €14.0 billion and €15.7 billion respectively.[136]

The Belgian industry is specialised in interior textiles and technical textiles, employing 18 000 people and involving 571 companies. Turnovers per product group are summarised below (Table 43). 75% of the Belgian textile production is exported with approximately 65% to the EU.[135] There is no production of industrial textile in Belgium, unlike in France or Germany.[137]

Table 43: Insight of the Belgium textile industry with associated PFAS uses

Product category	Product	Turnover in 2022	Share of EU industry	Export	PFAS uses
Interior textiles	Carpets, furniture fabrics, curtains, wall coverings, mattresses	€1.7 billion, including €1.4 billion for the carpet production.	4.0%	80%	Unclear, but decreasing
Technical textiles	PPE textiles, construction textiles, composite materials, medical textiles…	€2.4 billion	8.6%	70%	High volume and critical uses
Clothing textiles	Sportswear, rainwear, casual wear, fashion clothing, workwear	€0.41 billion	0.71%	80%	Unclear, presumably low market penetration
Aftermarket treatment for textiles		-	-	-	Known, but not characterised

135 Fedustria
136 https://stat.nbb.be/Index.aspx?DataSetCode=COMEXT&lang=fr#
137 Centexbel

According to Fedustria, the Belgian textile finishing activity employs 940 people in more than 40 companies, this sector has a turnover of €168 million with a growth of 5%. This activity is either integrated into a textile mill or carried out by independent specialist suppliers. Textile finishing comprises both decorative treatment for interior or clothing textile (bleaching, printing, colouring) and treatment of technical textiles to improve durability and resistance such as adding water and oil repellency properties.

The Belgian textile industry is closely dependent on the use of PFAS and PFHxA, with PFAS-containing products being a major market. However, the use of PFAS has been decreasing in the past 20 years. According to Fedustria and Centexbel, there are about 5-20 companies using PFAS in Belgium. These companies are rather big or medium-size enterprises who export in the EU and abroad, such as Sioen Industries NV.[138] This estimate complies with the list established by the Forever Pollution Project: 16 Belgian industrial sites are presumptively using PFAS during the finishing of textile processes.

Interior and decorative textiles such as carpets, furniture or curtains do not integrate as much PFAS as before. PFAS are not a standard anymore for interior textiles or furniture, but they are still integrated by one company in outdoor upholstery, and another company in an indoor wall covering paper. PFAS might be still used in carpets production. According to Centexbel and Fedustria these applications and volumes are trivial and non-significant. This statement is not in line with the results of the Wood/EU study and ECHA report, for which almost 100% of home textiles do contain PFAS at level up to 3% (w.w) At the same time, at the European scale, the ZeroF project (Horizon Europe, €5 million, 2023-2025, no Belgian partner) aims to phase out PFAS from upholstery textiles.[139] As a matter of fact, it is unclear whether Belgian producers and transformers of textile materials and Belgian federations are aware of the exact formulation of the coatings they use. For the following calculation, two scenarios will be considered.

In accordance with previous reports, PFAS are widely used for applications in technical textiles that must meet challenging specifications. These include military, police or medical textiles and PPE (Personal Protective Equipment) used by workers in manufacturing and chemical plants. PFHxA is both used for the production and for the repair of the textile equipment. For those products, PFHxA is used to (i) bring oil and chemical repellency, (ii) improve durability up to 10 or 20 years or up to a fixed number of washing and (iii) to reach the required specification of EN 13034 (chemical protection) or EN 465 (fire protection). It seems likely that PFASs are always used to reach oil repellency and are used in a significant share of the Belgian technical textile production.

Volumes (in Belgium)

The first study conducted by the European Commission & Wood in 2020 estimated that 62 400 tons are consumed in TULAC articles annually (mid-point, medical textile excluded). More recently, according to the ECHA survey, the total volume of PFAS is estimated at 91 224 tons/year (mid-point, medical textile excluded). The Belgium textile industry and the Belgium textile finishing industry represent respectively 3.5% and 3.7% of the European industries. Using this ratio, **a first estimate of the Belgian PFAS volume is 2 184-3 374 t/y.**

The PPE and chemical protective suits have been reported to contain respectively 1.5-3 % of short-chain PFAS and a few percents of FPs (PTFE, THV or FKM). In contradiction with NACE codes and textile federations, PPE have been classified as professional apparel in the ECHA and Wood reports. At the European scale, the estimated tonnage of PFAS used in professional apparel (PPE included) is 12 632 tons, including 601 tons on non-polymeric PFAS. Some part of this is used in PPEs which mainly consist in PFHxA for Belgium, but an exact quantification has not been established. Fluorinated polymer processing aids (PPA) for plastic fibres extrusion and manufacture of FPs fibres are also considered.

[138] Position statement by Sioen Industries on the proposal for a restriction on per- and polyfluoroalkyl substances (PFASs)
[139] https://cordis.europa.eu/project/id/101092164

The estimated tonnage of PFASs used in technical textile (PPE excluded) is 16 371 tons, including 2 710 tons of non-polymeric PFAS. Fluorinated PPA for plastic fibres extrusion and manufacture of FPs fibres are still considered. The ECHA volume and method have been applied to estimate Belgian volume. The PFAS volumes are summarised in Table 44.

Table 44: Estimate of the PFAS volume used by the Belgium TULAC sector

Product category	Estimation method	PFAS volume	Approx.
Interior textile	At the European scale, PFAS uses reach 16.8 kt for the professional apparel. According to EUROTEX and Fedustria, Belgium represents 4.0% of this European industry. This ratio has been applied.	675 t/y	PFAS uses in carpet production remain unclear
Technical textile *Professional apparel & PPE*	At the European scale, PFAS uses reach 12.6 kt for the professional apparel. According to EUROTEX and Fedustria, Belgium represents 8.6% of this European industry. This ratio has been applied.	1 086 t/y	
Technical textile *Other*	At the European scale, PFAS uses reach 16.4 kt for the other technical textiles. According to EUROTEX and Fedustria, Belgium represents 8.6% of this European industry. This ratio has been applied.	1 407 t/y	*Overestimation* -The Belgium market is not specialised in industrial textile
Clothing textiles *Excluding professional apparel*	At the European scale, PFAS uses reach 27.7 kt for the professional apparel. According to EUROTEX and Fedustria, Belgium represents 0.71% of this European industry. This ratio has been applied.	195 t/y	
Aftermarket treatment for textiles	An approximative calculation provided by the European Textile Services Association (ETSA) indicates that around 20 tons PFAS are used to reimpregnate PPE. No publicly available data exist on this market in Belgium.	0 T/y	*Underestimation* - Missing contribution of the aftermarket treatment for textiles
Total		**3 363 t/y**	

According to the above calculations, the volume of PFAS used by the Belgian textile industry is 3 363 t/y. It is likely that this PFAS volume is overestimated since only few evidence has been found on PFAS uses in interior or clothing textiles. Furthermore, according to Centexbel, no industrial textiles are produced in Belgium, the technical textile production (excluding PPE) is likely to be overestimated as well.

Considering that the production of PPEs and working apparel might be the only significant sector using PFAS in Belgium, volume would be 1 086 t/y. Obviously, this estimate suffers from several underestimations and contradictions with the European reports. **A more realistic estimate would be between 1 086-3 363 t/y.** For the rest of the study, two estimates are used: low volume (1 086 t/y) and high volume (3 363 t/y) scenario.

The ECHA ratio have been applied to estimate the share of the different PFAS molecules used for the two scenarios and for each textile category. The results are summarised in the table below.

Table 45: Estimate of the PFAS volume according to the two different scenario and PFAS groups

PFAS category	PFAA & PFAA precursors	Fluoropolymers	Total PFAS
Low volume scenario *Professional apparel & PPE from Table 44*	**51.6**	**1 034**	**1 086**
Interior textile	122	553	675

High volume *scenario* *Any textile from Table 44*	Technical textile *Professional apparel & PPE*	51.6	1 034	1 086
	Technical textile *Other*	233	1 174	1 407
	Clothing textiles *Excluding professional apparel*	57.7	138	195
	Total	**464**	**2 899**	**3 363**

Between 1.1 and 3.4 kt/y of PFAS are used in Belgium by the textile sector, including a significant part of PFAA and PFAA precursors: between 50 and 450 t/y. As 70-75% of the production is exported, only limited tons stay in Belgian territory. As no industrial textiles are produced in Belgian, it is likely that significant amounts are imported.

Environmental impacts

The ECHA approach has been used to estimate the emissions of PFAS during the production stage of PFAS-containing technical textiles. Emission occurs during the (i) manufacture and extrusion of non-woven membranes, (ii) manufacture of the coating mixture, (iii) manufacture of solid articles and (iv) application of the treatment on the textile. Two reference volumes have been used: low volume (1 086 t/y) and high volume (3 363 t/y) scenarios. It is obvious that not all textiles involve the four basic production steps. Without more data, we assumed that each production steps is applied to half of the textile products in Belgium. The emissions rate and volume are gathered in Table 46 (low-volume) and Table 47 (high-volume).

Table 46: Emission of PFAS during the production of technical textile in Belgium – Low volume scenario

Product	Production stage	Belgian volume considered (t/y)	Emission stream	Emission rate according to ECHA (% w.w)	PFAS emission (t/y)
Professional apparel & PPE	Manufacture of non-woven membranes	FPs: 543 Non-FPs: 25.8	Air	2.5	13.6
			Soil	2.5	13.6
			Wastewater	2.5	13.6
			Total	7.5	40.7
	Manufacture of mixtures	Non-FPs: 25.8	Air	2.5	0.65
			Soil	0.01	0.00
			Wastewater	2	0.52
			Total	4.51	1.2
	Manufacture of articles	Non-FPs: 25.8	Air	0.1	0.03
			Soil	0.03	0.01
			Wastewater	5	1.3
			Total	5.13	1.3
	Treatment of textiles	Non-FPs: 25.8	Air	5	1.3
			Soil	0.1	0.03
			Wastewater	2	0.52
			Total	7.1	1.8
	Production, all stages		Air	-	15.5
			Soil	-	13.6
			Wastewater	-	15.9
			Total	-	45.0

Table 47: Emission of PFAS during the production of technical textile in Belgium – High volume scenario

Product	Production stage	Belgian volume considered (t/y)	Emission stream	Emission rate according to ECHA (% w.w)	PFAS emission (t/y)
Any textile	Manufacture of non-woven membranes	FPs: 1,449 Non-FPs: 232	Air	2.5	42.0
			Soil	2.5	42.0
			Wastewater	2.5	42.0
			Total	7.5	126
	Manufacture of mixtures	Non-FPs: 232	Air	2.5	5.8
			Soil	0.01	0.02
			Wastewater	2	4.6
			Total	4.51	10.5
	Manufacture of articles	Non-FPs: 232	Air	0.1	0.23
			Soil	0.03	0.07
			Wastewater	5	11.6
			Total	5.13	11.9
	Treatment of textiles	Non-FPs: 232	Air	5	11.6
			Soil	0.1	0.23
			Wastewater	2	4.6
			Total	7.1	16.5
	Production, all stages		Air	-	59.3
			Soil	-	42.4
			Wastewater	-	62.9
			Total	-	165

According to the ECHA methodology, the production of technical textile in Belgium generates between 45 and 160 tons of PFAS per year. Emissions of PFAA and PFAA precursors reach between 6 and 56 t/y. Emission occurs through release into wastewater collection system (≈36%), air (≈35%) and soil (≈28%).

The emissions during use stages are highly application dependent. The ECHA and Wood / European commission reports proposed a complex methodology to estimate emissions resulting from textile article uses. Unfortunately, pertinent estimates on PFAS emissions occurring during the possible use stages are not available. The main emissions are coming from indoor use of treated articles that are subject to frequent cleaning/washing. According to the European commission report, significant emissions are also attributed to landfilling.

Existing alternatives

For PFAS-free PPAs and PAs, please refer to section 3.2.11 \Plastics

The textile industry is highly linked to PFASs due to requirements related to water, oil and chemicals repellency. Industrials are encouraged by public policies to phase out PFAS and several alternatives have been used (TRL=9) for many years. Alternatives include hydrocarbons (Ecorepel® by Schoeller)[140], polysolixanes, silicones, polyurethane (PurTex® by Freudenberg

[140] https://www.schoeller-textiles.com/en/technologies/ecorepel

New Technologies)[141], dendrimers (OrganoTex by OrganoClick)[142] or nanomaterials. Several textile article manufacturers already planned or achieved to phase out PFAS.[143,144,145]

Water repellency is achieved with paraffin-based formulations, silicones, polysiloxanes or surface nanostructuration. According to Fedustria and Centexbel, in the Belgian industry those products have already been used for the manufacture of home textiles such as carpets and curtains for the last 20 years with – almost – no penetration of PFAS anymore[146]. Nevertheless, the poor durability of these alternatives leads to more expensive maintenance, repair costs and shorter lifespan.

The real challenge for the Belgian industry concerns the PPE, where no alternatives exist for the C6 molecules such as PFHxA. Desk research, the ECHA reports or the Wood report lead to the same conclusions. Several reasons limiting the PFAS phase out were mentioned:

- No alternatives for the oil repellency requirement
- No alternatives for combining several resistance requirements (water & oil, temperature, chemicals…)
- PFASs ensure long-lasting properties, up to 10-20 years or for an acceptable number of washing cycles
- Challenging specifications of the EN 13034 (chemical protection) and EN 465 (fire protection) standards

According to Centexbel, **there is no viable alternative and no R&D opportunities even at low maturity.** The C4 PFAAs could poorly achieve comparable properties and the volumes needed are much bigger. Numerous companies have already invested in technology scouting or R&D alongside with Centexbel, without success. « *Our sector already investigated alternatives with no technical solutions* ».

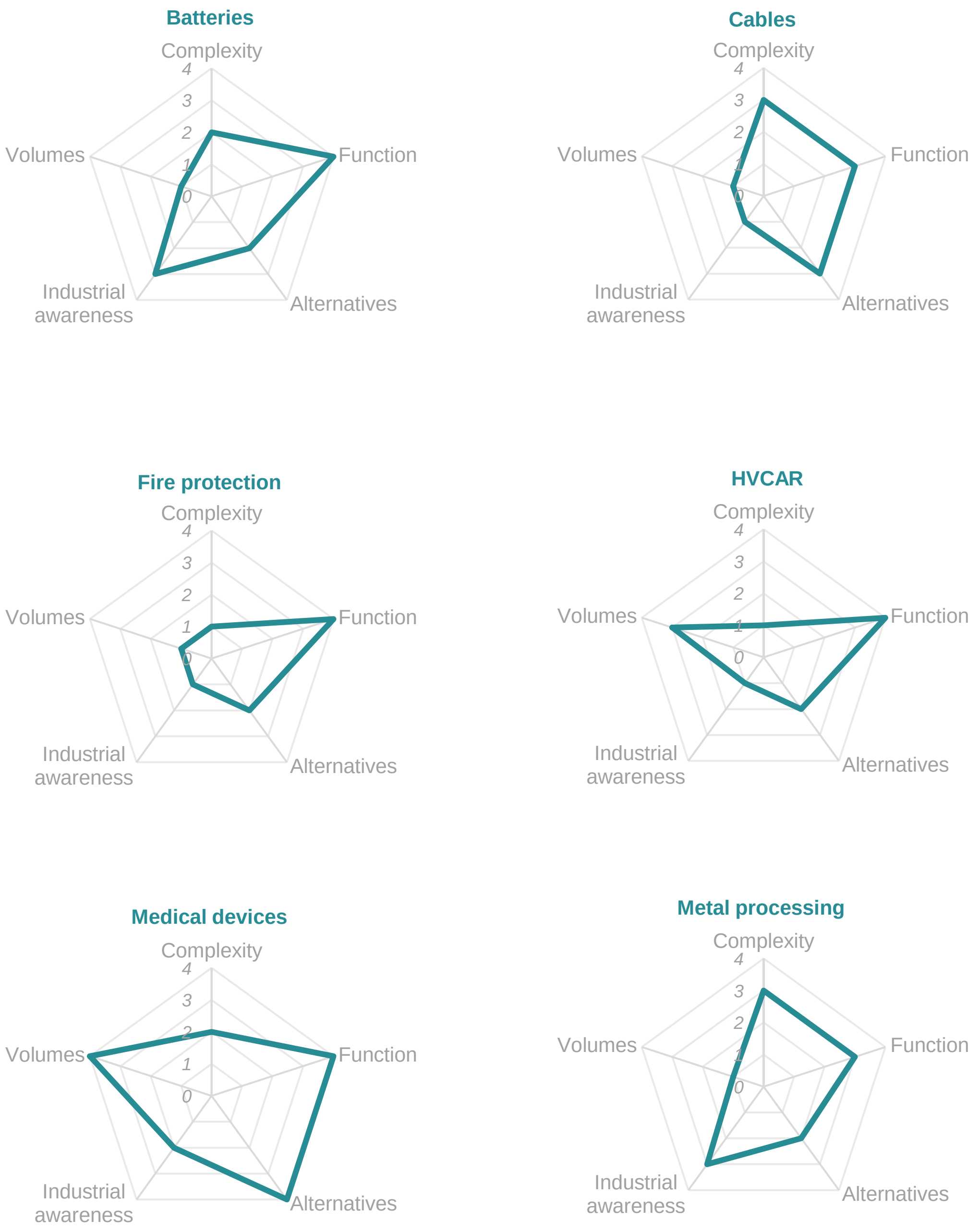
[141] https://www.spoteo.de/wissen/technologie/technologie_1291_PURTEX-Technologie.html
[142] https://organotex.com/sv/
[143] https://www.patagonia.com/our-footprint/pfc-free.html
[144] https://www.textiletechnology.net/technology/news/nassimi-pfas-free-textiles-with-good-stain-resistance-33551
[145] https://www.just-style.com/news/the-transition-to-a-pfas-free-textile-industry/
[146] Fedustria and Centexbel interviews

3.3 \ Comparative analysis

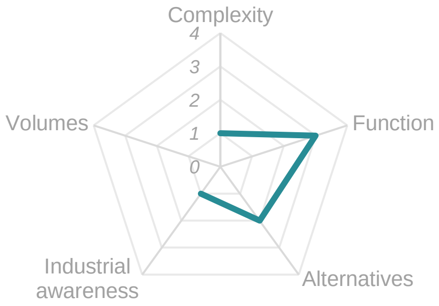
This review of the 12 different markets revealed heterogeneous contexts with different awareness on PFAS uses, penetration of alternatives or economic importance. Volumes of PFAS also largely differ, with three segments (Medical, TULAC & HVACR) gathering more than 75% of all the estimated PFAS volume used in Belgium (i.e., 8 330 t/y). In order to evaluate the relevance of public action and to orient the selection of instruments, all market segments were reviewed and characterised through the criteria detailed in the methodology section (page 15).

Applying this analysis leads to a series of graphs, as displayed in next pages. In some cases, the segment scope was restricted to the most relevant applications for Belgium; a distinction between uses belonging to the same segment, but with significantly different profiles, was also made for plastics and pesticides.

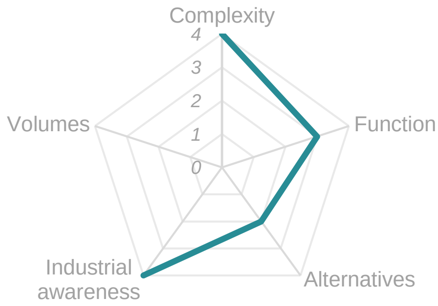
Figure 1: Comparative analysis of the 12 segments



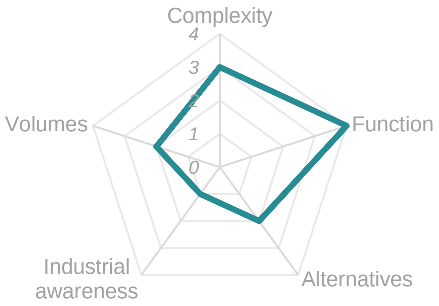
PPP: active ingredients



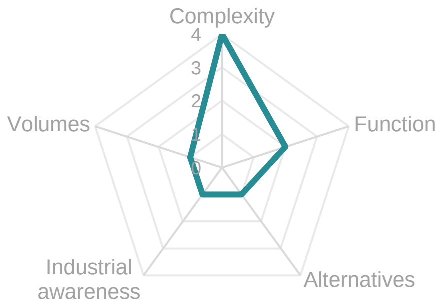
PPP: inert ingredients



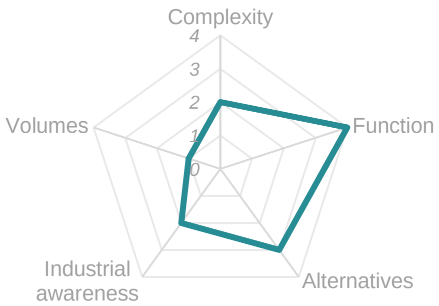
Plastics: fluoroplastic products



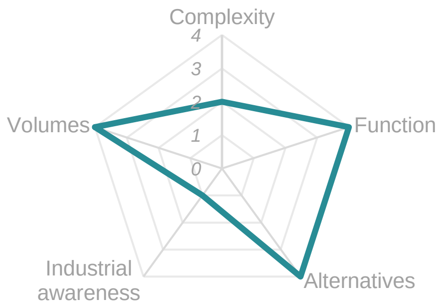
Plastics: polymer processing aids



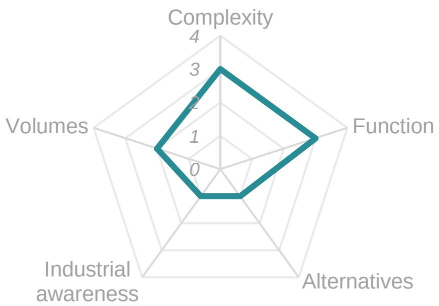
Semiconductors



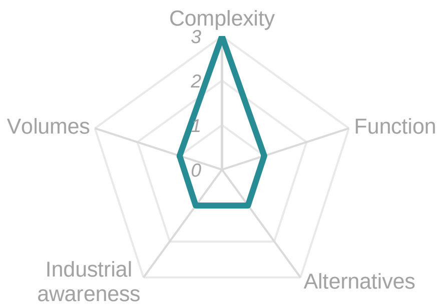
Technical textile



Paints and coatings



Paper, carboard, packaging



This evaluation is supported by the following comments:

- Batteries

Some main battery functions depend on the use of PFAS (binders, seals, coatings, electrolyte and additives), while others are secondary (surfactant, anti-grip agents). Furthermore, batteries are to be considered as critical for the transition towards a low-carbon economy.

PFAS uses in batteries are well documented, but debates about alternatives are only emerging. These alternatives are identified for some components but are considered as not yet satisfactory. A possible transition would be the adoption of new battery technologies, but which could also require the use of PFAS.

- Cables

PFAS are used in mature products, when a higher level of protection is needed, for example when failures would have significant impacts, in sectors such as telecoms, medical equipment, energy, etc.

The subject is rather well documented, and some alternatives are already tested. However, potential alternatives all have limitations and are still under development.

- Fire protection

PFAS are often key components in these applications, which are submitted to strict technical requirements. Obviously, final products are directly related to safety.

PFAS uses are well documented, and professional organisations (e.g., ANPI, PFPA, EAPFP, CFPA) play an active role on this subject. Some alternatives for firefighting foams have been developed in Europe (including Belgium) since the first bans and are already commercially available, while there seems to be no satisfactory alternatives for fire suppressants.

- HVACR

Fluorinated gases play a key role in these applications, as working gases or blowing agents (for foam production). Some applications are associated with fundamental needs, e.g., logistics in food, medical products, etc.

All uses are well documented, and several alternatives already known and tested. As a matter of fact, alternatives are implemented for consumer refrigeration, while alternatives for other applications display limitations (e.g., toxicity, flammability, efficiency).

- Medical devices

PFAS are rarely associated with the main product function. They are more commonly used in ancillary or secondary roles. However, product deficiencies may have impacts from the point of view of health.

PFAS uses are already well known, with some potential alternatives being investigated. However, as of today, limitations are identified for most potential alternatives.

- Metal processing

PFAS are involved in processes used for a long time by the industry. Considering the final product, mechanical parts, for example for the automotive and aeronautic industries, may have a critical function (safety).

The use of PFAS is globally well documented, but awareness in the Belgian industry seems very limited. There are several known alternatives, but hard chrome plating seems difficult to replace in some applications. Search for Cr(VI)-free processes is also supporting the adoption of PFAS-free alternatives.

- Paints and coatings

PFAS containing coatings are used when a higher level of « protection », in generally mature applications, is required. Deficiencies may have impacts in terms of product lifetime, and in some cases, product safety.

The topic is already discussed by the Belgian industry. Various alternatives are already available, except in specific cases (e.g., harsh environments).

- Paper, cardboard, packaging

PFAS are useful to provide repellency in food-contact packaging. As a matter of fact, they play a limited role in the preservation of food, for example.

PFAS uses and alternatives are rather well documented for food-contact products. Alternatives can already be implemented.

- PPP

There are two primary PFAS uses: as key components (active ingredients) and as co-formulants (secondary component). Deficiencies in pesticides is likely to have impacts on agricultural productions.

The industry has clearly identified the use of PFAS as a key component. However, the use of PFAS as a secondary component is not well understood, and there is limited knowledge of alternative options. Efforts to find alternatives to pesticides have generally aimed at reducing chemical pesticide usage, despite successful techniques, their effectiveness falls short compared to PFAS-containing pesticides.

- Plastics

A distinction has to be made between polymer processing aids (PPA) and fluoroplastics (FP). PPA play a role only during the production step, with a limited presence in the final product, while FP play a key role in several industrial plants and transport. In the latter case, there are critical risks in case of deficiency of some components (e.g., production equipment in chemical plants).

From a general point of view, PFAS uses and potential alternatives are well documented. Alternatives are available for PPA, while there may be limitations for some FP technical products (ex.: sealings).

- Semiconductors

PFAS do not play central roles, but are generally indispensable. Depending on the final application, electronic components may be considered as critical (e.g., telecom and energy infrastructure, aeronautics, medical, etc.).

Alternatives are difficult to evaluate, because of the multiplicity of uses. However, most PFAS uses are well identified, and debates are currently emerging within the industry, at a global level.

- TULAC

The scope is limited to technical textile (e.g., personal protective equipment), which are been highlighted as more complex products, with strict technical requirements defined by EN specifications. Obviously, there are safety challenges associated with the use of these products on industrial plants, fire sites, etc.

As of today, the subject of PFAS uses is well documented, and some alternatives were already, though unsuccessfully, tested. As a matter of fact, no viable alternative, even at low maturity, meet all the requirements.

The different profiles, as they appear through these graphs, reflect a variety of situations, which may significantly differ between the segments reviewed in this analysis.

There are, however, some common features:

- For example, the paper and packaging segment and the plastics/polymer processing aids segment have very similar profiles. This is mainly due to the fact that, in both cases, the PFAS issue concerns mainly food-contact packaging – more specifically, paper and polymer films. The end application itself cannot be considered as “essential”, and in both cases, alternatives are available. From this point of view, there should not be any major obstacle for the transition of the Belgian industry; in the longer term, a major issue could be the presence of PFAS in imported products, these substances being present in end-of-life packaging likely to be recycled in Belgium.

- The medical devices and semiconductors segments have common features: in both cases, numerous PFAS are used for a large variety of functions, which makes the elaboration of a common approach difficult. These various uses are well documented, and the industry currently considers that replacing PFAS is a major – even impossible – challenge. The main difference between those two segments lies in the quantities involved: small volumes for a limited number of companies for semiconductors, large volumes for numerous companies for medical devices.

From a more transversal point of view, the following comments can be made:

- Globally, there is a more or less high level of awareness about current uses of PFAS within the industry. There are a few exceptions, notably when, in a processing step, some companies use products (typically chemical products) incorporating PFAS, without knowing the exact composition of these products. However, this kind of situation tends to be more and more marginal, as most professional organisations disseminate information on this subject.

- Alternatives are known, validated and even implemented in some industries, such as paper and packaging, paints and coatings or polymer processing aids. The chemical industry, generally speaking, is already a provider of alternatives for these industries.

- The lack of alternatives is more prevalent for applications with high levels of requirements, e.g. from the point of view of safety (protection equipment) or health (medical devices). In these cases, compromises should be sought, between technical performances, cost, product lifetime, and possibly environmental impacts. In an industry such as HVACR, the transition to alternatives has to be tackled differently according to the specific use cases, taking into account, for example, challenges from the point of view of safety.

4 \ PUBLIC POLICIES: HOW TO SUPPORT THE TRANSITION TO ALTERNATIVES?

This section will discuss PFAS-free alternatives and the policies that can be put in place to help speed up the process of switching, depending on the technological readiness level of PFAS-free alternatives ("**alternatives**") and other considerations. More specifically, this section sets out the following.

1. PFAS substitution at the Belgian and EU levels.	**2.** Avoiding regrettable substitution.	**3.** Public policies to accelerate substitution.	**4.** PFAS alternatives across sectors.	**5.** PFAs alternatives and policies for priority sectors.

4.1 \ PFAS, Belgium and the EU

There are several key facts that should be considered in any Belgian policy towards PFAS substitution.

- Much of PFAS manufacture itself is outside of Belgium (and the EU).
- Companies manufacturing PFAS are often distinct from the companies using them in their final products.
- Companies active in Belgium (and the EU) will therefore often tend to be focused on the use and end of life phases rather than the development of the PFAS themselves. This is sometimes a limiting factor in the research of alternatives due to a lack of adequate skills and conflicting interests.[147]
- In many sectors, companies using PFAS in their products (e.g., in medical devices and HVACR sectors) are active across multiple EU countries. The location of R&D finding PFAS alternatives is unlikely to be significant to these firms, as long as they are able to effectively use them in their applications.

While the competitiveness of Belgian firms in a potential post-PFAS world is vital, any policy assessment will need to consider this broader cross-border context. It is unlikely that many of the solutions to substitution in a given sector will originate within one country (including Belgium), but rather from international collaboration and efforts. This is of course not to say that the firms active in Belgium should not be supported in this effort by public policy.[148]

4.2 \ Avoiding regrettable substitution

Substitution towards alternatives should be encouraged if and only if it is more sustainable than PFAS, considering the full supply chain. In many cases, the sanitary effects and potential trade-offs (e.g. on safety, climate change, circular economy…) of using direct PFAS alternatives are still uncertain and so, safe and sustainable substitution remains a long-term challenge. In cases

[147] For example, industry participants in the HVACR industry noted that material research tends to be done outside of Belgium (and often of the EU). In addition, as regulations are not harmonised globally, this can create conflicting incentives for PFAS producers to research PFAS alternatives urgently.
[148] As called for under Belgium Builds Back Circular at https://economie.fgov.be/en/themes/enterprises/calls-projects/belgium-builds-back-circular/call-projects-belgium-builds-0 for example (accessed 16/11/2023).

where functional substitution is possible[149], there may be a lower risk of regrettable substitution.[150]

To avoid regrettable substitution, it is therefore important to have a clear picture of:

- The applications an alternative would be used for.
- The risks of PFAS for this application.
- This should be balanced against the impact of specific alternative(s) throughout the supply chain. Comprehensive cost-benefit and/or life cycle analyses that tackle the environmental, social (including health, with toxicity models if relevant such as EUSES, Chesar) and economic aspects can help with these assessments.[151]
- How the switching to alternatives may interact with other regulations linked to global warming potential or EcoDesign targets.[152]
- In particular for cases with many possible alternatives or avenues for alternatives, a clear understanding of the hierarchy of alternatives (between themselves) and their technological readiness levels as compared to PFAS should also be communicated by the administration to help unlock the necessary means and support for the potential more desirable substitutes.

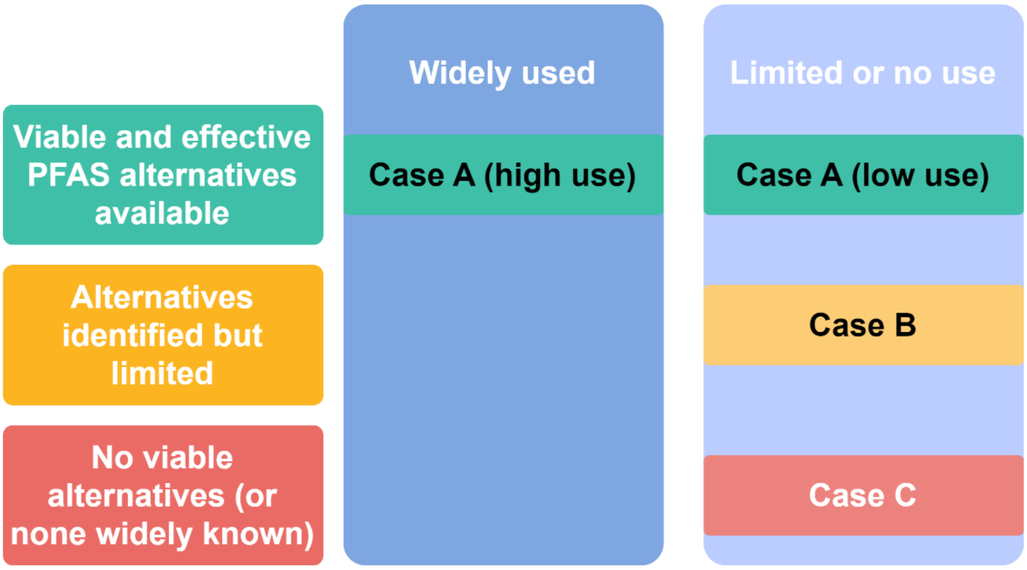
Part of the challenge across the industry is to group applications of PFAS together effectively (i.e., for which common alternatives can be found), which should be done in consultation with researchers, regulators and the industry.[153]

4.3 \ Public policies typologies

PFAS substitution is a highly complex issue, which differs significantly across industries, and even across sub-applications in these industries. Generally speaking, there are several sub cases that can occur (in terms of availability and usage), as summarised by the Figure below.

[149] Replacing products with products that carry out the same function but do not require a PFAS-like substance (for example, this can work for some patients with glasses over contact lenses - although it is important not to generalise to all patients).
[150] There may be instances where a performance reduction is unavoidable or the function is not replaceable in a post PFAS world.
[151] See for example p6 of the Annex to the Commission Recommendation establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials (https://research-and-innovation.ec.europa.eu/system/files/2022-12/Commission%20recommendation%20-%20establishing%20a%20European%20assessment%20framework%20for%20safe%20and%20sustainable%20by%20design%20-%20annex.PDF, accessed 16/11/2023).
[152] For an illustration of this for fluorinated gases, see Figure 8.
[153] ECHA's Strategy to promote substitution to safer chemicals through innovation (2018) (https://echa.europa.eu/documents/10162/17228/250118_substitution_strategy_en.pdf/bce91d57-9dfc-2a46-4afd-5998dbb88500?t=1516881185315, accessed 16/11/2023) notes the importance of using Registration and Risk Data for Substitution, that is (i) using structural similarity and grouping approaches to avoid regrettable substitution and (ii) disseminating information on groups of substances to downstream users, aiding their substitution efforts.

Figure 2: Different PFAS free alternative maturity levels



The cases represented above can be further explained as:

- **Case A - Available alternatives:** These should be understood as available and viable substitutes for the relevant applications and, as such, require minimal public support. This can be further split into cases where the viable alternative is widely or not yet widely used.
- **Case B - Imperfect alternatives/in development:** These are alternatives that result in significant trade-offs (cost increases or performance drops), which would need additional support and/or development (and given these trade-offs, they are not currently widely used).
- **Case C - No viable alternatives identified or very little development:** These are applications with no widely accepted alternatives (or none at all) as of today.

It is evident that there is no single broad policy which will fit every PFAS substitution case with over ten thousand different PFAS types.[154]

The following sets out different PFAS alternatives by readiness levels and potential public policy requirements. This is necessarily broad given the variety of applications and readiness levels and would clearly need adjustment to specific cases.[155,156]

4.3.1 \ Case A: Viable alternatives

In **Case A**, there are alternatives in the industry which are or are not widely used (**low** and **high use**).

- **Low use** relates to cases where customers or the industry are set in a market equilibrium where PFAS is the default option despite the existence of valid and viable alternatives.

This differs to the case where the alternative exists but is much less commercially viable or results in significance performance drops (case B).

- **High use** would refer to the case where most of the market already uses the alternative(s), and it would be a matter of accelerating full migration to convert laggards.

[154] PFAS ECHA restriction proposal – Annex XV, page 21.
[155] Where subsidies are mentioned, it is assumed that they are going towards an alternative that has had a comprehensive cost/benefit analysis/impact assessment to support its desirability as a replacement throughout the supply chain.
[156] Public policies for PFAS should not serve to help substitute products that are noncompliant with other regulations currently, rather to focus the transition of products that are compliant now but would not be with a PFAS ban.

The Figure below discusses public policies which can help accelerate full adoption, in particular where the alternatives are available but not widely used.

Figure 3: Types of policies for applications with PFAS alternatives (Case A)[157]

PFAS alternatives in use (viable, effective alternatives)

Low current levels of use in applications

Policy A1: Increase consumer/producer information levels.

Policy A2: Short term and decreasing over time subsidies for a given share of consumers to switch.

Policy A3: Ensure technical guidance on use of alternatives is widely available and accessible.

Policy A4: Ensure (through trainings or incentives) that there is enough competent staff to use and install alternatives to PFAS where relevant.

High current levels of use in applications

Policy A1: Increase consumer/producer information levels.

Policy A3: Ensure technical guidance on use of alternatives is widely available and accessible.

Policy A5: Place increasing restrictions on PFAS with environmental permits.

Providing consumers/producers with additional information can take many forms but can also include Ecolabels for example.[158]

4.3.2 \ Case B: Alternatives identified but with drawbacks

In **Case B**, there may be identified alternatives that technically work (or are expected to work) but have drawbacks. These can be due to significantly reduced performance as compared to PFAS, or increased cost: either CAPEX (capital expenditure) or OPEX (operating expense)[159]. The figure below sets out possible policies to help remedy these situations.

[157] Policy A5 likely be implemented at the regional level but could be suggested/coordinated at the federal level.
[158] As noted by Lessons Learned from Third-Party Approaches that Support Substitution of Chemicals of Concern, OECD Series on Risk Management, No.78, Environment, Health and Safety, Environment Directorate, OECD: "*What ecolabels have in common is their role in informing consumers and stimulating market demand for products with improved hazard profiles. Ecolabels not only provide consumers with information that allows them to choose safer and more sustainable products and services, but they also simplify business-to-business (institutional) purchasing (Golden et al., 2021). Ecolabels enable consumers and other purchasers to effect change throughout the supply chain, including product manufacturers as well as chemical suppliers, by allowing them to signal with their purchases that they want less hazardous products.*"
[159] OPEX (operating expenses) are the costs associated with running a business on a day-to-day basis, such as salaries, rent, and utilities. CAPEX (capital expenditures) are the costs associated with investing in new assets or infrastructure, such as buying new equipment or building a new factory.

Figure 4: Types of policies for applications with problematic PFAS alternatives (Case B)[160]

Alternatives identified but limited	**CAPEX Barrier: Capital expenditure required to bring solution to market**	**For new installation of alternative / system / unavoidable CAPEX increase** **Policy B1-1:** Subsidies decreasing over time, based on percentage of CAPEX covered, with different criteria for attribution by size of applicant, (automated for domestic small applications, project reviewed for larger scale).	**For R&D related CAPEX** See performance barriers below.
	OPEX barrier: Operating expenditure required to run solution	**OPEX increase can be reduced** **Policy B1-2:** R&D subsidies to reduce OPEX. **Policy B2:** Facilitating information exchange or collaborative R&D.	**OPEX increase cannot be reduced (and there are no better product alternatives)** **Policy B1-3:** Creating time limited subsidies on basis of usage. **Policy B1-4:** Where there are exisiting product subsidies, modify them to be more favourable to PFAS-free alternatives.
	Performance barrier (alternative exists but results in signficant drop in performance in key properties)	**If R&D is unlikely to reduce the performance gap** **Policy B1-5:** Subsidies (decreasing over time) for switching or identifying functional alternatives (if they exist) instead of product alternatives.	**If R&D is likely to reduce the performance gap** **Policy B4-6:** Subsidies for R&D to improve performance. **Policy B1:** Facilitating information exchange or collaborative R&D. **Policy B3**: Ensuring private incentives to improve process are optimised (patent protection etc).

In many of the scenarios above, creating or reinforcing existing working groups between industry participants, regulators and public bodies will be beneficial to avoid duplication of work and accelerate progress.[161]

- There are many references to the **benefits of enhancing industry collaboration**, for example ECHA's substitution strategy to safer chemicals through innovation[162] or the OECD.[163] These note that the following can aid with substitution:
  - **Capacity Building and Collaboration:** Promoting supply chain collaboration through capacity building, encouraging knowledge sharing among stakeholders, and organising workshops for dialogue and collaborative projects on safer alternatives. This can also include (i) supporting filling of data gaps (leveraging existing data and sharing it effectively whilst considering other

[160] Given that relevant PFAS may simply be banned, this means that PFAS free alternative OPEX do not necessarily have to be OPEX-competitive to PFAS OPEX. OPEX subsidies should be carefully considered based on the specific case. For example, in the case where the OPEX increase is so high that it materially discourages the adoption of socially desirable products (e.g., heat pumps or electric vehicles), then OPEX subsidies may be desirable, but this should not be seen as a general conclusion which can apply regardless of the case. That is, in some cases it may be better for subsidies to be provided elsewhere and usage costs increase somewhat for users, if it does not mean shifting away from socially desirable outcomes and product use.

[161] For a further discussion of collaboration, see the discussion in the HVACR section (0).

[162] See Strategy to promote substitution to safer chemicals through innovation – ECHA – 2018: https://echa.europa.eu/documents/10162/17228/250118_substitution_strategy_en.pdf/bce91d57-9dfc-2a46-4afd-5998dbb88500?t=1516881185315, accessed 15/11/2023.

[163] See OECD (2023), Cross Country Analysis: Approaches to Support Alternatives Assessment and Substitution of Chemicals of Concern – 2nd edition, OECD Series on Risk Management, No. 77, Environment, Health and Safety, Environment Directorate, OECD.

sources of information[164] and (ii) promoting transparency along the supply chain. Indeed, governments have a unique position to coordinate dialogue across the supply chain and with other relevant stakeholders (NGOs, regulators and so on), as well as for creating regulatory stability and predictability.

- **Development of Substitution-Related Networks**: Networks are vital for informed substitution, for example by the creation of a multi-stakeholder network involving ECHA, the European Commission, industry organisations, NGOs, research institutions, and consumers' associations. ECHA also recommends collaborating with OECD groups on substitution.[165]

- **Third party organisations** (e.g., academic institutions, research clusters, non-profit organisations and retailers) can also be key to advancing substitution, their contributions including providing technical assistance and training, conducting R&D themselves, developing labels, leading advocacy campaigns and capacity building.[166]

This could also include medium to long-term partnerships between environmental public bodies and industry participants (see for example the 2009 ADEME – Total partnership for innovation in energy efficiency).[167]

Research in **Case B** to improve performance or cost may result in finding cases where the identified alternative is simply not feasible to bring to market, which could lead to being back in **Case C.**[168]

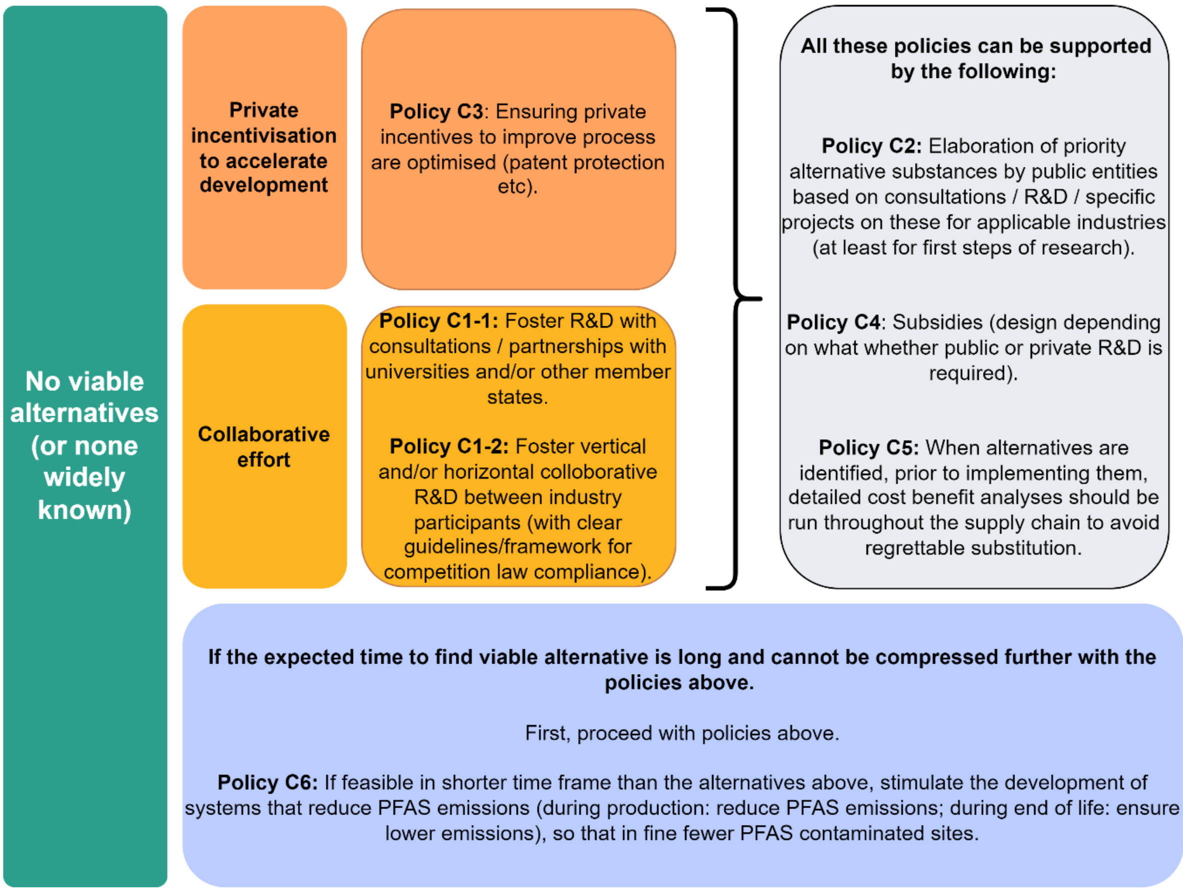
4.3.3 \ Case C: No viable alternatives identified

In this scenario, the industry has not identified viable alternative products for an application or groups of applications. This is the most problematic segment and is likely to affect the more complicated sectors with more stringent regulations to comply with.

As set out in the Figure below, there are a range of policies that can be rolled out depending on whether it is preferable in the specific use case to favour private research within firms or favour collaborative projects in the industry at horizontal and/or vertical levels.[169]

[164] See also https://research-and-innovation.ec.europa.eu/system/files/2022-12/Commission%20recommendation%20-%20establishing%20a%20European%20assessment%20framework%20for%20safe%20and%20sustainable%20by%20design.PDF. See also COMMISSION RECOMMENDATION of 8.12.2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials (https://research-and-innovation.ec.europa.eu/system/files/2022-12/Commission%20recommendation%20-%20establishing%20a%20European%20assessment%20framework%20for%20safe%20and%20sustainable%20by%20design.PDF) in paragraph 2.2.
[165] See also OECD (2023), Lessons Learned from Third-Party Approaches that Support Substitution of Chemicals of Concern, OECD Series on Risk Management, No. 78, Environment, Health and Safety, Environment Directorate, OECD.
[166] See OECD (2023), Cross Country Analysis: Approaches to Support Alternatives Assessment and Substitution of Chemicals of Concern – 2nd edition, OECD Series on Risk Management, No. 77, Environment, Health and Safety, Environment Directorate, OECD.
[167] See https://infos.ademe.fr/lettre-recherche-avril-2021/de-la-recherche-de-lefficacite-energetique-a-la-decarbonation/, accessed 16/11/2023.
[168] In other cases, products with comparable properties but without PFAS may not be feasible to bring to market, so there may have to be instances where products are no longer brought to market or are of inferior quality (where the socio-economic consequences of this are not too severe). In other cases, some properties may need to be sacrificed. For example, it may be necessary to sacrifice durability in some applications (and have less re-use of a given product if the alternative is less sustainable).
[169] Article 101 of the Treaty on the Functioning of the European Union prohibits agreements or exchanges of information between competitors with an anticompetitive object (e.g., fixing prices). However, article 101 paragraph 3 allows efficiency justifications where the agreement or exchange of information contributes to improving the production or distribution of goods. The revised guidelines for Horizontal Agreements (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023XC0721(01) includes a section which provides further input on the application of the efficiency principle to sustainability related agreements. What is clear is there is still a degree of legal uncertainty for firms as to what constitutes safe collaboration related to sustainability agreements. Thus, in many instances, the creation of a "safe" framework by public authorities for the industry to collaborate (whilst protecting business secrets and ensuring fair sharing of the results between producers but also reserving some of the benefits for final consumers) may be essential to accelerate the process of PFAS substitution.

Figure 5: Types of policies for applications with no PFAS alternatives (Case C)



In some applications, there will be a period of time during which no alternative will be available (hence the derogation proposals in ECHA's restriction report[170]). For these cases, to minimise the negative effect of PFAS (assuming derogations are granted) and as noted in the Figure above, there should be efforts made to contain the emissions of PFAS as much as is practically possible.

4.3.4 \ Prioritisation of alternatives

In many sectors, there can be a plethora of potential alternatives (or avenues for alternatives). Comparing and choosing alternatives to currently used PFAS is often challenging and delays investments from industry and users. In order to accelerate substitution, a comprehensive comparison of alternatives to establish a hierarchy would give some certainty to the sector in order to invest (mostly for Cases B and C but with some relevance to Case A). This should include:

- Establishing a list of common priority requirements of the industry to help focus research by the chemical and material development industries.
- This would be done in consultation with manufacturers, material and chemical development industries and relevant public bodies.[171]
- Once a list of requirements and sub-applications is established, certain streams of research should be prioritised. This list may also identify overlaps in R&D.

[170] See https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea.
[171] An example of centralised alternatives to hazardous chemicals can be found at https://substitution.ineris.fr/en, https://marketplace.chemsec.org/alternatives with a wider range at https://sdg.iisd.org/news/oecd-launches-online-toolbox-for-chemical-substitution-and-alternatives/.

- This could allow the creation of a common list of alternatives with assessments of the full supply chain and a positive list of alternatives to reduce duplication of costs.

4.3.5 \ Regulation and taxation

In all of the scenarios above and given the volume of new products / alternatives that would to be brought to market, there may need to be special regulatory exemptions or rather simplifications for product approval (where safe). A significant component of many alternative transition estimates from the industry is the regulatory approval period. Whilst in some cases this cannot (and should not) be compressed to ensure the safety of the product, in other cases a special regime or procedure could perhaps be set-up to accelerate the transition to alternatives.[172]

The policies above have not entered into discussions of taxation-based measures to accelerate substitution.

This is generally as PFAS substitution comes in the context of a ban on PFAS which already results in (at least short to medium term) negative impacts on the firms using them.[173] Nevertheless, there are instances where taxes and various market-driven tools can provide important complements to other forms of regulatory measures as mentioned above.

Taxing hazardous chemicals can be an effective way to accelerate its substitution through a change in the relative price.[174] That is, if the cost of substituting PFAS becomes lower than the cost associated with using them, there is then an incentive to make the switch.

- Hence, implementing taxation on PFAS (in advance of the ban) could help to accelerate substitution, where there are PFAS-free alternatives (in Case A and to a lesser extent in Case B discussed above), by encouraging substitution in the (firms') interest of cost efficiency.

- In Case C (no alternatives), a tax on PFAS would likely only induce an increase in final prices (no alternative to substitute to for customers or producers, so the cost increase would just be passed through – depending on the elasticity of demand). It is also however possible that a well-designed announcement of future taxes, after a realistic time frame for an alternative to be found, could help increase the ex-ante incentives to innovate (and get away from future taxes).[175]

- Implementing taxation can help support R&D through other channels. The revenues generated from the taxes could be then used to fund research in other sectors that have yet to find viable alternatives. Combining taxes and subsidies in collaboration with industry sectors through hybrid schemes can be a solution for finding alternatives.[176]

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[172] An example of accelerated timelines could be for COVID vaccines as set out here: https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/covid-19-public-health-emergency-international-concern-2020-23/covid-19-vaccines-development-evaluation-approval-monitoring.

[173] See Cross Country Analysis: Approaches to Support Alternatives Assessment and Substitution of Chemicals of Concern – 2nd edition, OECD Series on Risk Management, No. 77, Environment, Health and Safety, Environment Directorate, OECD (2023) (https://www.oecd.org/chemicalsafety/risk-management/cross-country-analysis-approaches-alternatives-assessment-and-substitution-second-edition.pdf) accessed on 16/11/2023 notes that: "*One of the main reasons why price-based instruments are still relatively rare in chemicals regulation is that a primary focus has been on very hazardous substances, where other regulatory measures such as bans and restrictions are more appropriate. There are, however, cases where taxes and other market-based instruments can provide important complements to other types of regulatory measures*".

[174] Economic instruments to incentivise substitution of chemicals of concern – a review, OECD Series on Risk Management, No. 79, Environment, Health and Safety, Environment Directorate, OECD (2023), https://www.oecd.org/chemicalsafety/risk-management/economic-instruments-to-incentivise-substitution-of-chemicals-of-concern-a-review.pdf, accessed on 16/11/2023.

[175] Provided the announcement of taxes is credible from the firms' perspective.

[176] Economic instruments to incentivise substitution of chemicals of concern – a review, OECD Series on Risk Management, No. 79, Environment, Health and Safety, Environment Directorate, OECD (2023) (https://www.oecd.org/chemicalsafety/risk-management/economic-instruments-to-incentivise-substitution-of-chemicals-of-concern-a-review.pdf, *accessed on 16/11/2023) notes that "By returning revenues from fees on chemicals of concern to the regulated sector in the form of a subsidy or technical assistance, strong incentives for substitution can be generated in sectors where substitution is challenging".*

All of this would need to be considered in a broader EU context, or at least how taxation would affect imported products (if only Belgium were to implement such a scheme it would have negative effects on the competitiveness of Belgian firms).

Permit based systems (used for example in lead, CFCs and fluorinated greenhouse gases reduction) with an increasing cost of permits over time can also help increase the incentives for substitution but may not be practicable in a short to medium time frame.[177]

4.4 \ Overview of PFAS alternative readiness levels

As noted previously, there is a very large range of sectors and applications that use PFAS, all of which would need specific tailored policies to suit their needs.

While designing policies it will be important to group applications which can use the same or similar solutions as much as is practicable (based on consultations with the industry and public bodies). In other words, and to ensure that policies are designed effectively, applications of PFAS should be carefully grouped by industry to reduce duplication of work, without selecting categories that are too broad to support with a single type of policy.[178]

With this additional complexity in mind, the Figure below provides a rough classification of the twelve sectors discussed above into technological readiness levels to help guide which policies could be applied to each sector. Cables and semi-conductors are classified in between the red and orange boxes as they appear to be in very early stages of alternatives identification but are more advanced than medical devices for example.

[177] For an example of this in practice: the U.S. experience used several tools to phase out leaded gasoline. Through a phased program, the allowable lead concentration in leaded gasoline was reduced to 1.1 gram per gallon (0.29 g/l) by 1982. This rule also introduced the trading of lead rights between refineries, so that a refinery that was able to produce gasoline containing less than 1.1 gram per gallon could sell the excess "lead rights" to another refinery that needed them. By 1984, about half of the refineries in the United States were participating in this market, with the larger, more complex refineries generally selling lead rights to smaller refineries that had less capability to produce high-octane gasoline through process changes. Separately, the OECD found that, in phasing out the use of leaded fuel, different countries used a variety of policy tools. Taxation policies that keep unleaded gasoline less expensive than leaded gasoline were very effective in promoting rapid conversion to unleaded fuel as well as minimising the deliberate use of leaded gasoline in catalyst equipped cars. (https://www.oecd.org/chemicalsafety/risk-management/1937036.pdf).

[178] In some cases, with more niche applications, these sub-industries may have to rely on slightly more differentiated sectors for the research as it may be not be feasible for the sub-industry to conduct its own research.

Figure 6: Classification of sectors by technological readiness levels, based on Erdyn research[179]

[179] See Section 3.3 \ above.

The three high priority sectors will be discussed in detail in dedicated sections above. For the 9 remaining sectors, specific recommendations are provided in the following table.

Table 48: Key points on PFAS use and specific recommendations to facilitate PFAS substitution for the non-priority sectors

Sector	Key points on PFAS use in Belgium	Specific recommendations
Batteries *Case B*	- Approximatively 10 companies are likely to use PTFE and PVDF to produce materials and components of batteries in Belgium. - Debates about alternatives are only emerging and PFAS-free membranes, separators are under investigation.	- R&D subsidies, information exchange and either/or collaborative R&D or optimising private incentives to innovate.
Cables *Case B & C*	- PFAS mainly consist in fluoropolymers, a volume of 40 t/y have been extrapolated for Belgium. - Different alternatives have already been tested (PEEK, PC, EPDM), with currently no technically feasible alternatives for all cables.	- R&D subsidies, information exchange and either/or collaborative R&D or optimising private incentives to innovate. - Provide subsidies that decrease over time to encourage substitution
Fire protection *Case B*	- Fire suppressants & firefighting foams are a well-known stream of PFAS pollution, subject to specific regulation. - PFAS play a key role and the use of less performing chemistry leads to other environmental and health issues. - CO_2, hydrocarbon, siloxanes are among the best alternatives, some of them are developped in Belgium	- R&D subsidies, information exchange and either/or collaborative R&D or optimising private incentives to innovate. - Provide subsidies that decrease over time to encourage substitution
Metal processing *Case B*	- Industrials widely use 6:2FTS in hard chrome plating (1-2t/y) for the automotive, aeronautic or firearm markets. - Industrials are already facing challenge with the Cr(VI)-based process and seems unaware of the PFAS use. - Various strategies have been adopted for substituting PFAS: other chemistry, plating, process…	- Focus on the development of alternatives that are both Cr(VI)-free and PFAS-free - Increase producer information levels - R&D subsidies
Paints & Coatings *Case A*	- According to IVP Coatings, PFAS-containing paints & coatings may represent up to 10% of the Belgian market (i.e., € 200 million). - Industrial & transportation protective coatings are the main application of PFAS (FPs, 300t/y). - Epoxy, PU or silica-based coating already have high market share	- Increase consumer information levels - Ensure technical guidance for substitution - Place increasing restriction on PFAS
Paper & Cardboard *Case A*	- PFAS are not essential; and widely accepted alternatives already exist, no evidence and limit hint of PFAS use in Belgium have been found. - PFAS are mainly introduced via import, increased recycling leads to spreading PFAS throughout all the paper and board market.	- Gain knowledge on PFAS content of import product - Gain knowledge on PFAS incorporation during the end-of-life management
PPP *Case B*	- Belgium is one of the largest consumers (7 kg/ha) and producers (10% of the EU industry) of PPP in Europe, suggesting high PFAS use of both active and inert ingredient	Active: Increase consumer information levels, gain knowledge on PFAS use and its essential functions, R&D subsidies

	- The subject of PFAS used as active substance in the manufacture of PPP is widely unknown in Europe & Belgium - There is very limited work on PFAS alternatives.	Co-formulant: Increase consumer information levels, Place increasing restriction on PFAS
Plastics *Case A & B*	- Numerous PFAS-free polymerisation aids and polymer processing aids are already commercialized and used, none of them have been developed by Belgian actors. - FPs-free sealings appear to be extra-challenging: PEEK, PPS PPA, ACM or nitrile rubber do not fulfil all requirements, and would lead to higher leakage risk and maintenance cost.	Aids: Place increasing restrictions on PFAS use Sealings: Focus the help on the downstream actors of the value chain (R&D & substitution subsidies)
Semiconductors *Case B & C*	- FPs and PFBS are used in highly diverse applications. However, the Belgian share of the EU industry only represent 1.5% (i.e., 66t/y PFAS used). - For a limited set of applications, HDPE, mineral oils or NF_3, are potential alternatives. - Some companies do not share information on alternatives because of possible competition	No specific recommendation, see all Case B recommendations

We will now focus the analysis on the three priority sectors as set out in Section 2.2 \.

Technical textiles	HVACR	Medical devices

The following sections provide, for each of the priority sectors:

- An overview of the technological readiness level of alternatives to PFAS, distinguishing by sets of sub applications where possible. This is largely based on the workshops conducted with industry participants by RDC Environment.[180]
- On this basis and the discussion on public policies in Section 4.3 \, barriers to substitution and policy measures are discussed.

A full comprehensive list of every possible alternative to every possible application of PFAS is beyond the scope of this study (in particular for sectors such as medical devices or even HVACR), the information below is intended to provide more of a bird's eye view of the key issues and avenues in each sector.

4.5 \ Technical textiles

4.5.1 \ Overview and context

Technical textiles are engineered fabrics designed for specific functionalities beyond traditional uses like clothing. They exhibit superior performance, durability, and specialised properties for applications such as:

- Personal protective equipment of military, police, law & order maintenance personnel, emergency workers (ambulance, firefighters, …), security companies, chemical industry and so on.

[180] See Annex for further details.

- Automotive textile used as seats covers.
- Construction materials.

4.5.2 \ Properties of PFAS for technical textiles

PFAS enables textiles applications to one or several of the following properties: water repellence, oil repellence, resistance to chemicals, fire protection, protection against infectious risk. The most important property for most applications is oil repellence.

- Oil repellence is a key property for personal protective equipment but also for automotive applications.
- Oil repellence is less important for construction applications (e.g. roofing).
- For personal protective equipment, oil repellence is heavily linked to other properties: water[181] repellence, fire protection, chemical resistance.
- Fluorocarbon coatings applied on the surface to enable oil repellence, and:
  - Allow water repellence.
  - Ensure fuels do not enter textiles fibres and thus resulting fires do no burn the textile, rather the fire stays on surface (fire protection).
  - Ensure chemical protection as several of chemicals that can be tested to demonstrate resistance to chemicals are oil-based.

  These are the reasons why there is a heavy link between oil repellence and other properties.[182] There are no sub-applications amongst personal protective equipment where at least both high oil repellence and durability (see paragraph below) are not needed.
- PFAS enables also the combination of properties, which is needed for all applications except construction.

Durability over time and after washing is also a key property of PFAS for personal protective equipment. This equipment needs to be washed for several reasons: ensure that they function properly (remove dust, dirt and chemicals), maintain a low (e.g. military)/high[183] (e.g. chemical industry) visibility, and guarantee hygiene. After a certain number of washes, fluorocarbon layers are added to the equipment to preserve their properties. The lifecycle of the personal protective equipment for most sectors lasts between 3 and 5 years for firefighters, police and the chemical industry for example. The total number of washes varies between 25 and 150 times[184] depending on the application.

4.5.3 \ Performance of alternatives in the technical textile sector

Currently, there is no PFAS free solution that enables together:

- Oil repellence.
- The combination of properties listed above.
- Washability (and therefore reusability).

[181] Note that for the water repellence property, there are alternatives.
[182] https://www.sciencedirect.com/topics/engineering/oil-repellency
[183] E.g. ISO 20471.
[184] On the whole lifetime of the application.

For construction applications (e.g. roofing), there are PFAS free solutions that are water repellent but the fire protection performance is lower. These alternatives are developed by the Belgian industry.[185]

Note that for Chemical protection EN 13034, to reach a certain protection level, four chemicals are tested but only one must pass the test at the highest level to get the protection claim.[186] Therefore, some technical textile producers can legally claim to have efficient PFAS-free alternatives that conforms EN 13034 even if they use one of the less critical chemicals (water-based) so they can pass the test. This gives a false feeling of safety to the wearer for a range of other chemicals that are oil-based. The most critical chemical out of the four that can be tested is o-xylene.[187,188] The industry highlights that no alternative to PFAS can pass the chemical protection for all oil-based chemicals. This also negatively affects the fire protection property because it means that other chemicals (i.e. solvents, oils…) can penetrate the garments and that flammable chemicals can also stick on the surface of flame-retardant textile and make them flammable in certain conditions.

4.5.4 \ Barriers to PFAS substitution in technical textiles

The solution will come from chemical companies that develop chemicals for the textile industry. The main chemical industry companies have been doing R&D for years/decades because there is a big demand for alternatives.[189]

As regards personal protection equipment, price would not be a key issue because both public authorities and the industry have a high willingness to pay to protect wearers. PFAS-free solutions for personal protective equipment would be used for all the customers of the Belgian companies because the clients are high-income countries that would follow the EU. Personal protective equipment is not used in low-income countries.

Several issues will arise when the solution is found:

- Price due to possible monopoly/oligopoly situation with patents of the chemical company.
- Access to the solution for the personal protection equipment producers because the company will have the power to select the companies.

After the solution is found and available, there are several steps for technical textiles producers:

- Lab testing per application: 3 months.
- Certification (in some cases): a couple of years in the automotive industry.
- Feedback after real life testing: up to 5 years.

In the short-term, as there are no PFAS alternatives for personal protective equipment, the applications would be less effective. It is therefore a trade-off between environmental toxicity (PFAS) and the health of the people wearing PFAS-free personal protective equipment, having lower performance.

[185] Silicone is technically viable because of its ability to repel water which is the main requirement for the mentioned sector. However, it is worth noting that its performance is weaker than using PFAS. "PFAS free" Protective Personal Equipment (PPE) products using alternatives such as Silicone or Hydrocarbons, without being necessarily oil repellent or resistant to certain (important) chemicals, endangers the life of workers using chainsaws for instance. According to ECHA, there is strong evidence indicating that Hydrocarbons, Silicone, and Polyurethanes can potentially serve as alternatives for 7 out of the 13 assessed PPE uses (but not indicated which), considering that Silicone, for instance, is not oil repellent. There are no supply issues associated with these alternatives (weak evidence suggesting substitutability for the remaining uses). However, for High Performance Membranes and medical textiles, no conclusive evidence has been found to suggest viable substitutes for PFAS.
[186] https://app.nbn.be/data/r/platform/frontend/detail?p40_id=246349&p40_language_code=nl&p40_detail_id=57379
[187] In testing o-xylene is used to show protection to all oil-based chemicals. In this oil-based chemicals you find chemicals that, in contact with skin, can give blistering, nerve damaging or carcinogenic symptoms.
[188] Also, firefighter suits following the standard EN 469 need to fulfil chemical tests (also against o-xylene).
[189] See list established by Chemsec at https://chemsec.org/chemsec-identifies-the-top-12-pfas-producers-in-the-world-and-reveals-shocking-societal-costs/

If a single use solution for PFAS were possible, there would be a trade-off between environmental toxicity (PFAS) and circular economy (linked to other environmental impacts).

4.5.5 \ Public policies technical textiles

There is little need to financially support the technical textiles industry in the short-term because they are not able to carry out research to find an alternative. The technical textiles sector does not think that chemical industry needs financial support because they already are very active in R&D due to strong market signals.

When the solution is found by the chemical industry, public policies could help the Belgian technical industry to speed up the substitution through testing subsidies for example. There were already collaborations in Belgium to test alternatives in the past, there seems to be no need for additional support to it.

Another way to reduce the use of PFAS for technical textiles would be to assess the need for personal protection equipment in public call for tenders and possibly to reduce the requirement in some cases. There are cases where the personal protection equipment is the same for field and offices workers. In this situation, it would be relevant to adapt the personal protection equipment for the office workers.

Assess the need for personal protection equipment in public call for tenders

(i) Policy

One possibility to reduce the use of PFAS in personal protective equipment is launching an assessment of the need for high performance personal protective equipment in public call for tenders.
This would imply the following steps:

- Assess the relevance of previous public call for tenders regarding the protection requirements.
- Possibly adapt new requirements for certain uses.
- This policy will lead to a possible reduction in the use of PFAS but not to a substitution with the same properties. Nevertheless, this policy is relevant in the short-term despite the lack of alternatives for high performance personal protective equipment.

(ii) Cost

The cost of this policy measure can be split in two components:

- **The cost of the study:** We estimate a cost around 100 000 € for the study.
- **The time of the public authorities to organise the study for the tender and to steer the study:**
  - We estimate 15 days for the drafting of the specifications and the tendering process and 10 days for the steering of the study.
  - With a day rate including overheads of 400 €, the total amounts to 10 000 €.

The total cost of the measure is therefore around 110 000 €.

Testing subsidies

(i) Policy

Once an alternative is available on the market, testing subsidies could help to speed up the substitution.

The subsidies could be designed in several ways:

- Flat subsidies per test.
- Subsidies in percentage terms.

(ii) Cost

Given the fact that between 5 and 20 Belgian textile companies are using PFAS and with the following assumptions:

- Cost of tests per product: 10 000 – 100 000 € depending on the products.[190] We assume an average cost of 20 000 €.
- Tests per companies: 100.[191]
- Number of companies running tests for personal protective equipment: 10.

The direct cost of a subsidy of 50 % would be around 10 000 000 €.

The indirect cost of the work of public authorities would be 40 000 € (100 days * 400 €/day).

Organise a collaborative workshop to foster the development of alternatives

(i) Policy

Once an alternative is available, a collaborative workshop could help the companies to share some R&D findings to speed up and mutualise the testing process on the road to substitution.

(ii) Cost

The total cost is estimated around 12 000 €:

- 5 days of work for public authorities (5 * 400 €/day)
- External consultants to organise the workshop: 10 000 €

[190] Industry interviews.
[191] Industry interviews.

4.6 \ HVACR

4.6.1 \ Overview and context

HVACR stands for Heating, Ventilation, Air Conditioning and Refrigeration. It refers to the technologies and systems used in buildings and vehicles to control indoor environmental conditions, including temperature, humidity, air quality, and refrigeration. This includes, for example, heat pumps which are powered by (potentially green) electricity and are therefore viewed as a relevant alternative to conventional heating systems based on fossil-fuels in the future decarbonated world.

Belgian (and EU) companies are not typically involved in the production of PFAS for HVACR but are rather involved in the use of PFAS in final or intermediate products.[192]

There are many different applications of PFAS in HVACR, and it is important not to overgeneralise a solution for a particular application to others as they may have their own characteristics, needs and specificities that make extrapolation to other applications irrelevant.

The discussion below principally focusses on the use of fluorinated gases for simplicity. However, PFAS are also used in other parts of the equipment (including PFAS polymers, e.g., for gaskets and sealings) that combine several key properties (water repellence, pressure resistance …) and are an essential part of some HVACR systems. The fluoropolymers used in components can be even more essential while using non-fluorinated refrigerants in HVACR systems, due to their durability, heat- and pressure-resistant properties.

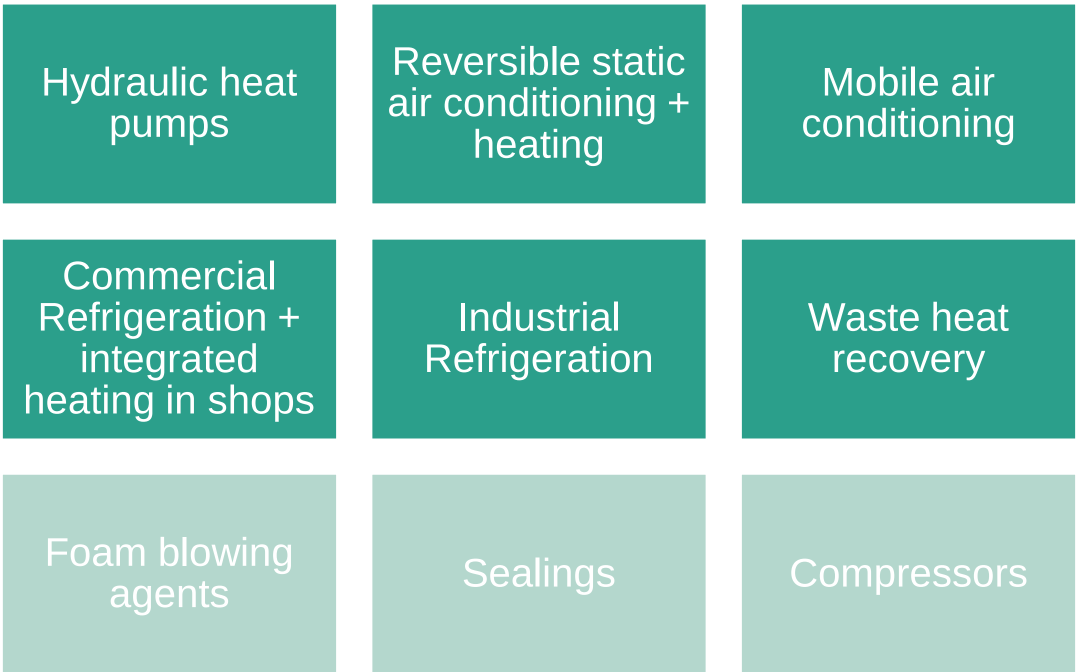
4.6.2 \ Properties of PFAS for HVACR

Given there are so many sub-applications of PFAS within the HVACR industry, the discussion with industry participants covered a generalised set of categories within the HVACR industry, which included those in the figure below.

The workshop focussed less on the last row in lighter green (sealings, foam blowing agents and compressors) due to the participants' more limited knowledge in those fields (hence the different highlighting). As explained above, some of the PFAS used in the remaining items are not fluorinated gases, but the following discussion is focused on fluorinated gases.

[192] The main problems of PFAS (in terms of emissions in Belgium) in the context of HVACR relate to the end of life. For example, refrigerant gases with PFAS need a very high temperature to be broken down at end of life and prevent it from contaminating the air and hence the people around it This temperature is reached in incinerators for hazardous waste (1200°C) but not in municipal waste incinerators (850°C).

Figure 7: Categorisation of products in HVACR



Each category of applications is designed to reach a specific target temperature of the cooled environment.

- The selection of the refrigerant gas is based on this target temperature. From a technical viewpoint, the refrigerant must be in a gaseous form at this target temperature and relatively low pressure to allow the compression and relaxation cycles.

- Using a very low pressure to make any refrigerant gaseous is not an option in practice as the heat flow becomes low (low mass in case of low pressure) and the energy efficiency decreases, leading to significantly higher energy consumption and cost.

- Therefore, the refrigerant thermodynamic properties are key to judge the suitability of an alternative, and the adequacy is specific and must evaluated for each category of applications separately.

- Even within a category, extrapolation may not be relevant, e.g., indoor vs. outdoor unit for air conditioning.[193] Consequently, the assessment of specific alternatives will need to consider this additional level of granularity.

Within these categories of HVACR applications, many PFAS properties were found to have significant importance including: the precision of temperature control, range of temperatures they can reach, life span, low energy consumption, consequences on the pressure of the circuit, low flammability, heat capacity (energy per unit of mass) and low GWP (Global Warming Potential). There was little differentiation regarding the importance of properties across sub-applications.

[193] For example, for domestic air conditioning, safety properties and technical feasibility may be more or less important depending on whether the unit is inside or outside.

4.6.3 \ Performance of alternatives in the HVACR sector

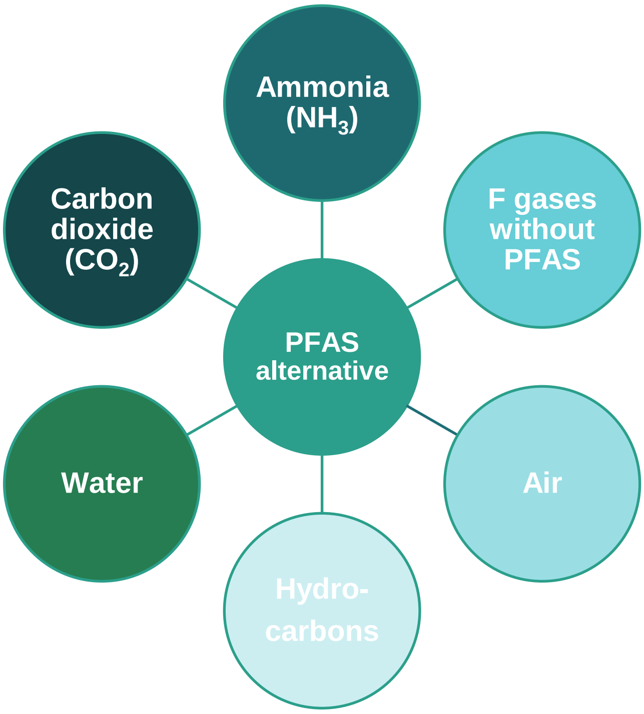
Overview

In the HVACR industry, there are some applications where there are:

- **PFAS-free alternatives already in use** (car air conditioning with CO_2 for example) – Case A in Section 4.3 \.
- **Potential alternatives that are not or barely used currently** – cases 2 and 3 in Section 4.3 \. This can be either down to:
    - More research being required on its applications; or
    - Strong barriers to its use (cost, redesign or drops in performance/bad properties such as increased flammability, toxicity, price, pressure requirements, lack of information …).

Some of the potential alternatives for some applications are summarised in the chart below.

Figure 8: Potential alternative products to PFAS in the HVACR industry[194]



There are performance limits to some of these which are summarised below.

Ammonia

Ammonia (NH_3) is a colourless gas with a distinct, pungent smell. It is highly soluble in water and is commonly used in various industrial applications, including refrigeration, cleaning agents, and the production of fertilisers. Ammonia is also found naturally in the environment, being a byproduct of biological processes and decomposition. The use of ammonia is limited by current

[194] Air was not discussed as an alternative: air is envisaged as a ventilation option for "natural" cooling when target temperature is close to ambient temperature. In some niche markets it might be an option for clients but the workshop participants did not consider it a strong alternative. Moreover, using alternative energy sources such as geothermal energy was not put forward as an alternative during the workshop.

safety standards (EN 378)[195] requiring risk assessments when using some refrigerants. Exposure to high concentrations of ammonia in air causes immediate burning of the eyes, nose, throat and respiratory tract and can result in blindness, lung damage or death.

Figure 9: Ammonia as a PFAS substitute

Performance compared to PFAS	Likely uses	Cost impact
Ammonia has a more elevated aquatic toxicity and present a higher fire risk[196] (which also means it is preferable to keep the machines outside or in well-ventilated spaces). As a result, its use may require the presence of dedicated service teams to maintain the equipment and manage the risk.[197]	This is less likely to be used in smaller applications (such as domestic heat pumps), rather in industrial applications.[198] This is partly due to the security requirements (in particular if inside) but also the required space for the installations (in particular if outside) – which is not available for the user in every case. [199]	It was estimated that there would be a 50 to 100% CAPEX increase[200] for using ammonia as opposed to fluorinated gases (as well as an increase in OPEX due to a slight decrease in energy efficiency depending on where the installation is located to possibly mitigate the toxicity risk). Some of the participants noted that there is a skills gap for technicians familiar with NH_3 applications, installation and maintenance.

Hydrocarbons

Hydrocarbons, composed of hydrogen and carbon atoms, are fundamental organic compounds. They include alkanes with single bonds (e.g., methane), alkenes with double bonds (e.g., ethene), alkynes with triple bonds (e.g., propyne), and aromatic compounds like benzene.

Hydrocarbons are also limited by current safety standards.

[195] See for example https://area-eur.be/publications/introduction-refrigeration-standard-en-378.
[196] Including being very toxic to aquatic life with long lasting effects. It is also flammable (https://echa.europa.eu/substance-information/-/substanceinfo/100.028.760) .
[197] The civil responsibility of industrial site safety managers can be engaged if these standards are not abided to.
[198] There are limited examples of commercial refrigeration, such as by Colruyt, but they have service teams.
[199] In Flanders, restrictions linked to Nitrogen may also complexify its use.
[200] From maintenance and security teams, larger compressors and so on. This is based on input from industry participants.

Figure 10: Hydrocarbons as a PFAS substitute

Performance compared to PFAS	Likely uses	Cost impact
Hydrocarbons have an elevated flammability and explosion risk. They are similar to F-Gas but without the additives used to reduce explosivity. As a consequence, the volume of refrigerant that can be stored inside is limited, which reduces capacity or forces the use of outside refrigerant circuits connected to an air/water circuit coming inside the buildings.[201]	Hydrocarbons are more used by large chemical industrial sites because they already have safety teams and protocols inside their facilities.[202] Similarly to applications with ammonia, these installations may also require more space to mitigate the safety risk (which again may not always be available).	This can lead to CAPEX increases between 25 and 200% depending on the application of hydrocarbons and installation needs. This can be caused by mitigating the security risk along with more maintenance or installing facilities further away from the end use, which can also increase OPEX due to reduced energy efficiency from distance. Some of the participants noted that there is a skills gap for technicians familiar with hydrocarbons applications, installation and maintenance.

Water-based solutions

Water-based solutions are used in some settings but currently are not able to reproduce the full temperature range of PFAS (so some applications are not replaceable by water as of now). In some cases, it can be combined with ammonia or hydrocarbons to reduce the safety risk (but this means higher CAPEX and lower energy efficiency).

Figure 11: Water-based solutions as a PFAS substitute

Performance compared to PFAS	Likely uses	Cost impact
This shows some promise but currently has a limited temperature range which limits the applications it can replace PFAS for.	Water-based systems relying on steam / hot water circuits are commonly used in some heating applications. Water as a refrigerant for cooling applications requires compressors operating under vacuum which requires R&D.[203]	Generally uncertain. R&D in Belgium is organised around optimising heat exchangers in general, but not developing the specific equipment needed for water refrigeration / systems relying on alternatives to PFAS. Integration of solutions within a full system (e.g. refrigerant + compressor + heat exchanger) is investigated by the private sector, for their global market.

[201] For domestic applications, monoblocks for heating are possible but would likely be placed outside. Inside, the monoblocks would be limited by the permitted refrigerant charge (by regulation). For air conditioning it is less likely it will be used (for stationary AC, one product with propane was commercialised by the firm exiting the market) – there is however some research on how to increase the use of propane in stationary air conditioning. The risk is lower for mobile air conditioning as those spaces tend to be better ventilated and require less hydrocarbons.
[202] Noting that the risk significantly increases with the size of the machine.
[203] R&D projects at European level are investigating the subject, with the contribution of German Universities. Some workshop participants indicated it might take up to 20 years to develop this industrially.

Carbon dioxide

Carbon dioxide (CO_2) is a colourless, odourless gas. It is a naturally occurring component of Earth's atmosphere and is produced through various natural processes, such as respiration, volcanic activity, and the decay of organic matter. Carbon dioxide is also a byproduct of human activities, particularly the burning of fossil fuels and deforestation.

CO_2 is used in various HVACR applications (mainly related to refrigeration and air conditioning).[204]

Figure 12: Carbon dioxide solutions as a PFAS substitute

Performance compared to PFAS	Likely uses	Cost impact
CO_2 flammability and toxicity properties are appealing, but pressure requirements and temperature resistance can be an issue.	It can be used for refrigeration (with some cooling). It can be combined with ammonia for even lower temperatures, although it may not be suitable for certain applications like RNA vaccines. Mobile air conditioning systems employ CO_2.[205] CO_2 can be used for domestic water heating in some cases, but it is generally preferred for cooling applications.	Some of the participants noted that there is a skills gap for technicians familiar with CO_2 applications, installation and maintenance. In addition, it can mean a significant CAPEX for more complex machines (including R&D), or to deal with the increased pressure requirements of CO_2 or for sensors to detect potential CO_2 leakage. For static heating, this could mean a 300% increase in cost (so not feasible for residential applications). Industrial heat pumps would require a lot of energy if they use CO_2.

F-gases without PFAS

Some F-gases do not contain PFAS. They have similar properties in some instances but tend to have higher GWP.

[204] Commercial refrigeration can use CO_2 but may result in higher equipment costs (and lower efficiency for cooling). CO_2 is efficient in refrigeration, particularly at low temperatures.
[205] While petrol or diesel cars use engine heat for heating, electric cars may necessitate a heat pump, which is currently not very practical with CO_2. CO_2 is also used in some truck refrigeration.

Figure 13: F-Gas (non-PFAS) solutions as a PFAS substitute

Performance compared to PFAS	Likely uses	Cost impact
While these can function over a large range of temperatures, these gases are likely to be banned with the F-Gas regulation.[206] The Global Warming Potential of the PFAS-free alternatives is very high.	They have similar uses to PFAS in terms of range but are generally considered an inferior substitute to PFAS (also for the higher GWP).	NA

4.6.4 \ Barriers to PFAS substitution for HVACR

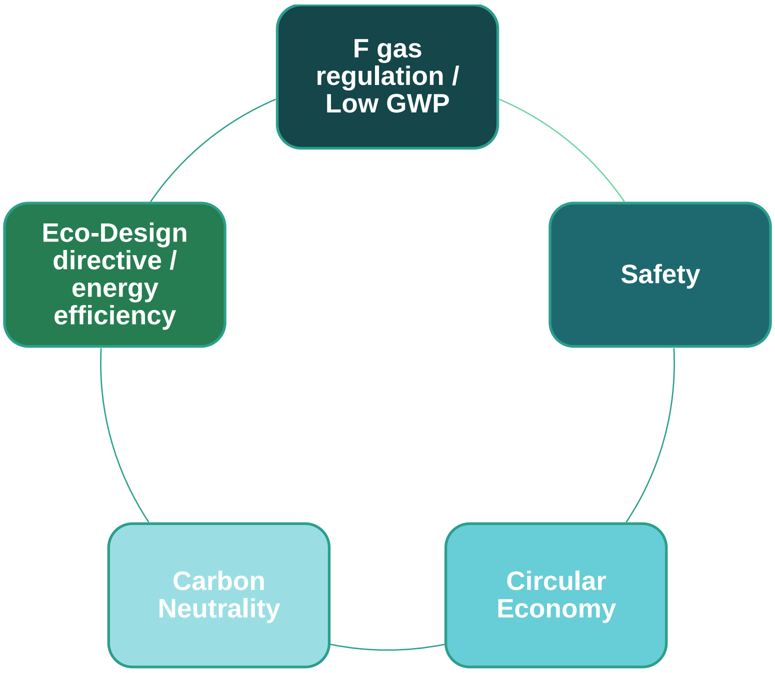
As briefly touched on above, there are a number of barriers to the development of the alternatives above, at least in some applications, which include:

- **Technical barriers** where some of the alternatives listed above currently are not functional for certain temperature levels/applications (more research needed).
- **Increased CAPEX or OPEX linked to the alternative** (for example due to increased maintenance, energy requirements[207], security, pressure requirements, additional space, different locations, more material required and so on).
    - As a general point, the performance of a gas will fundamentally depend on the design of the product and solution, beyond the gas' base properties and limits.
    - In some cases, it may be possible to redesign the product to compensate for deficiencies from a potential PFAS substitute, but this can often entail a significant cost as well as other potentially undesirable effects.
- **Lack of technical capacity to implement alternatives:**
    - The workshop participants also mentioned that the development of new refrigerant gases is not done in Belgium (and mostly not in Europe). In general, the development of alternatives in this sector will come from the European or even global scale.
    - There is sometimes a knowledge gap of installations and maintenance of PFAS-alternatives by relevant staff in Belgium (as well as for production processes), as there is often more specialisation in PFAS products.
- **Uncertainty as to what substances will be banned and when**: as well as which alternatives to the industry should prioritise research on.[208] This also includes requirements from different types of legislation. The PFAS proposal co-exists with other

[206] See https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/eu-legislation-control-f-gases_en.
[207] This will also be linked to future energy costs (and potential variations) together with the need to reduce energy consumption for climate change, which in turn affects the energy efficiency effect of a substitution and making alternatives that use more energy harder to bring to market. As one participant to the HVACR workshop notes, for the OPEX of heat pumps, it is important the electricity-gas price ratio is adjusted and electricity is maximum twice as expensive as gas (in many countries, like Belgium, this is currently 3 to 4 times more expensive). For heat pumps to be deployed at large scale, this becomes even more important if they run in non-fluorinated alternatives (https://www.ehpa.org/frequently-asked-questions/#:~:text=To%20make%20heat%20pumps%20even,twice%20the%20price%20of%20gas).
[208] In addition, HVACR products are typically durable goods and require maintenance over their life cycle. This means that spare parts containing PFAS have to be used to maintain the current installations in use.
This being long-term investments for customers, uncertainty over PFAS timing of bans and scope may be leading to customers delaying investment decisions (i.e., to avoid getting a shorter life span of a product due to a potentially shorter allowed maintenance period).

regulatory obligations or targets for producers (thus creating many trade-offs relating to prioritisation), including relating to the areas in the following chart.

Figure 14: Regulatory constraints and other obligations for producers in HVACR industry



4.6.5 \ Public policies for HVACR

In this setting, there are a number of technologies which can potentially replace some of the PFAS applications. However, in some cases this means additional costs or security constraints and in other R&D is needed to bring a viable product to market. There are also cases where the additional needed space is not available.

Thus, detailed cost benefit analyses may be beneficial to establish a path forwards, but should be coordinated / co-financed by several member states (or ECHA at the EU level) to avoid duplication of work (following the "one substance, one assessment" principle).[209]

There are a number of policies which can help accelerate the transition, which are listed below. It is not possible to quantify all the costs of implementing these policies without going into significant levels of detail, so the cost of public policies is only quantified where practicable.

Subsidies / call for R&D projects

As discussed above, the state of development of PFAS-free alternatives is mixed depending on the application and the sector. Thus, there will be a need for different types of subsidies depending on the readiness level (i.e., in some cases it is to facilitate installation of the alternatives, and in others to help create a viable alternative in the future).

(i) Policies

There are several types of subsidies that may be required here for different applications. [210]

[209] See for example, https://www.echa.europa.eu/documents/10162/21877836/efsa-echa-position-paper-osoa_en.pdf/74b1ae31-290b-a608-85e9-05b340840b34, accessed 16/11/2023.
[210] ECHA's Strategy to promote substitution to safer chemicals through innovation (2018) (https://echa.europa.eu/documents/10162/17228/250118_substitution_strategy_en.pdf/bce91d57-9dfc-2a46-4afd-

- **Subsidies for PFAS-free installations or infrastructure (e.g., industrial heating or cooling):**
    - **New subsidies decreasing over time:** Once a desirable alternative (considering the full supply chain) is identified, then agents in the Belgian supply chain could be incentivised (or compensated for an increasing cost due to the alternative) with a subsidy.
        - To ensure that this is done in a timely fashion, subsidies could be decreasing over time, that is the maximum percentage of subsidisation is available at the start date which decreases over time over pre-defined periods. Thus, for firms to get the maximum support possible, they receive an incentive to start innovating as early as possible.
        - An alternative to this subsidy is a limited number of firms that get the subsidy on a first come first served basis (e.g., 80% of firms get the subsidy).
        - This subsidy would expire during the transition period after which a particular PFAS would be banned.

    - **Modulation of existing subsidies**:
        - In some cases, there are already subsidies for installation or use of certain devices in the HVACR industry.[211] In these cases, existing subsidies could be modified to favour PFAS-free alternatives (once approved and deemed to be robustly more desirable than the PFAS version).

        - There is an example of a version of this in Germany where the Federal Funding for Efficient Buildings program provides subsidies for alternative heating systems, including a bonus for heat pumps charged with natural refrigerants. The subsidy covers up to 40% of the cost, with a minimum eligible investment of €2 000. The program prioritises natural refrigerants and will only fund heat pumps that use these refrigerants starting in 2028.[212]

- **Subsidies for PFAS-free R&D:**

    - In this case, this would aim to support Belgian and international R&D projects in developing alternatives (either to PFAS-alternatives or functional alternatives).[213]

(ii) Cost of R&D subsidies

All of these subsidies would have to be carefully considered for the specific application and the total need for that particular case.

However, to give an order of magnitude of the level of subsidies that may be needed, we can calibrate a simple estimation based on the total value of the industry, making assumptions on what share of that would be necessary to subsidise the R&D costs (other CAPEX or OPEX costs are not quantified here).

5998dbb88500?t=1516881185315) lists "Facilitating Funding and Technical Support" as one of the four areas to underpin ECHA's substitution strategy by (i) addressing the scarcity of funding specifically dedicated to substituting hazardous chemicals and proposes the mapping of available funding mechanisms, (ii) improving links between industry R&D needs and funding sources, (iii) connecting companies with technical support and institutions providing alternative substances or technologies to facilitate substitution.

[211] See p6-7 of https://www.ehpa.org/wp-content/uploads/2023/03/EHPA_Subsidies-for-residential-heat-pumps-in-Europe_FINAL_April-2023.pdf, accessed 16/11/2023, for Belgium.

[212] See https://hydrocarbons21.com/germany-grants-bonus-subsidy-to-home-heat-pumps-that-use-natural-refrigerants/, accessed on 14/11/2023.

[213] A version of this already exists at: https://economie.fgov.be/en/themes/enterprises/calls-projects/belgium-builds-back-circular/call-projects-belgium-builds, accessed 15 November 2023.

This relies on assumptions as precise industry wide estimations are not available. We used the industry turnover and applied R&D intensity estimations to provide scenarios of R&D requirements for PFAS-substitution.

For simplicity, this is based on the industry revenues in Belgium, so would not represent the total cost of R&D for these multinational companies, but rather an illustrative share for Belgium.

- The revenue generated by the industry totals €4.32 billion per annum in Belgium.[214]
- The average R&D intensity in the EU [215] of the "Industrials" sector (representing HVACR here)[216] is 2.5%.
- Applying this R&D intensity to the total value of the HVACR sector in Belgium would give total approximate per annum R&D HVACR spending in Belgium of around €108 million.
- Given the uncertainty surrounding exact costs of PFAS substitution as well as timings and possible cross-country interactions, we also consider:
    - **Variations of total PFAS alternative R&D**: in other words, what is the total amount of R&D required for PFAS alternatives as a percentage of total industry R&D.
    - **Variations of subsidisation levels (for indicative purposes):** Of the total above, we show various levels of subsidisation.
- Thus, the table below shows amounts of subsidisation which vary based on the two parameters above. For example, if 25% of the value of annual R&D is required for PFAS-substitution, and 10% of this was subsidised, this would mean around €3 million of subsidies.

Figure 15: Illustration of possible R&D subsidy requirements (per annum), in millions €

Sector	Share of total R&D needed for PFAS	Subsidy (millions of EUR), by percentage of R&D expenditure covered		
		5%	10%	25%
HVACR	25%	1	3	7
	50%	3	5	14
	75%	4	8	20
	100%	5	11	27

On top of this, there would be costs for the public authority of coordinating and approving subsidies for R&D projects, which are not quantified here.

Collaborative R&D – working groups

There is evidence of R&D being conducted in the HVACR industry across Europe (for example for some applications of water in Germany) but it appears scattered rather than being driven centrally. As noted previously, there are different levels of knowledge and development of alternatives for different applications.

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[214] As stated in Section 3.2.5 \, the Belgian HVACR market is estimated at €4.32 billon.
[215] R&D spendings divided by the gross value added/revenue of the industry.
[216] Based on the 2022 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/sites/default/files/contentype/scoreboard/2022-12/EU%20RD%20Scoreboard%202022%20FINAL%20online_0.pdf). Of the available categories on page 15, "Industrials" is the closest match for HVACR.

Given the substitution of PFAS may need to occur in a short time frame, encouraging collaboration or stimulating private incentives to invest is crucial. Policies to stimulate collaborative research or private research between market participants or public entities have different requirements (the choice will depend on the case and how relevant the alternative is as a dimension of competition between firms):

- **Collaboration or information sharing between private (and potentially competing) market participants:**
  - If this means information sharing or R&D joint ventures between private (and potentially competing) companies, this should come with specific guidance or competition guidelines for PFAS alternatives projects.
  - This would to (i) reassure the companies that would engage in such projects that they are compliant with competition law and (ii) ensure this collaboration does not lead to sharing non-necessary and competition relevant information (that would breach antitrust laws).[217]
  - If the collaboration approach is chosen, this should ensure that the results are fairly exploitable by each participant, whilst also providing guarantees or incentives to the participants that is concurrent with their level of contribution (to minimise free-riding incentives[218] and hold-up problems[219]).
  - There may also be scope for common testing of the alternatives, but given that products are often highly specific to each sector and company, it is likely that large parts of this phase would remain company-specific.[220]

- **Increasing private research incentives:**
  - To ensure that private incentives are optimised for this research, particular attention should be paid to the intellectual property that results from this.
  - Given the significant costs and time involved in developing alternatives (for example from the PFAS suppliers), patent protection should make it clear that the investors would be able to recoup and profit from their investment (or provide appropriate subsidies to compensate for the potential losses) to maximise their incentives for efficient and timely innovation and substitute creation.
  - It should also ensure that market participants are able to fairly license the resulting technology (not be foreclosed out by the lack of access to a successful alternatives). The exact form of this will depend on the innovation, but could be similar to FRAND requirements.[221]

There can of course be a hybrid system where both collaborative and private R&D incentives are stimulated depending on the firms active in the relevant sub-segment and their R&D capacities.

The initiatives that come out of these working groups or private firms can then be awarded subsidies (which remain available but decrease over time to avoid firms delaying R&D and the introduction of PFAS-free alternatives).

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[217] This will also require entering into the discussion of whether the finding of a PFAS alternative is a strong dimension of competition. If it is, it may be preferable to encourage private research incentives and ensure that the results are exploitable by the industry under fair conditions.

[218] Free riding incentives: the temptation for participants to benefit from a collaborative effort without making an equitable contribution, potentially leading to an imbalance in shared resources or efforts.

[219] Hold-up problems: situations where participants face the risk that, after committing resources to a collaboration, they may be exploited or face difficulties in realising the full benefits of their contributions due to changing circumstances or the actions of other participants.

[220] Specific device testing can include material feasibility testing (pre-clinical, animal safety testing and design verification), sample testing and producing parts for testing, formal Verification and Validation, biocompatibility testing, clinical phase submissions and approvals, clinical trial enrolment, follow-up and report.

[221] Reasonable and Non-Discriminatory (RAND) or Fair, Reasonable, and Non-Discriminatory (FRAND) terms are voluntary licensing commitments ensuring fair access to essential patented technologies in industry standards. This agreement, often part of contracts between patent holders and standard-setting organisations, aims to prevent monopolistic practices and promote fair competition. In the context of finding PFAS-free alternatives, a similar principle could be applied. Stakeholders, such as manufacturers or industries using PFAS-containing materials, could voluntarily commit to fair, reasonable, and non-discriminatory terms in transitioning to PFAS-free alternatives. This would balance the interests of those holding patents on PFAS-free technologies and the wider public, promoting fair access and fostering a competitive landscape for safer alternatives.

Ensuring skilled installers or users are present

(i) Policy

There is a lack of skilled people for the industry (manufactures and installers) for some alternatives. To address this[222], policies could:

- Change student programs that do not cover non-PFAS solutions (e.g., propane, CO_2, ammonia…).
- Support training of installers.
- Organise partnerships between companies and schools.
- Make certifications in alternatives installation and maintenance mandatory (on a progressive basis).

(i) Cost

The cost of **changing student programs or organising partnerships in universities is harder to quantify in the absence of exact alternatives.**

Supporting training of installers remains difficult to precisely estimate ahead of time. However, it is possible to provide an indication of the order of magnitude on the basis of the time needed to train installers in the alternative technology (by making a series of assumptions on th**e time needed to train). This makes a number of assumptions that can be modified, which are set out below.**
An order of magnitude of the cost to train 20% of existing staff per annum can be calculated as follows:

- There are 6 500 workers estimated to be in the HVACR sector which install or repair installations (20% of this would be 1 300).[223]
- If it takes 7 days to train one person[224], and assuming a “labour cost” of 300 € per day, this would mean a total per annum labour cost of 2.73 million €.
- Assuming a cost per person of 1 890 € for the course itself.[225]
- This would mean a total (labour + certification cost) of around 5.19 million € per annum for 20% of the workforce to be certified each year.
- On top of this, there is the cost of designing, coordinating and teaching the course, which is not quantified here.
- This could be subsidised to different levels, the table below provides total costs for 5%, 10% and 25% subsidisation levels for indicative purposes.

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[222] See also AREA internal survey - Training & certification on f-gases and alternative refrigerants dated January 2021 https://www.area-eur.be/sites/default/files/2021-01/AREA%20survey%20training%20%26%20certification%20210125.pdf (accessed 23/11/2023) which finds that (i) there around 5 200 F-gas certified personnel in Belgium and (ii) 7% of these were trained for ammonia, 6.9% for CO_2.
[223] Precise figures are not directly available, however the AREA internal survey - Training & certification on f-gases and alternative refrigerants dated January 2021 https://www.area-eur.be/sites/default/files/2021-01/AREA%20survey%20training%20%26%20certification%20210125.pdf (accessed 23/11/2023) finds that (i) there around 5 200 F-gas certified personnel in Belgium. The figure was then increased by 25% to 6 500 to allow for increases in demand of installers over time (see for example the end of page 4 of https://ehi.eu/wp-content/uploads/2022/08/EHI-report-Heating-systems-installers-Expanding-and-upskilling-the-workforce-to-deliver-the-energy-transition.pdf) as well for possible increases since January 2021, and possible other competent staff that could be trained that is not F-gas certified. This 25% increase is designed to be a conservative estimate.
[224] An example of a F-gas certification course of 5 days can be found at https://www.efp.be/formations/formation-continue/professionnels/certification-froid.html (accessed 23/11/2023). Assuming less prior knowledge of alternatives as well as possible additional complexity, the amount of time to train was expanded to 7 days.
[225] This course also has a cost of 1 350 € at https://www.efp.be/formations/formation-continue/professionnels/certification-froid.html, this is just linearly transformed from 5 days to 7 to 1 890 €.

Figure 16: Illustration of potential subsidy spending for staff training, thousands of €

Percentage of subsidy	Subsidy amount (thousands of EUR)
5%	259
10%	519
25%	1 297

Prioritisation lists

(i) Policy

HVACR is at the crossroad of multiple public policies. Comparing and choosing alternatives to currently used refrigerants is challenging. Therefore, establishing prioritisation lists (ideally centralised and complete at the EU level) as set out in Section 4.3.4 \ could help accelerate substitution. This should also consider the impact of competing regulations affecting this sector.

(ii) Cost

While there is a degree of uncertainty as to the complexity of this exercise and how accessible the information will be, it should be feasible to conduct cost benefit and/or life cycle analyses of the different alternatives in the supply chain. These analyses should clearly distinguish between different applications and their alternatives.

There is no need for each Member State to replicate these analyses, so this could be funded by multiple countries or across the EU (say centralised by ECHA), and for the applications in HVACR should be possible conduct the various studies for under 1 million €.

Collaboration with city planning

For centralised heating and cooling (e.g., district heating), this will need close collaboration with city planning (relevant for new areas), which could be facilitated by the government.[226] Collaboration between businesses and urban planners can be beneficial in several respects:

- It can help companies reduce fixed costs (CAPEX) by optimising the location and design of the installations to fit the network. This can help companies become more energy and resource efficient through economies of scale and centralised maintenance expenses.
- Increased centralisation also allows for centralisation of security and maintenance teams (and avoid a more dispersed network).
- Finally, for alternatives with a higher risk profile (for example higher toxicity or flammability as compared to PFAS), the heating infrastructure can be adapted to account for these risks.

4.7 \ Medical devices

PFAS are used in various medical technologies to enhance patient safety and comfort. These include vascular grafts, stent-grafts, surgical meshes, heart patches, catheters, defibrillators, pacemakers, imaging devices, contact lenses and 3D printing.

[226] Efficient district heating and cooling (DHC) systems in the EU are diverse, requiring a blend of policy support, financial incentives, stakeholder cooperation, and innovation to achieve low-carbon, flexible, and locally adaptable infrastructure. See efficient district heating and cooling systems in the EU (2016) - https://op.europa.eu/en/publication-detail/-/publication/f428333d-dede-11e6-ad7c-01aa75ed71a1.

4.7.1 \ Overview and context

PFAS used in the medical devices sector can be grouped into three main categories:

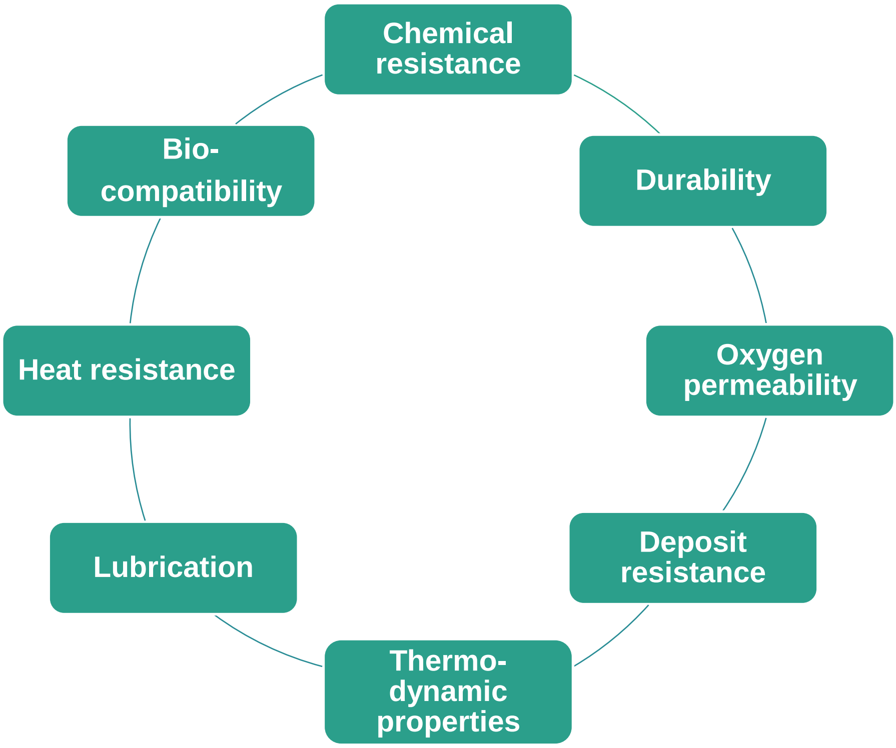
- **Fluorinated gases**: used in anaesthetic gases and refrigeration (cold chains …).
- **Polymeric PFAS** (fluoropolymers): used in implants, syringes, tubing and other applications.
- **Monomeric PFAS**: used in a variety of medical devices including contact lenses.

As noted in Section 3.2.6 \, the Belgian medical sector represents over 500 000 technologies (in-vitro diagnostics, consumables, implants and so on).[227]

4.7.2 \ Properties of PFAS for medical devices

The medical devices sector covers a broad spectrum of applications. As a result, different PFAS properties or combinations of properties are more or less relevant depending on what they are applied to (for example, hardness / rigidity, deposit resistance and oxygen permeability are all largely related to contact lenses). In general, however, some of the most important properties of PFAS for medical devices include the following.

Figure 17: Non exhaustive list of key PFAS properties in the medical devices sector[228]



Many medical devices rely on PFAS for their performance in each category but also for the combination of properties, which is hard to reproduce without PFAS.[229] In the past, alternatives to PFAS have tended to be other PFAS (in part for this reason).

[227] See Section 3.2.6 \.
[228] Other relevant properties of PFAS for this sector include: hardness/rigidity, flexibility, bio-inert, non-toxicity, strength, tissue growth allowance, thermal expansion, Surface resistivity, Electrical resistivity, Elongation, Chemical constituents, Tear strength, Elastic (Young's) modulus, Tensile strength.
[229] For further context, some of the standards for these properties include: bio-compatibility (standards such as ISO 10993), electrical insulation (such as IEC 60601) or properties such as the ability to withstand harsh environments including from cleaning chemicals which can range from a pH of 2 to 14 in hospital environments or ability to be sterilised for 10 minutes.

4.7.3 \ Performance of alternatives for medical devices

At this stage, there is a general lack of consensus on viable and wide-ranging alternatives for PFAS in the medical devices industry considering the very wide range of products which vary in terms of chemical and material design as well as complexity.[230]

An additional complication is the strict regulatory standards for performance levels of new products (which lays down requirements for their design, safety, quality, performance, alternatives assessment and validation)[231]. Any alternatives to PFAS within the current regulatory framework will need to guarantee as small as possible decrease in quality of the product where it relates to a crucial health function.

4.7.4 \ Barriers to PFAS substitution for medical devices

In general, problems with bringing PFAS alternative to market are as follows:

- **Identification of viable potential alternatives** (lack of clear alternatives with sufficient performance).
- **Uncertainty regarding passing regulatory approval** and long delay to do so.
- **Segmented and sometimes small markets** complexify finding viable alternatives that work broadly across different applications. For example, often these markets may represent very small volumes for the chemical or materials companies upstream and so will have limited incentives/ability to propose alternative solutions for each sub-sector.

Research on alternatives is being conducted in-house by the operators selling medical devices but also by some suppliers of PFAS (depending on the company).

- **There is no or very little collaborative research on the topic at the moment** (as far as the participants to the PFAS in medical devices workshop were aware), either via private collaboration, research centres or universities.
- **Research is conducted by each company / requested to individual suppliers** without putting requirements in common or sharing testing phases cost.
    - A study led by a contact lenses company has shown limited collaboration across sectors (outside of the medical device world), at least in part due to the specificity of requirements for certain properties, combinations of properties or applications for specific categories of products.
- In addition, there is currently no workable regulatory obligation for relevant information disclosure in the supply chain. As a result, the medical technology sector is likely not yet aware of all PFAS uses in components they use or in the manufacturing of those components.[232]

While there are stages of R&D and testing which are likely to be highly product specific, there is perhaps potential for some R&D combination / efficiencies in collaboration, especially to channel priority areas of research for suppliers of materials and chemicals by highlighting potential downstream market size needs.

Once alternatives are available (past the R&D phase), testing costs could be a significant issue as many different aspects need to be tested, in some cases this includes studies on long-term possible effects which cannot be significantly shortened or compressed due to the nature of the test itself.

The whole process can be long (some estimates put it at 10 to 12 years or more). At this stage, quantifying the cost of switching is a very difficult process without a clear view of what form these

[230] ECHA's restriction report (Annex XV) also notes that there is a lack of feasible alternatives in the medical sector (see pages 98-101).
[231] See Medical Devices and in vitro diagnostic medical devices regulations.
[232] Based on information from MedTech.

alternatives would take (including as to whether the bulk of the cost would be due to an initial capital expenditure outlay or would take the form of higher variable / operational costs).

4.7.5 \ Public policies for medical devices

Policies which may help accelerate the identification and development of viable alternatives could include setting (i) priority requirements, (ii) facilitating collaborative R&D and (iii) stimulating private investment.

As noted previously, it is not possible to quantify all the costs of implementing these policies without going into significant levels of detail.

Prioritisation lists

The medical devices sector is lacking widespread alternatives. Finding promising avenues for R&D is providing a challenge for many sub-applications. Therefore, working towards establishing prioritisation lists (ideally centralised and complete at the EU level) as set out in Section 4.3.4 \, could help accelerate substitution.

The cost of this policy is harder to quantify than in the HVACR setting as there are more applications and it is not clear which sets of applications could be grouped under similar analyses/research streams.

Collaborative R&D / working groups

As stated above, there is a general lack of consensus on alternatives in the various medical device subsectors. Thus, increased collaboration/information sharing could be beneficial. For further details, see Section 4.3 \.

Subsidies / call for R&D projects

(i) Policy

Some R&D is already ongoing in the industry, but in some sub-sectors it may need accelerating further with access to subsidies. For more details, see Sections 4.3 \ and 0.

(ii) Cost of R&D subsidies

This section follows the same approach as set out for HVACR in Section 0. It should be noted that that the degree of uncertainty of total R&D needed in the medical devices sector is even higher, for the reasons listed previously in this Section.

- The revenue generated by the industry totals 3.5 billion € per annum in Belgium.[233]
- The average R&D intensity in the EU [234] of the "Health Industries" sector (representing Medical Devices here)[235] is 12.4%.
- Applying this R&D intensity to the total value of the medical devices sector in Belgium would give total approximate per annum R&D medical devices spending in Belgium of around 434 million €.

[233] See Section 3.2.6 \.
[234] R&D spendings divided by the gross value added/revenue of the industry.
[235] Based on the 2022 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/sites/default/files/contentype/scoreboard/2022-12/EU%20RD%20Scoreboard%202022%20FINAL%20online_0.pdf). Of the available categories on page 15, "Health industries" is the closest match for medical devices.

- Given the uncertainty surrounding exact costs of PFAS substitution as well as timings and possible cross-country interactions, we also consider:
  - **Variations of total PFAS alternative R&D**: in other words, what is the total amount of R&D required for PFAS alternatives as a percentage of total industry R&D.
  - **Variations of subsidisation levels (for indicative purposes):** Of the total above, we show various levels of subsidisation.
- Thus, the table below shows amounts of subsidisation which vary based on the two parameters above. For example, if 25% of the value of annual R&D is required for PFAS-substitution, and 10% of this was subsidised, this would mean around 11 million € of subsidies.

Figure 18: Illustration of possible R&D subsidy requirements (per annum), in millions €

Sector	Share of total R&D needed for PFAS	Subsidy (millions of EUR), by percentage of R&D expenditure covered		
		5%	10%	25%
Medical devices	25%	5	11	27
	50%	11	22	54
	75%	16	33	81
	100%	22	43	109

5 \ CONCLUSION

The search for PFAS-free alternatives affects a wide range of sectors and uses. One of the things that makes finding alternatives to PFAS so challenging is how well they function for certain properties (oil repellence, biocompatibility, durability, chemical resistance and so on), but also how they combine properties, which is often hard to replicate. Barriers to the development of alternatives varies by industry and application, but often appears to include:

Technical and knowledge barriers

Lower performance, safety concerns, skills gap for use.

Competing regulations imposing other demands

For example concerning global warming, EcoDesign, safety requirements.

Additional costs which can be prohibitive

CAPEX (installations, more complex products) or OPEX (operating costs).

Uncertainty as to which PFAS will be banned

When and for what applications; together with which alternatives will be brought in.

Concerns over sharing of innovation results

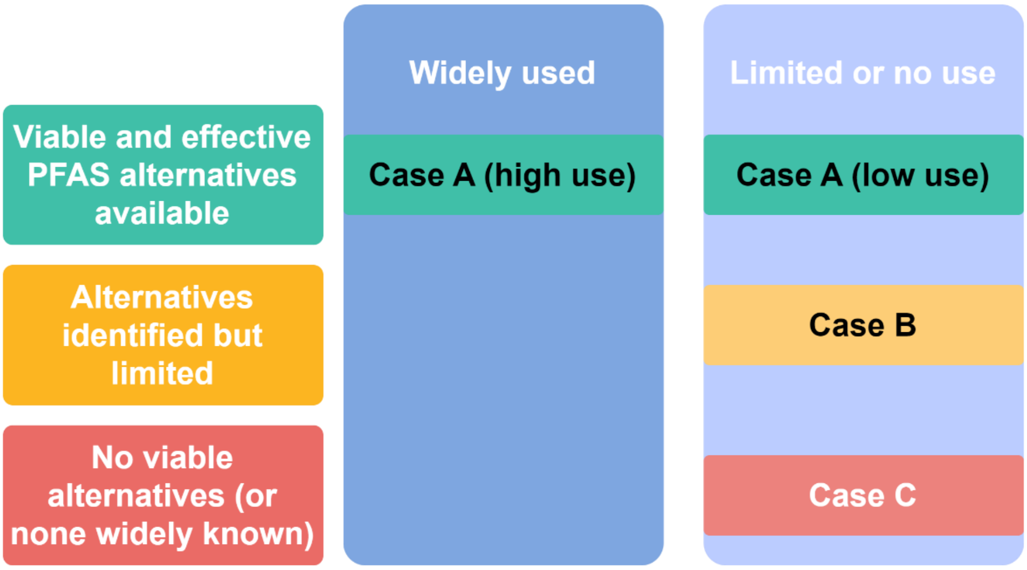
Potential market power of companies finding viable alternatives).

Lack of centralisation of information / coordination

Reduces flow of information as to potential solution and possible duplication of work.

Considering these barriers, this study has found three levels of PFAS-substitution which go from Case A to C below (from viable alternatives to alternatives existing but with drawbacks, to non-existing or very preliminary alternatives).

Figure 19: Different PFAS free alternative maturity levels



Depending on the case, different public policies can be rolled out accelerate substitution away from PFAS. It should be noted that in some cases, the process for finding viable alternatives will be a long-term task, even with the aid of these policies (due to technical or regulatory limits).

In Case A, policies that can assist with ensuring that viable alternatives effectively replace PFAS include (i) increasing consumer / producer information on products containing (or not) PFAS, (ii) short term subsidisation to encourage users to switch system, (iii) ensuring the easy availability of technical information on the alternatives for users, (iv) ensuring that there is sufficient competent and trained staff to install and maintain these systems and (v) place increasing restrictions on PFAS use by way of environmental permits (up until a full ban would be implemented).

In Case B, there may be different types of roadblocks which stop the identified alternatives from being sufficiently viable, which can be linked to:

- **Performance restrictions/limits:**
    - Where R&D can help mitigate these reductions in performance, subsidies to R&D can be provided to accelerate innovation, together with facilitating (antitrust-compliant) information exchange and either/or collaborative R&D or optimising private incentives to innovate.
    - Where R&D cannot mitigate this performance drop, subsidies could be provided to encourage switching to products with quality reduction or for switching to alternative products providing a similar function but that do not require PFAS.
- **High CAPEX cost to switch**:
    - Where this relates to an elevated cost of installation or purchase, subsidies that decrease over time could be provided to encourage switching (or existing subsidies for certain products could be modulated to favour non-PFAS products).
    - Where this relates to R&D cost, the measures described in the performance restrictions/limits can be used.

- **High OPEX cost to run the alternative solution**: Similar policies to CAPEX can be levied here, however this will depend on what level of additional use cost is deemed acceptable and demands for R&D subsidies elsewhere.

In case C, similar subsidies R&D and encouragement to collaboration or private innovation incentives can be provided as in Case B. This can also be supported by:

- The establishment of priority alternative substances for R&D for certain applications.
- In cases where PFAS substitution may be in the longer term and cannot be compressed, a short-term intermediate solution could be supporting measures to reduce emissions of existing PFAS systems until they can be replaced.

An overarching theme is there is sometimes a lack of knowledge regarding what alternatives to prioritise as well as comprehensive studies as to their desirability throughout their life cycle as compared to PFAS. This could be addressed with centralised studies (across Member States) clarifying these issues for the industry (via cost-benefit or life cycle analyses for example).

This report then discussed PFAS alternatives and policies in the context of priority sectors identified for Belgium, namely technical textiles. medical devices, HVACR.

- **In the technical textiles sector**, there are currently no alternatives which allow sufficient oil repellence properties. Policies that could help this sector include:
    - Assessing the need for personal protective equipment in a public call for tenders and potentially adapt new requirements for certain uses (to reduce the need for PFAS in the short term).
    - Once an alternative is available from the chemicals industry, subsidies for testing them could be provided.
    - Organising a collaborative workshop to foster the development of alternatives (once an alternative is available).
- **In the HVACR sector**, there are many sub applications of PFAS, some with PFAS-free alternatives, but others do not or entail significant cost increases or performance drops/safety risks.

  Policies that could help this sector (depending on the application) include CAPEX and R&D subsidies, collaboration with city planning[236], stimulation of collaborative R&D/private incentives to innovate, ensuring the presence of skilled workers who can install and maintain PFAS alternatives and finally the establishment of prioritisation lists of desirable alternatives.
- **In the medical devices sector**, PFAS are still being discovered in some parts of the supply chain), with many applications. There appears to be a general lack of knowledge of potential viable alternatives at this stage, and a lack of significant collaborative research/information sharing. Given the number of applications, there may be some applications where the solution will be relatively straightforward but many where it will be difficult. This complexity of applications and various niches of this sector means that there is not a clear path at this stage of which applications or potential alternatives to stimulate. Policies that could help this sector (depending on the application) include R&D subsidies, stimulation of collaborative R&D/private incentives to innovate, the establishment of prioritisation lists of desirable alternatives together with groups of applications which can mutualise some of the steps of research for alternatives.

[236] In the context of district heating and heat pumps.

LIST OF ABBREVIATIONS

General

CAPEX	Capital Expenditures
ERC	Environmental Release Categories
IVD	In Vitro Diagnostics
MAC	Mobile Air Conditioning
MDI	Metered Dose Inhalers
OPEX	Operational Expenditures
POP	Persistent Organic Pollutants
PPA	Polymer Processing Aids
PPE	Personal Protective Equipment
PPP	Plant Protection Products
SAC	Stationary Air Conditioning
SVHC	Substances of Very High Concern

Chemical & Polymers

6:2 FTS	6:2 fluorotelomer sulfonate
ECTFE	Ethylene Chlorotrifluoroethylene
EPDM	Ethylene propylene diene monomer
ETFE	Ethylene tetrafluoroethylene
FEP	Fluorinated ethylene propylene
FEPM	Tetrafluoroethylene propylene
FEVE	Fluoroethylene vinyl ether
FFKM	Perfluoroelastomer
FKM	Fluoroelastomer
FP	Fluoropolymer
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFE	Hydrofluoroethers
HFO	Hydrofluoroolefins
HFP	Hexafluoropropylene
HFPO	Hexafluoropropylene oxide
PBSF	Perfluorobutanesulfonyl fluoride
PCTFE	Polychlorotrifluoroethylene
PEEK	Polyether ether ketone
PFA	Perfluoroalkoxy
PFAA	Perfluoroalkyl acids
PFAS	Per- and poly-fluoroalkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutanesulfonate
PFC	Perfluorocarbure
PFCA	perfluorocarboxylic acids
PFHxA	Perfluorohexanoic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PFPE	Perfluoropolyethers
PFPMIE	Perfluoropolymethylisopropyl ethers
PFSAs	Perfluoroalkane sulphonic acids
PFUdA	Perfluoroundecanoic acid
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylideifluoride
SCFP	Side-chain fluorinated polymers
TFE	Tetrafluoroethylene
THV	Terpolymer, Hexafluoropropylene, Vinylidene fluoride

LIST OF TABLES

LIST OF FIGURES

ANNEX

WORKSHOP

RDC Environment conducted three workshops, one for each high priority sector of concern identified (technical textiles, medical devices, HVACR). The attendees were a mix of representatives of companies and federations active in each sector in Belgium. Representatives from the following industries were present.

Technical textiles

- Personal Protective Equipment (PPE), Automotive seat textiles, Construction, and textiles maintenance

HVACR

- Refrigeration (industrial, commercial), Heat pumps and air conditioning (mobile and static), heating and cooling.

Medical devices

- Contact lenses, medical devices manufacturing and pharmaceuticals.

The workshops were conducted either in sessions with all participants or sub-working groups depending on the number of people and the part of the discussion.

While each workshop differed in its structure (as it was adjusted dynamically depending on input from participants), the following broad structure was used for each workshop:

- Opening with a general discussion on PFAS and inviting the participants to share their thoughts on PFAS-free alternatives.
- Identifying the most relevant properties of PFAS to each PFAS-application.
- Discuss and identify the level of performance needed for each application (where possible), to understand requirements but also barriers for PFAS alternatives. This meant:
    - Discussing the existence of PFAS-free alternatives for each application.
    - Discussing the performance of alternatives if they exist and if not, the barriers / state of play of the development of replacements.
- This was then recapped, and then this was followed by a brief discussion of what public policies could help accelerate the transition.

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