Fluoropolymers and Fluoropolyethers:
Critical Industrial Uses Emmission Control and Abatement and End of Life Management

Contents

******Please note that all sources cited are either directly attached to this submission or links are provided to access these sources******

1. Introduction

As one of the largest manufacturers of fluoropolymers and fluoropolyethers (in the following the term fluoropolymers is meant to include fluoropolyethers), Chemours maintains a very comprehensive overview of the numerous uses of fluoropolymers in various industries. Our customer base includes small- and mid-size companies as well as multinational corporations from different sectors, all of which rely on fluoropolymers to a certain degree, and many of which operate in the European Union and create added value for the European society and economy. In our unique position as industry leader in fluoropolymer manufacturing, and with a comprehensive overview of our diverse supply chain across numerous sectors, we intend to use this submission to emphasize the interconnectivities of fluoropolymer uses across sectors. While other submissions might give insights into specific fluoropolymer uses on their respective sectors, we believe we are particularly well-suited to highlight interconnections between these uses across different sectors and the impact the Universal PFAS restriction could have across industries.

Fluoropolymers, as a class of specialty plastics, portray a variety of advantageous characteristics. They have excellent chemical resistance to most solvents, acids and bases. They are stable at extreme temperatures and retain their mechanical properties at both very high and very low temperatures. Thanks to their low surface tension, they exhibit excellent non-stick properties. They also offer excellent electrical insulation properties and low coefficient of friction. This unique combination of properties makes fluoropolymers an indispensable material in a wide range of industries.

In the context of this submission, we will focus on the so-called industrial and professional applications, which we would like to distinguish from consumer applications of fluoropolymers. By industrial and professional applications, we mean the use of fluoropolymers where the fluoropolymer is not in direct daily contact with consumer. For example, a laptop or a car, which contains fluoropolymers, is considered industrial and professional use, since the consumer is not in touch with the fluoropolymer. An example of consumer applications would be in textile or ski-wax.

Building upon our knowledge about the industrial and professional uses of fluoropolymers in different sectors – specifically the chemicals, electronics, energy, transportation, medical, and industrial machinery sector – with this submission we intend to demonstrate that fluoropolymers are not only critical for these sectors in many different ways, but that individual uses of fluoropolymers are also strongly interconnected across industries. Based on this assessment, we emphasize the need to consider entire value chains when assessing the socio-economic relevance of specific uses of fluoropolymers.

With a share of only 0.1% of global polymer production (2021), fluoropolymers represent a niche market that serves a particular demand.[1] Fluoropolymers are essential for the specific applications in this niche as they fulfill crucial functions for which there are no alternatives as documented in the cases studies in this submission. They are often used as a last resort when other materials fail, since their cost is significantly higher than that of standard plastics in addition to the specialised equipment that it is required to process them into articles Furthermore, by accounting for the large number and numerous links between the specific uses of fluoropolymers, we will point out certain limitations of the use-specific derogation approach proposed by the Dossier Submitters.

[1] Ref A - Invertec (2023, May). Chemical recycling of fluoropolymers (Presentation). Slide No. 12.

In another submission we discussed the manufacturing of fluoropolymers[2], in this submission we will cover the conversion of the fluoropolymers produced into articles. This can be done by a wide variety of processes like various forms of extrusion, coating or molding[3] by downstream users. We outline how fluorinated emissions resulting from these conversions of fluoropolymers to articles can be managed and controlled using standard emission abatement technologies. We further point towards emissions during the industrial and professional use of fluoropolymers.

Thereafter, we focus on already existing waste management regulations and innovative recycling technologies in the sectors outlined above, which are well suited to ensure appropriate end of life management for fluoropolymers in industrial and professional settings.

Based on this analysis, we conclude that a combination of existing EU legislations (or with minor modifications) with strict technological guidelines and standards in the manufacturing and emission abatement processes can ensure the safe use of fluoropolymers in professional and industrial settings throughout their life cycle by minimizing the potential for fluorinated emissions and exposures. Considering this ability to control and minimize concerns of the use of fluoropolymers, and taking into account the large number of uses of fluoropolymers that provide critical functions and benefits within and across key sectors of the European Economic Area (EEA), we conclude that the current risk-management option proposed by the Dosser Submitters in the PFAS Restriction Dossier (i.e. the phase-out of fluoropolymers) is not proportionate.

This is especially the case considering that various studies have shown that the fluoropolymers most commonly used in various applications, namely PTFE, ETFE, FEP, PFA, PVDF and FKM, meet the OECD criteria of 'polymers of low concern'.[4] They are chemically stable, non-toxic, non-bioavailable, non-water soluble and non-mobile materials.

Anticipating that use-specific derogations will fail to ensure that critical uses of fluoropolymers within and across industries can continue, the socio-economic costs of phasing out fluoropolymers significantly exceeds the concerns, which, as outlined above, can be minimized through the application of alternative risk-management approaches.

In Chemours' discussions with customers and value chain partners, we already note that the PFAS Restriction Proposal is creating great uncertainty within the industry, harming investments in innovative technologies that are important for achieving the EU Green Deal, RePowerEU, the European Chips Act and other ambitious policy programs aiming at the sustainable transformation of the EU economy.

In addition, we see that with the publication of the restriction proposal by the five European States in which a phase-out of the fluoropolymers is envisaged, the EEA risks business moving production outside the EEA where the legislation on fluoropolymers allows for their continued use.

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[2] Chemours submission to REACH PFAS restriction proposal consultation – part 37, reference 6337

[3] Chemours Introduction to Fluoropolymers – [too large for attachment, can be provided upon request]

[4] VDMA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20. Reference 4471. Appendix page 3.

In light of the criticality of fluoropolymers for numerous uses and applications across industries, the shortcomings of use-specific derogations, as well as the possibility to control and minimize concerns associated with the use of fluoropolymers, we urge ECHA to consider a general exemption for fluoropolymers from the PFAS restriction or, at the very least, to provide a very broad derogation for fluoropolymers in industrial and professional use.

2. Critical Uses of Fluoropolymers

With their unique set of properties (durable, efficient, reliable, versatile), fluoropolymers have important characteristics (high temperature resistance, chemical resistance, weather/UV stability, excellent electrical insulation, high-performance dielectric performance, non-wetting and non-sticking, low friction, low/no flammability) that provide significant benefits for various applications in numerous different sectors.[5] There are no other materials that have this combination of properties; we see fluoropolymers being selected for an application when a combination of these properties is required that other materials don't have. In general, it can be said that when Fluoropolymers are being used, articles and equipment last longer, making them more durable and safer.

The significance of these benefits becomes clear when considering that fluoropolymers are comparatively expensive materials. This implies that downstream users have an inherent economic incentive to use comparatively cheaper alternative materials wherever possible. This is why downstream users typically only select fluoropolymers for applications that require a combination of two or more of fluoropolymers' characteristics and must guarantee high reliability, performance, and quality. These characteristics have led to performance improvements across a number of industries and applications. A restrictive regulation could lead to a regression towards older, inferior solutions with the associated loss in performance and reliability.

Chemours provides various fluoropolymers in different grades for more than 1,400 applications in a wide variety of sectors in more than 30 industries across the EMEA region.[6] A detailed description of all of these 1,400 applications is not our objective of this submission phase, as industry associations and downstream users already provide in-depth information about the uses of fluoropolymers within the sectors they operate, respectively. This submission instead aims to highlight the interconnectivity between individual sectors and applications.

As such, based on our comprehensive overview and knowledge about the different uses of fluoropolymers, and based on sector-specific submissions already provided by other stakeholders, we focus in this chapter on illustrating fluoropolymers' criticality in a number of industrial and professional uses in different sectors. With this, we aim to provide a comprehensive overview of how fluoropolymers are used in respective sectors and how these uses are connected to each other. **This is a very important point, which we visualize in Graphic 1; sectors cannot function on their own, sectors rely on each other to function, each of these sectors, and many others, have many applications that require fluoropolymers.**

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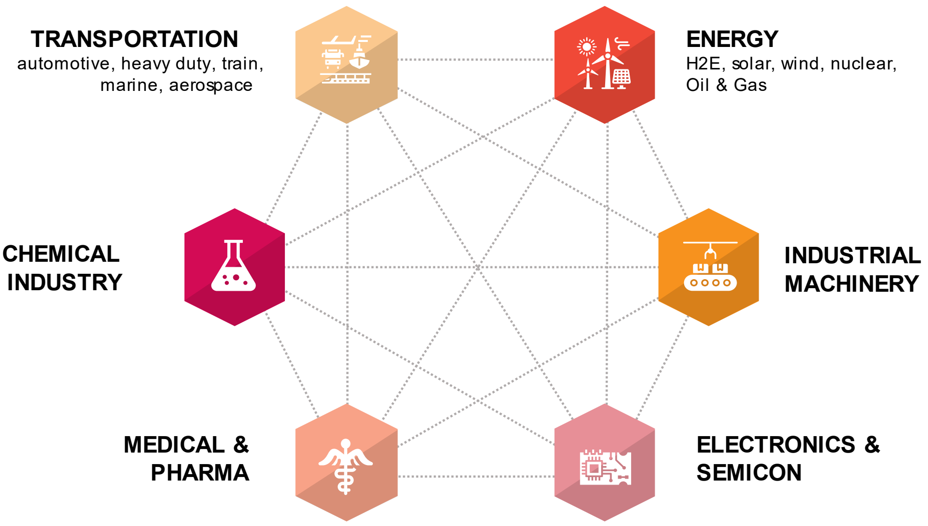
[5] Ref B – Chemours (2017). An Introduction to Chemours™ Fluoropolymers. Page 5. – [too large for attachment, can be provided upon request]

[6] Ref C – Chemours served EMEA Market Application 2022

As such, it is misleading to assess the functions and benefits of fluoropolymers within the scope of individual applications. **Instead, it is important to also consider the use of specific fluoropolymer-containing applications within and across industries and value chains. For this reason, the only practical way to regulate the use of fluoropolymers for industrial and professional use in the restriction dossier is to exempt them or, if this is not possible, to provide a very broad derogation for fluoropolymers in industrial and professional use. Such an exemption would thereby also be justified by controlling any possible risks throughout the lifecycle, as we will address in the next chapters 3 and 4.**

Graphic 1: Uses of fluoropolymers within and across industries



2.1 Selected uses of fluoropolymers within different sectors and industries

In the following, we describe exemplary uses of fluoropolymers in the chemicals, electronics, energy, transportation, medical, and industrial machinery sector by first explaining the overall role of fluoropolymers in the respective sectors before providing information on specific selected uses. Where possible and where data is available, we also assess the applicability of potential alternative materials. These selected sectors should be seen as an exemplary selection to present the range of applications for fluoropolymers, as there are many other sectors and applications outside of these examples presented.

Table 1 shows a generic overview of the combination of key properties that are needed for each sector.. (In this Table fluoropolymers are considered in their pure form, without any additives). It is the combination of these properties of fluoropolymer in its pure form that makes it a unique material. Within a sector , specific applications may need more properties, than the typical ones listed, to achieve the requirements

Table 1: Fluoropolymer properties as pure polymer without any fillers

	Chemical Industry	Transportation	Semicon	Electronics	Medical/Pharma	Energy
Chemical Resistance	√	√	√	--	√	√
High Temperature Resistance	√	√	--	√	--	√
Low friction/non stick	√	√	√	--	√	√
Excellent electrical insulator	--	√	--	√	--	--
UV /weather stability	--	√	√	--	--	√
No/low flammability	√	√	--	√	--	√
High purity	√	--	√	--	√	--

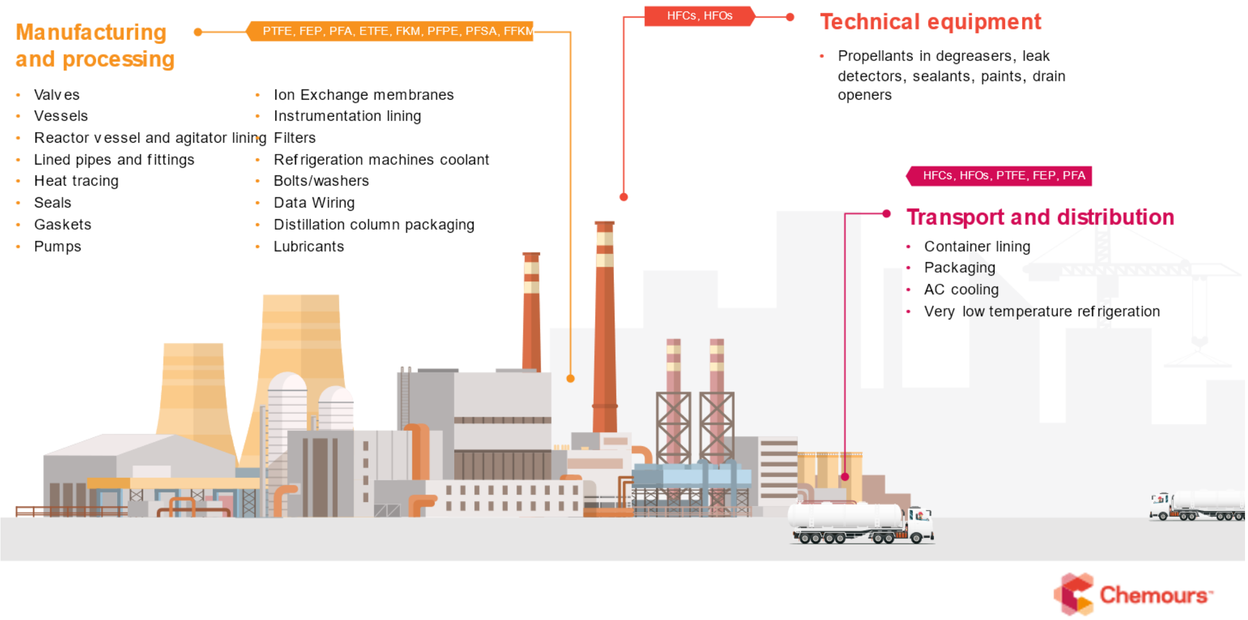
2.1.1 Chemical Industry

The European Commission defines the chemical industry as "one of Europe's largest manufacturing sectors" and considers it to be "at the heart of the EU's manufacturing industry."[7] In line with this assessment, the chemical industry, including fluorinated chemistry, plays a pivotal role in advancing technology and innovation. Notably, 56% of chemicals produced within the chemical industry are sold to downstream users in other industries.[8] The chemical industry is highly regulated through the SEVESO regulations[9], which set the highest reliability requirements to avoid accidental leaks and emissions. Given their unique combination of properties, fluoropolymers are widely used within the chemical industry itself (e.g. coatings, linings, piping, vessels, and vents; hoses, sealants, gaskets, and tubing for corrosive fluid handling; lining for heat exchangers or incinerators; transmissions (membranes / water service); conveyor belts; wire and cable coatings for sensors, high-frequency data cable, and high mechanical strength cables; filters systems (filter housing, cartridge, woven filters, etc.)). Their use allows a high level of efficiency and safety in various chemical and industrial manufacturing processes, and they are crucial for the prevention of leaks or emissions, corrosion, and leaching. This is particularly important in applications involving aggressive chemical fluids or in power installations.[10] In addition, fluoropolymers also play an essential role in chemical industry R&D, and

[7] European Commission. (n.d.). Chemicals. Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/chemicals_en
[8] European Commission. (n.d.). Chemicals. Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/chemicals_en
[9] https://echa.europa.eu/nl/regulations/clp/understanding-seveso
[10] Chemours Advanced Performance Materials (2023). *Fluoropolymers in Chemical and Industrial Processes: Chemours as a user perspective*. PFAS Restriction Proposal Consultation. Comments on the Annex XV report. Submission reference fe66ebe9-80b8-49e1-9bab-2724b323f4f7

they can be found in the equipment of all chemical laboratories.[11] As shown in Table 1 , it is their unique combination of characteristics such as resistance to various chemicals, heat resistance and purity that make fluoropolymers indispensable for use in the chemical industry. In the following, we illustrate the uses of fluoropolymers in the chemical industry as coatings, sealants and gaskets, and lubricants in more detail, demonstrating their multifaceted benefits for chemical production.

Graphic 2: Chemical production components containing fluoropolymers



Coatings and Linings as Protective Layers

Fluoropolymers are used as a protective layer to other materials like metals. They can be applied as a coating to the other substrate, this coating adheres to the substrate, or as an internal liner. The liner is inserted through an extrusion process or physical insertion and is typically not adhered to the substrate. The combination of characteristics the chemical industry is looking for are chemical resistance, high temperature resistance, low friction/nonstick, no/low flammability, and as well as the high purity required for some chemical processes. Because of the combination of these characteristics, when used as a protective layer, fluoropolymers provide a high level of protection to a variety of materials. The anti-corrosive properties of fluoropolymers make them optimal for protecting metals that would otherwise be corrosive to chemicals such as acetone, ammonia, hydrochloric acid, sulfuric acid, sodium hydroxide or chlorine.[12] Also, specific fluoropolymers, such as perfluoropolyether (PFPE), PFA, and PTFE, are preferred in the chemical industry as protective layers for the insides of valves, preventing loss of chemical from sticking to the sides of the valves, and as sealants, not letting external contaminants into the vessels. This, in turn, significantly increases the efficiency and safety of operations. Furthermore, fluoropolymers are used as a protective layer in machinery used in chemicals

[11] Chemours Advanced Performance Materials (2023). *Fluoropolymers in Chemical and Industrial Processes: Chemours as a user perspective*. PFAS Restriction Proposal Consultation. Comments on the Annex XV report. Submission reference # fe66ebe9-80b8-49e1-9bab-2724b323f4f7

[12] Chemours Advanced Performance Materials (2023). *Fluoropolymers in Chemical and Industrial Processes: Chemours as a user perspective*. PFAS Restriction Proposal Consultation. Ref fe66ebe9-80b8-49e1-9bab-2724b323f4f7

production to prevent materials from sticking and to increase their durability. Without fluoropolymer protective layers, machines in the chemical industry would have a shorter life span and would be subjected to quicker corrosion or contamination from outside factors.[13]

Sealants and Gaskets

As elaborated upon within the European Sealing Association (ESA)'s submission, fluoropolymers are critical sealants in the chemical industry.[14] Fluoropolymers are used to create an industrial seal on containers holding powders, gas, and liquids, and inside various hardware, such as storage equipment. Fluoropolymers are used specifically because of the combination of chemical and broad temperature range resistance, which assure the required performance and prevents leakage and emissions. In particular for individual applications in which more than one property of fluoropolymers is required, there are therefore no alternatives that can meet the same required performance~~.~~ The simultaneous strength and softness of fluoropolymer sealants, particularly PTFE and FKM, makes them preferred by the industry for use across different applications. This in combination with their other properties such as corrosion resistance and ability to withstand vast ranges of temperatures allows them to protect both the vessel and the product inside the machinery, as well as numerous other applications.[15]

Lubrication

The non-stick properties of fluoropolymers make them a preferred option for lubricants used within the chemical industry. Fluoropolymer-based lubricants are used on machinery to reduce friction and ensure production processes run smoothly. The high temperatures generated by various types of machinery and exothermic chemical processes require a lubricant that can withstand vast ranges of temperatures and still operate successfully, such as the fluoropolymer-based lubricants of PFPE, PCTFE, and fluorosilicone. They are also used at places where relubricating is very complex, facilitating the "fill for life" concept, preventing complex maintenance and downtime.

2.1.2 Electronics: Semiconductors

Semiconductor manufacturing is a complex process that involves the repeated etching and deposition of materials on a wafer. Etching, which involves the removal of materials from the wafer surface using techniques like dry etching with plasma or ion beams, stands in contrast to deposition, where materials are added. One deposition method is sputtering, where a target material is bombarded with ions, causing particles to be ejected and deposited onto the wafer. Another is evaporation, in which a material is heated until it evaporates and then condenses onto the wafer as a thin film. The manufacturing process starts with a pure silicon wafer, onto which then circuits are patterned using photolithography. Following this, impurities are introduced by doping, undesired portions are etched away, and various materials are deposited in thin layers, leading to the formation of integrated circuits. Due to growing demand for smaller, ever more powerful chips, the ongoing miniaturization and integration of numerous transistors has caused the manufacturing procedures to become profoundly

[13] Chemours Advanced Performance Materials (2023). *Fluoropolymers in Chemical and Industrial Processes: Chemours as a user perspective*. PFAS Restriction Proposal Consultation. Ref fe66ebe9-80b8-49e1-9bab-2724b323f4f7.

[14] ESA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20. Reference 4472.

[15] ESA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20. Reference 4472. Appendix page 1. Doc 20. Reference 4472 Appendix page 1 (case study example).

more refined and intricate over the years. In this complicated process, many different chemicals are being used, including very strong acids and active surfactants. These chemicals are needed to maintain their extremely high purity to prevent contamination and defects on the wafer, that would result in errors integrated circuit and low yields for the semiconductor fabrication plants. The fluid handling system for these chemicals consists of vessels, piping, pumps, valves, filters, flow meters which are made with Fluoropolymers.

According to the European Chemicals Agency (ECHA), the semiconductor sector consumes 45% of the fluoropolymers used in the electronics industry.[16] Fluoropolymers play such a key role as they offer a whole range of specific physical and chemical characteristics that are vital for semiconductor manufacturing to function efficiently and optimally. They exhibit a unique combination of low surface tension, stability and chemical compatibility, inertness, purity, chemical and permeation resistance, a wide range of temperature stability, a low coefficient of friction, electrical properties, bacterial growth resistance, non-flammability and a long lifetime (more than 25 years).[17]

Thus, they play an important role in numerous sub-steps of the manufacturing process, including photolithography, plasma etch/wafer cleaning and deposition processes, as well as semiconductor assembly, testing and packaging.[18] The PFAS Semiconductor consortium has created excellent white papers extensively describing the importance of fluoropolymers in the many applications of the semiconductor manufacturing process.[19]

Any alternatives tested so far have been shown to have significantly higher leakage rates.[20]

To maintain and promote a competitive semiconductor industry in Europe, the use of fluoropolymers remains indispensable. Concretely, restricting access to fluoropolymers for the semiconductor industry would make the targets set out in European Chips – which aims to strengthen and improve Europe's semiconductor industry to reduce its dependency on imports – unattainable.[21] To date, no alternatives have been found that can meet the range of performance requirements on par with fluoropolymers, especially with regards to chemical resistance and purity. Researching, developing, qualifying, and implementing alternatives would be a lengthy process, and could require a fundamental overhaul of semiconductor devices and structures. Even a slight change in semiconducting properties would not allow the EU semiconductor industry to achieve the high standard of efficiency and sophistication required by various downstream user industries, such as automotive or energy, for which semiconductors are indispensable.[22] According to a socio-economic analysis (SEA) we commissioned of a potential restriction on the fluoropolymer perfluoroalkoxy (PFA), a full PFA restriction would risk bringing the semiconductor supply chain in Europe to a standstill, resulting in calculated economic

[16] Cheng Ting-Fang (2023, May 22). *The crackdown on risky chemicals that could derail the chip industry*. Financial Times. https://www.ft.com/content/76979768-59c0-436f-b731-40ba329a7544

[17] ESIA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 18 ref 4449.

[18] ESIA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 18 ref 4449.

[19] Semiconductor PFAS Consortium (2023). Technical Papers. https://www.semiconductors.org/pfas/.

[20] Ref D - Chemservice (2022, July 19). Technical Report. Analysis of alternatives to fluoropolymers and potential impacts related to substitution in different sectors of use, page 28.

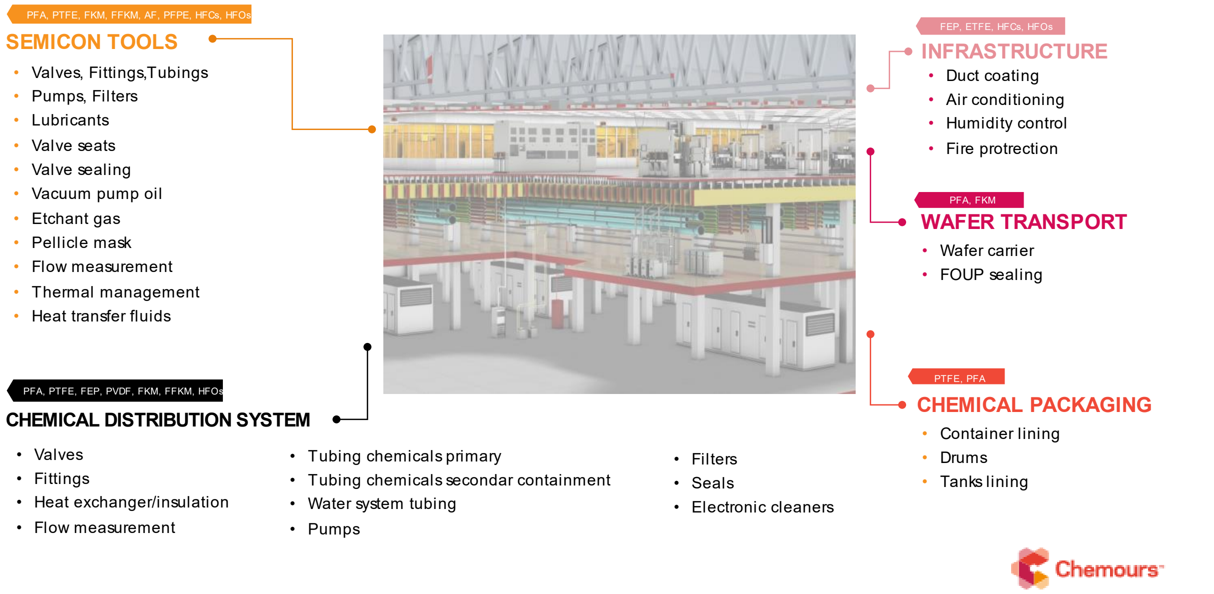
[21] Ref E - Risk & Policy Analysts (2023 June). Socio-Economic Analysis of a potential REACH Restriction on Fluoropolymers, page 8.

[22] ESIA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 18 ref 4449; Answer to specific info request 7.

losses of €63.4 billion over the course of the assessment period between 2026 and 2035, and estimated job losses for more than 21,000 employees.[23]

In the following we highlight certain key applications throughout the semiconductor manufacturing to reflect some of the critical functions and benefits of the uses of fluoropolymers in this context in more detail.

<u>Graphic 3</u>: Semiconductor manufacturing components containing fluoropolymers



<u>Coatings, linings, sealants</u>

Fluoropolymers, due to their heat resistance and chemical inertness, are used in the infrastructure of the semiconductor industry to protect the equipment from chemical and thermal stresses, improve its performance and thus extend the life of the equipment used. Their high resistance also ensures an extremely high purity of the materials involved in the process. For the semiconductor industry, it is vital that streams treated in the vessels, piping and armature systems have the highest possible degree of purity – as this is the basis for the quality of modern chips. Materials used must therefore not decompose or leach any metal or particulates The High performance sealing materials, which can withstand high operating temperatures, that are used are fluoroelastomers.[24] In addition, most tubing and hose systems used in the semiconductor industry are fully based on fluoropolymer material to allow for effective tubing systems in environments that require very high chemical and temperature resistance while maintaining flexibility.[25]

- Various chemical processes are used in semiconductor manufacturing, such as etching and depositing layers on the wafers. These processes can involve aggressive chemicals that come into contact with the materials of machines, pipes, pumps or seals within the production environment.

[23] Ref E - Risk & Policy Analysts (2023 June). Socio-Economic Analysis of a potential REACH Restriction on Fluoropolymers, page 9.
[24] SEMI (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 13 ref 4304.
[25] Ref D - Chemservice (2022, July 19). Technical Report, page 26.

Fluoropolymer coatings provide protection from these chemicals to prevent them from attacking or damaging machine components.

- During the manufacturing process, machines can also be exposed to high and varying temperatures. This is especially true for lithography machines, which typically use intense UV light. Fluoropolymer coatings have high-temperature resistance and protect machines from the high temperatures and associated thermal stresses. They help prevent excessive heating or deformation of the machine components, pipes, pumps and gaskets.

- Fluoropolymer coatings also provide protection against abrasion and wear. In the semiconductor industry, machines often operate at high precision and high speed. By using fluoropolymer coatings on the surfaces of the machines, friction and wear can be reduced, helping to extend the life of the machines. By protecting the machines from chemical and thermal stresses, fluoropolymer coatings ensure longer life and better equipment performance. This contributes to the efficiency and reliability of the manufacturing process, which in turn improves the quality and yield of the microchips produced.

- In tubing, pumps, and seals, fluoropolymers provide a smooth, non-reactive surface that reduces the formation deposits and of contaminants, helping to maintain remarkably high purity throughout the manufacturing process, which is key to minimize impurities or particles that could affect the quality of the semiconductors.

- Flowmeters are used for accurate control of the chemicals, these flows meters are also produced with fluoropolymers to protect against the aggressive chemicals. By using reliable materials such as fluoropolymers, the flowmeters keep their reliable performance and as such optimize the manufacturing process and achieve consistent results.

- Columns and tanks lined with fluoropolymers are required to produce and store high-purity sulfuric acid for etching silicon wafers used in the manufacture of electronic chips. This technology enables larger wafers and ultimately a more efficient production process for microchips. Larger wafer sizes enable the production of more semiconductors on a single wafer, increasing productivity and efficiency. [26]

<u>Duct coating</u>
Fluoropolymers play an important role as duct coatings in the semiconductor industry. Fluoropolymer-coated stainless steel tubes as non-corrosive exhaust ducts meet the performance standards for cleanroom applications due to their chemical resistance, while at the same time fulfilling high safety requirements due to their high resistance to fire and smoke. As such, fluoropolymer coating on stainless steel pipes provides an effective solution to prevent accidents and increase safety in semiconductor fabrication facilities. This is important as accidents in the semiconductor industry have shown that fires caused by reactive chemicals and flammable materials can result in significant losses.[27]

[26] Ref D - Chemservice (2022, July 19). Technical Report, page 26.
[27] Shu Ching Chiu et al. (2008, Jan). Trends in Major Incidents of Semiconductor-Related Industry in Taiwan. https://www.researchgate.net/publication/229040158_Trends_in_Major_Incidents_of_Semiconductor-Related_Industry_in_Taiwan

The spread of fire from common exhaust ducts or relief heads consistently resulted in the largest reported losses. In this context, polyvinylchloride (PVC) and fiberglass reinforced plastic (FRP) cannot be considered equivalent alternatives. PVC tends to become brittle over time and has undesirable burning behavior in terms of smoke generation. FRP, on the other hand, has poor chemical resistance. Both materials are therefore not suitable alternatives to fluoropolymers for applications in the semiconductor industry, as they imply trade-offs between flame spread, smoke development and chemical resistance. [28]

Vacuum pump fluid oil

In semiconductor manufacturing facilities, a vacuum in the process chambers ensures optimal conditions for processes such as evaporation, sputtering, and dry etching. In this context, dry vacuum pumps are often the preferred choice due to their reliability and contamination resistance. Their longer maintenance intervals result from the non-oxidation and low contamination of pump oil. Lubrication of moving parts in these pumps requires lubricants with characteristics such as low viscosity, thermal resistance, compatibility with materials of construction and non-flammability. Manufacturers recommend PFPE-based oils and greases for lubrication. They provide numerous functions such as sealing, lubrication, cooling and corrosion protection. They must also remain inert in the chemically aggressive environments of semiconductor production. PFPE-based oils and greases meet these requirements, ensuring high pump reliability. Currently, there are no known suitable alternatives that would be compatible with the variety of chemicals used in manufacture of semiconductors.[29]

Filters

Semiconductor production uses chemical solutions and process liquids that must be extremely pure. Any contamination, even at the molecular level, can affect the quality of a semiconductor chip and lead to production downtime. Teflon™ PTFE fluoropolymers are therefore indispensable in high-purity filtration membranes, as they are able to filter out the finest particle contamination from process liquids and gases. They are also used in venting membranes in chemical chambers.[30] Effective filtration keeps the system efficient, with the regular removal of contaminants ensuring that the line does not need to stop for constant maintenance. Fluoropolymers such as PFA and PTFE are practically the only materials that remain inert to the extremely aggressive environments of a wafer fabrication facility and do not leach any metals and particles. Therefore, fluoropolymers are crucial for semiconductor manufacturing as they ensure the integrity and purity of the processes and thus guarantee high product quality. In addition, fluoropolymer-based filters are durable due to their chemical resistance and mechanical stability, resulting in a long service life of more than 25 years; making them cost-effective.[31]

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[28] Ref F - Chemours duct coating application description

[29] Semiconductor PFAS Consortium Lubricants Working Group. PFAS-Containing Lubricants Used in Semiconductor Manufacturing, page 9. (https://www.semiconductors.org/pfas/)

[30] Poly Fluoro Ltd. (2018, July 9). PTFE in Semiconductor Manufacturing. https://polyfluoroltd.com/blog/ptfe-in-semiconductor-manufacturing/

[31] Semiconductor PFAS Consortium (2023). PFAS-Containing Articles Used in Semiconductor Manufacturing. Technical Papers. https://www.semiconductors.org/pfas/, page 37.

In addition to the membranes themselves, the housings and fittings that are in contact with the process fluids are made of materials that do not add contaminants. As fluoropolymers are inert to most chemicals, Teflon™ PFA HP and HP Plus resins are particularly well suited for these applications.[32]

2.1.3 Electronics: Insulation of Cabling and Circuit boards

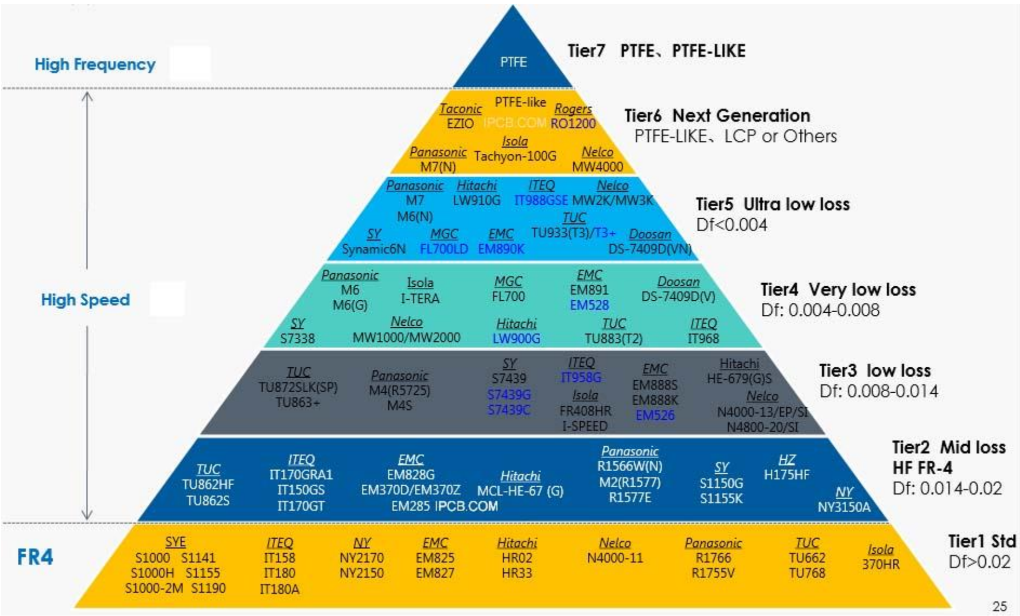
Apart from semiconductor manufacturing, another example of fluoropolymers in electronics is the use as insulation in cabling and circuit boards. Especially PTFE, FEP, PFA and ETFE, are used as insulation for various industries as they meet their required performance requirements: They have exceptional electrical insulation properties and resistance to chemical and thermal stresses such as high temperatures, and are inherently flame retardant without the need for additives.[33] They are also responsible for allowing cables to be thinner, as they have high dielectric strength, and they provide for minimal signal interruption, which is essential for data transmission. This also allows them to be used as insulators for cables, wires and circuit boards in high-frequency electronics in communication facilities, ensuring optimal data transmission characteristics. Fluoropolymers are thus critical to many applications like 4G and 5G technology, aerospace, military and automotive radar (see example in transportation section 2.1.5), data centers and many specialized niche applications that require high frequency and high speed. None of the potential alternative materials can provide this combination of properties and characteristics. A good way how different materials can be represented is shown in Graphic 4 for the dielectric materials in printed circuit boards, where the top of the pyramid materials are used for the highest frequency and speed applications. The pyramid shows different tiers based on Dissipation Factor (Df), it is a measurement of how good a material keeps the electrical signal in a conductor. The lower the Df, the better it keeps an electrical signal in the conductor. The example in graph shown is for circuit board materials. The standard material for circuit board is FR4, a grade designation for glass reinforced epoxy laminate material[34], the materials higher up in the pyramid have improved performance which is needed for higher speed and higher frequency data signals. The top of the pyramid has the best electrical insulating materials, from which PTFE has the lowest Df (less than 0.001) and best insulating performance.

[32] Teflon (2023). High-Purity Bulk Chemical Distribution Systems. https://www.teflon.com/en/industries-and-solutions/industries/semiconductor-manufacturing/bulk

[33] Ref D - Chemservice (2022, July 19). Technical Report, page 29.

[34] https://en.wikipedia.org/wiki/FR-4

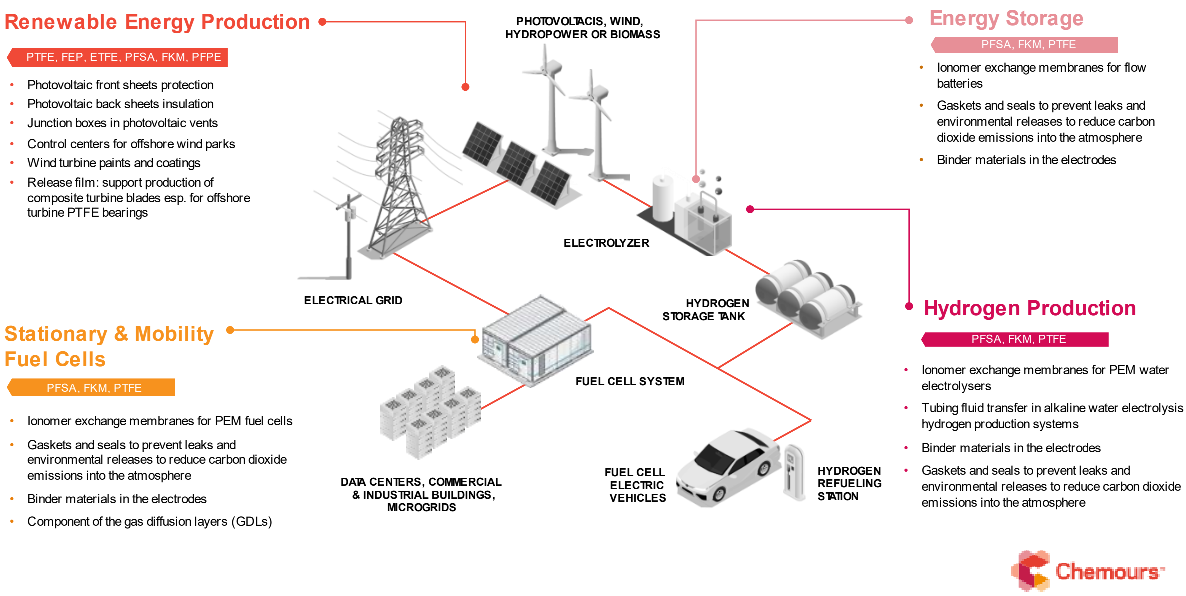
Graphic 4: Materials pyramid for electrical properties [35]



2.1.4 Energy

The energy sector mostly operates under extreme conditions that require very high temperature, weather, and chemical resistance, protection against corrosion, and overall high durability and reliability. In many cases, safe energy production would not be possible without these characteristics. Therefore, fluoropolymers are used for various applications in the production and storage of energy, as Graphic 5 demonstrates. In this section, we emphasize the use of fluoropolymers in the production of hydrogen as well as in the solar and oil & gas industries.

Graphic 5: Energy production components containing fluoropolymers



Hydrogen

Renewable hydrogen is considered a reliable chemical storage medium for energy initially generated by renewable sources, which in turn depend on external, unsteady variables such as wind and sunshine.

[35] Source: https://www.ipcb.com/technical/787.html

Renewable hydrogen also has the potential to be used to decarbonize some industries with a very high energy demand, such as the steel and chemicals industry. Renewable hydrogen can also be used as an electrochemical power generation, fuel cell vehicles and in internal combustion engines modified for the use of hydrogen

One way to produce renewable hydrogen is through the electrolysis of water, powered by renewable energy sources. In the context of the electrolysis, fluoropolymers are a critical component in polymer electrolyte membrane water electrolysis (PEMWE) and polymer electrolyte membrane fuel cells (PEMFCs), as the advancement of PEMWE and PEMFC technology highly depends on the use of fluoropolymer membranes.[36] Moreover, in the production and storage of hydrogen, fluoropolymers are also used as sealants.

- **PEM (Polymer Electrolyte Membrane) Water Electrolysis** is a process of using electricity to split water into hydrogen and oxygen. This process is carried out in a so-called electrolyzer. The electrolyzer, in the case of PEM Water Electrolysis, has a fluoropolymer membrane, working as an electrolyte. The membrane in the process serves to separate the formed oxygen and hydrogen from reacting with each other and forming a potentially explosive mixture. The electrolyzer is typically operated in a flooded state, therefore the membrane contained in the electrolyzer is more likely to creep, with maximum water uptake. In such flooded conditions, fluoropolymers help to make the membrane durable and ensure reliable operations. Fluorine-containing membranes, such as Nafion[tm], are particularly resistant to this corrosive attack by chlorine, which adds to them being uniquely suited for PEM Water Electrolysis.[37] The hydrogen produced by the electrolysis can be used as an energy source for electrical grids or can be stored and used in fuel cells, which in turn rely on fluoropolymer-based ion-exchange membranes.
  Hydrocarbon membranes are being promoted, but they have significant issues in performance and durability. We describe these issues in detail in one of the attached references.[38] The proposed hydrocarbon alternatives suffer from mechanical brittleness, insufficient chemo-mechanical durability, excessive water uptake, catalyst poisoning, and electrode diffusion limitations. These issues impact both performance and durability to the extent that commercially relevant implementation is not practicable.

- **Alkaline Water Electrolysis** is essentially the same above process, but uses a liquid alkaline solution as the electrolyte instead. A porous diaphragm, without PFAS, is used instead of a solid fluoropolymer membrane. Yet, like for the PEM Water Electrolysis, fluoropolymers play a role in this process, for example as sealing materials and gaskets as well piping. Also, the liquid electrolyte (KOH) required for this process is best produced through electrolysis using fluoropolymer membranes, as the alternatives would involve highly toxic substances like mercury and asbestos, which are already restricted.[39]

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[36] Ref G - Risk & Policy Analysts (2023, May 18). Socio-Economic Analysis of a potential REACH Restriction on Fluoropolymers Nafion[TM] Ion Exchange Membranes.
[37] XiaoZhi Lim (2023, August 1). Could the world go PFAS-free? Proposal to ban 'forever chemicals' fuels debate. Nature, https://www.nature.com/articles/d41586-023-02444-5 .
[38] Ref H - Alternative Fluoropolymers Ionomer issues by Chemours 2023-07
[39] Hydrogen Europe (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 9 ref 4144.

- **PEM Fuel Cells** are used to power vehicles, especially light-duty vehicles. Other applications are for example stationery and portable power generators. The Proton Exchange Exchange Membrane Fuel Cells (PEMFCs) are found to have up to twice the efficiency of conventional internal combustion engines. Given the harsh operating environment of PEMFCs, they must withstand high ionic conductivity, high electrical resistivity, low gas permeability and high durability. For this, fluoropolymer-based ion exchange membranes are used, since fluoropolymers provide a unique set of properties and characteristics. Applied to the PEMFCs, these fluoropolymer-based ion-exchange membranes themselves are relatively thin and must withstand an aggressive hygrothermal, chemical and dynamic operating environment, as well as significant mechanical stresses due to pressure and swelling. Here, PTFE ensures that the membrane is exceptionally durable, as PTFE is highly robust, inert and resilient, while still enabling high performance. This durability is key because the membrane must function for more than ten years or 8.000 operating hours – to ensure it survives the PEMFC's lifecycle.

- PTFE and FEP are also used for **sealing** components used in production, transport and storage of green hydrogen. Fluoropolymer based sealing systems can be involved in many steps in the hydrogen process involving cryogenic conditions, for example for rotatory swivels for loading arms at transport of liquid hydrogen, during storage for hydrogen liquefaction or at pumps and valves used at fueling stations. This application is challenging particularly from the temperature perspective. On one hand, cryogenic conditions (e.g., close to -268°C) are involved during storage of hydrogen. On the other hand, hydrogen is one of the few gases (with helium and neon) that actually heat up when expanded. Given their unique set of properties and characteristics, PTFE and FEP are well suited to cope with the extreme shift in temperatures that may occur during hydrogen production and storage. In this context, steel seals and other rubber materials such as nitrile butadiene rubber (NBR) may be seen as potential alternatives. Steel, however, would eventually fail because they could not provide the reliability required during the hydrogen cycle. Flanges and bolts to be used in the process require significantly stronger materials during harsh temperature conditions, and steel solutions would eventually break, leading to releases and significant risks for the operators and the environment. Similarly, NBR is a material that cannot resist temperatures below -70°C, which is significantly far from the lowest possible temperature during the hydrogen storage and transport processes, which can go as low as -263°C.[40]

Solar

In the manufacture of solar panels, fluoropolymers were used as **insulation** in photovoltaic (PV) modules. While the industry was able to substitute the use of fluoropolymers in the PV modules themselves, PVDF is still used as the back sheet in most solar panels to protect and enhance the durability of the installations. PVDF is used for this application due to its excellent resistance to chemicals and corrosion, resistance to high temperature, high compatibility with many chemical substances, stability, inertness, durability, flame retardant and UV resistance properties. Its exceptional flexibility allows the use in the complex forming and bending of metal building panels. PVDF is also resistant to high humidity environments, non-toxic, and its smooth surface does not encourage the growth of microorganisms, therefore this anti-fouling property is helpful to prevent stains and dirtiness. In this context, in-depth analysis has shown that that trade-offs from the use of

[40] Ref D - Chemservice (2022, July 19). Technical Report. Chapter 3.2.3. Application 2.3: Use of PTFE and FEP in the production sealing systems for storage, transport and production of green hydrogen.

alternatives to PVDF in the back sheet are not related to appearance or other aesthetics properties, but to safety and integrity.[41]

Technologies to replace fluoropolymers as back sheets are being developed.[42] In this way, solar modules could be produced without fluoropolymers in the future. However, other applications of fluoropolymers will still be needed for photovoltaic modules[43,44] Furthermore fluorpolymers are used in the chemical production process for the safe manufacture of these alternative materials, as it is and will be demonstrated by the multiple submissions from the chemical industry to the consultation by different companies and industry groups[45,46] . The same is true for the semiconductor layer in a PV cell, as the fluid handling system also requires fluoropolymers.

Oil & Gas

Fluoropolymers are used in the **seals** for well head equipment in the oil and gas industry. This is a highly regulated industry, similar to the chemical industry as mentioned earlier, as material failure entails high risks. Fluoropolymer seals are the only option available for many wellhead applications. These fluoropolymer seals need to withstand low temperatures and highly corrosive environments.[47]

Similarly, fluoropolymers such as FEP (Fluorinated Ethylene Propylene) and ETFE (Ethylene Tetrafluoroethylene) are used as **sheathing materials** for permanent downhole cables in the oil and gas industry, as they can withstand high temperatures and the aggressive downhole environments; in particular chemical and electrical stresses.[48] The selection of the correct jacketing material is thereby based on the bottomhole temperature and the presence of gases such as CO_2. Permanent downhole cables play a critical role in reservoir and production monitoring by connecting sensors deep in boreholes to the surface and providing both data transmission and power. Similar applications of fluoropolymers for cable sheathing in aggressive environments can also be found in the chemical industry.

2.1.5 Transportation: Automotive

In the automotive industry, machinery and equipment often have to withstand harsh (outdoor) environments and extreme operating conditions, while also providing a high level of reliability and safety. In this context, fluoropolymers, with their unique set of properties and characteristics, are used

[41] Ref D - Chemservice (2022, July 19). Technical Report. Chapter 3.7.2. Application 7.2: Use of PVDF in facade and infrastructure protection for the construction sector.

[42] Example: Sabic (2023, Feb 1). Solar Photovoltaic Systems (Fact Sheet). PLASTINDIA 2023, https://www.sabic.com/en/Images/Factsheet-PlastIndia-2023-Solar_tcm1010-38572.pdf

[43] See for instance Comments # 4080 (part 7), # 5975 (part 26), # 6306 (part 35)

[44] G. Graffini et al, Novel high-durability luminescent solar concentrators based on fluoropolymer coatings, Progress in Organic Coatings (2014), G. Graffini et al. Polymeric materials for long-term durability of photovoltaic systems, J. of Applied Polymer Science (2015),

[45] See for instance Comments # 4092 (part 8), #4453 (part 18) #4503 (part 20),

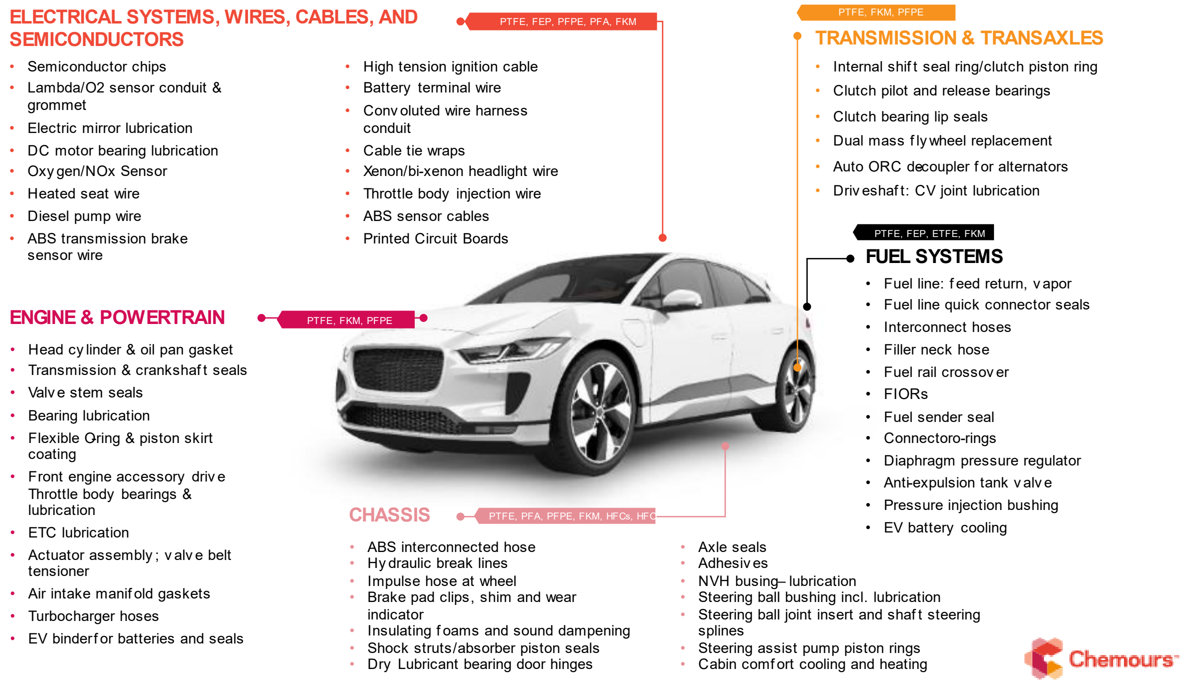
[46] S Ebnesajjad et al., Fluoropolymer applications in the chemical processing industries: the definitive user's guide and handbook (2nd Edition, 2017)

[47] European Sealing Association (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20 ref 4472.

[48] Schlumberger (2014). Permanent Downhole Cable (Product info sheet). https://www.slb.com/-/media/files/co/product-sheet/permanent-downhole-cable-ps.ashx

to ensure that different automotive components meet their respective quality and performance requirements to ultimately allow for safe and efficient operations.

<u>Graphic 6</u>: Automotive components containing fluoropolymers



As Graphic 6 demonstrates, fluoropolymers are used in a wide variety of individual automotive components. For many of these uses, individual car manufacturers have specific requirements which result in slightly different uses of fluoropolymers in automotive components. Therefore, in line with our approach to this submission described above, we focus on highlighting key functions and benefits of fluoropolymers in certain selected automotive components, which underline the criticality of fluoropolymersproperties and characteristics.

<u>Radar (Safety)</u>

Radar sensors have become an essential part of modern driving, enabling assisted driving comfort and safety, as well as automated driving. For this, they must be able to detect any objects around the vehicle quickly and reliably in a wide range of different traffic scenarios and weather conditions.[49] High frequency ranges of electromagnetic waves emitted and received by the sensor enable detailed detection of the speed and distance of the respective objects; for the benefit of applications such as adaptive cruise control, blind spot detection or collision avoidance. High frequency range of 67-77 GHz thereby require fluoropolymer based circuit boards.[50][51] The laminates used to manufacture these printed circuit boards consist of ceramic-filled PTFE composites, as only these can provide the required stability of the dielectric constant over different temperatures and frequencies. This ensures that the

[49] Bosch Mobility (2023). Front radar sensor. https://www.bosch-mobility.com/en/solutions/sensors/front-radar-sensor/

[50] IDTechEx_Fullreport_FluoropolymerMarketsinElectricsElectronics20212041 – chapter 6

[51] Rogers Corporation (2023). RO3003™ Laminates. https://rogerscorp.com/advanced-electronics-solutions/ro3000-series-laminates/ro3003-laminates

radar sensor can operate consistently and reliably, regardless of external conditions such as temperature fluctuations.

Seat heating (Comfort)

In the automotive industry, heated seats must be considered a standard comfort component that many consumers expect. Such seat heating requires special electronic heating technology. To ensure that these heating components function reliably and safely, PTFE fine powders and Tefzel™ ETFE resins are used to wire the components. Both PTFE and ETFE offer maximum durability, are resistant to chemicals, improve wear resistance through a low coefficient of friction and thus protect against heat, aggressive liquids and mechanical damage, ultimately ensuring high safety levels and preventing fires through short-circuit faults or in case of accidents. [52]

Internal combustion engine

- The **lambda sensor** measures the residual oxygen content in the exhaust gas of a car – an instrument for exhaust gas control of gasoline, diesel and gas engines. These small sensors are thus indispensable in modern vehicles and help to comply with increasingly stringent exhaust emission regulations. The insulating layer of the cables connected to the sensor is made of fluoropolymers (FEP/PTFE) to withstand the high temperatures and temperature fluctuations. Fluoropolymers also provide a low water vapor permeability to cope with high humidity values. In addition, fluoropolymers' non-flammability and high insulation strength are important to allow sensors to operate safely and reliably, all while maintaining a small diameter which is necessary due to size limitations for the sensors. Any alternatives to FEP and PTFE as insulating layers are not able to meet all of these requirements simultaneously while maintaining the same size.[53]

- In internal combustion engines, it is critical that toxic and flammable materials such as fuels and engine oils cannot escape from the engine fuel systems, especially to prevent the risk of fires and operator exposure, as well as to ensure engine efficiency. Therefore, fluoropolymers are used in **seals** such as **O-rings** and **fuel hoses**, for example, to prevent unwanted fuel leaks throughout the life of the product. Such seals must be resistant to a wide range of conditions, including high temperature and pressure, marine environments, and ozone, as well as contact with aggressive chemicals and materials such as grease, fuel, corrosion inhibitors and additives, all while maintaining a maximum swelling rate. High swelling rates would result in reduced tensile strength, causing cracks to form due to mechanical stress, leading to seal failure. To our knowledge, only FKM and fluorosilicone are able to withstand engine operation at temperatures above 175°C with a maximum swelling rate of 25% and in contact with engine oils, while maintaining their mechanical properties and characteristics. There are no alternative materials with an equivalent set of properties and characteristics to meet all these requirements simultaneously.[54]

- In combustion engines low friction is key to achieving higher efficiency and lower emissions. Also other automotive components typically contain moving parts that could quickly wear off through

[52] Ref B - Chemours (2017). *An Introduction to Chemours™ Fluoropolymers* (Fluoropolymers Properties and Benefits), p. 25. – [too large for attachment, can be provided upon request]

[53] Euromot (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 16 ref 4370, appendix page 16.

[54] Euromot (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 16 ref 4370, appendix page 20-21.

friction. As such, PTFE is used as **dry lubricant** in components such as **slideways, racks, spindles, lead screws, piston balls, yokes and rotators**. Given the harsh use conditions, e.g. changing temperatures and weather conditions, PTFE does not only help to ensure minimal friction but is specifically used since its properties make it very durable and reliable. This is particularly important as many parts are inaccessible after installation, making it impossible to change lubricants used. At the same time, alternatives such as greases would risk to contaminate the systems.[55]

- **Brake and transmission systems** require very high reliability. Here, PTFE **coatings** are used as they provide low friction properties and can be used at high temperatures. In addition, bearing manufacturers have identified fluoropolymers as a promising viable alternative in their efforts to move to lead-free alternatives for bearing overlay. Currently, lead is used as a thin layer to reduce friction between two moving parts, helping to prevent them from sticking together, while catching any waste that could potentially lead to engine failure.[56]

- **Control cable liners** are special coatings or inner sleeves used in control cables of vehicles, aircraft and other applications. These inner sheaths are often made of fluoropolymers such as PTFE, which is selected for its low coefficients of friction and durability.[57] The main function of control cable liners is to reduce friction between the inner metal wires of the control cable and the surrounding sheath. Control cables are used to control various moving parts in vehicles and aircraft, such as the accelerator or brake pedals in a car or the control surfaces in an aircraft. As the inner metal cables move through the sheathing, friction can occur, causing wear and energy loss. The use of Control Cable Liners with PTFE coatings significantly reduces this friction. The Control Cable Liners allow the metal cables to slide through the liner, which improves the functionality of the control cables while extending their service life. This is especially important in applications where precision, reliability and safety are critical, such as vehicles, aircraft and even spacecraft. Such cables therefore have to function in very demanding and highly variable conditions, such as temperature fluctuations (from cables close to engines to external equipment at high altitude and therefore very low temperatures), resistance to aggressive chemicals (fuels and other fluids in vehicles) without fault tolerance – challenging situations that only PTFE, with its excellent properties, can master.

- The international standard ISO 6722-1 defines the specifications for copper conductor single core **cables** in road vehicles.[58] For all applications in the higher temperature classes according to the standard, fluoropolymers are the material of choice, as only they can withstand high temperatures. Such temperatures can occur, for example, in the vicinity of engines or exhaust systems. Fluoropolymers are also resistant to chemicals, including oils, fuels and other fluids present in vehicles; ensuring the insulation of the cables. In addition, fluoropolymers provide excellent electrical insulation, reducing the risk of short circuits or other electrical faults. Fluoropolymers are

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[55] Euromot (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 16 ref 4370, appendix page 30.
[56] Euromot (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 16 ref 4370, appendix page 31.
[57] Ref D - Chemservice (2022, July 19). Technical Report. Chapter 3.4.3. Application 4.3: Use of PTFE in the production of control cable liners for the transport industry.
[58] ISO (2011). International Standard IO 6722-1. https://cdn.standards.iteh.ai/samples/50022/025962355eb24d95b13c98566c51f17e/ISO-6722-1-2011.pdf

also highly resistant to UV rays and ozone, which means they don't age or become brittle as quickly. Despite their resistance and other advantages, many fluoropolymers are flexible, making them ideal for applications where the cable must be bent or moved. Fluoropolymers thus provide the durability and reliability needed in vehicles by ensuring that cables will perform even under the harshest conditions. This is especially important as electrical faults or cable failures can cause serious safety issues in a vehicle.

- FKM fluoroelastomers are used as sealants in **turbocharger hoses**. Turbocharger hoses are part of the charge air system of a vehicle with a turbocharger. A turbocharger increases the power output of an engine by increasing the air supply to the cylinders. Turbocharger hoses transport compressed air (charge air) from the turbocharger to the engine's intake manifold. Such hoses must be able to withstand pressure changes, vibrations and high temperatures that occur in the charge air system. Due to the development of modern and fuel-efficient turbochargers with high-pressure direct injection, technical requirements for such sealing systems have increased even further. In addition, under no circumstances should leaks occur in vehicles at high temperatures, otherwise the safety of passengers and the surrounding population would be jeopardized. Only fluoropolymers can meet these high requirements. Other elastomer materials have much higher coefficients of friction, which are not suitable for materials that must constantly interact with other parts of the vehicle during operation.[59] Most importantly, they cannot withstand the temperature ranges in which car engines operate. For cases such as car engines, where the highest demands are placed on thermal resistance, FKM is therefore currently the only reliable option on the market.

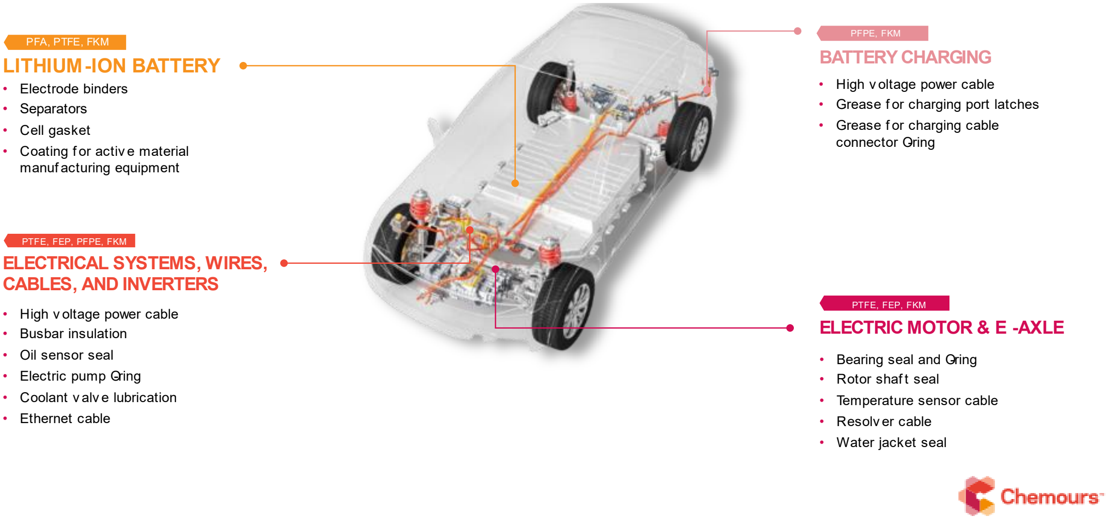
- **Fuel hoses** transport fuel from the tank to the engine. They must therefore be resistant to the corrosive nature of fuel with variable proportions of ethanol and aromatic compounds and also be able to withstand the pressure of the fuel pump; thus reliably **sealing** fuel tank bushings and nozzles. Moreover, these hoses' material properties must not change during service life or at different temperatures to ensure the safe and reliable operations. As such, FKM is used to makes these hoses resistant to contact with fuel without the addition of plasticizers.[60] In addition, the use of FKM for hoses prevents the formation of microcracks and ensures low fuel evaporation and thus lower emissions.

Electric Vehicles

- Fluoropolymers are used in key components for all high performance and **lithium-ion battery technologies** as they provide high chemical resistance and tolerance to a wide range of operating temperatures, both of which are critical for batteries. To be more precise, in batteries fluoropolymers are used in active material compounds, electrolytes, valves, seals, washers and membranes, and battery coatings.[61]

[59] Ref D - Chemservice (2022, July 19). Technical Report. Chapter 3.4.5. Application 4.5: Use of FKM for sealing applications in the automotive industry.
[60] Euromot (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc doc 16 ref 4370, appendix page 30.
[61] RECHARGE (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 13 ref 4276, appendix page 7.

<u>Graphic 6</u>: EV components containing fluoropolymers



Each battery electrode consists of a composite material that is formed when an active substance is applied to a current collector. This active substance is held together by a **binder**, which also ensures that the electrode adheres strongly to the current collector. Therefore, this binder is of great importance for battery manufacture and performance. Because of their resistance, thermal stability, flexibility and good adhesion, fluoropolymers (PTFE/PVDF) are used as binders in many battery technologies: they (1) help disperse the active substance and create a bond to the current collector without compromising conductivity, (2) protect the electrode from corrosion and the electrolyte from consumption, (3) allow a smooth coating on the current collector. PVDF and PTFE are the only known material that can withstand high voltage for various battery designs Other bonding materials oxidize at a high voltage on the positive electrode. For the negative electrode other materials are being used as described in the RECHARGE submission.[62]

- Another application of fluoropolymers in the battery is **sealing.** As highlighted by the RECHARGE submission, they play a crucial role in protecting against electrolyte leakage and external moisture ingress, thus preventing short circuits and serious safety issues.[63] Because safety and performance are paramount, fluoropolymers are widely used for seals in various types of batteries. Especially in high energy density batteries, such as those used in automotive applications, stringent sealing performance requirements are only met by fluoropolymer-based materials. Their combination of inherent chemical and thermal stability, along with high permeation resistance, makes them indispensable. Thus, especially in view of aggressive electrolytes in lithium batteries, fluoropolymer-based materials are crucial for resisting reactive compounds such as SOCl2 and ensure battery longevity of up to 20 years.

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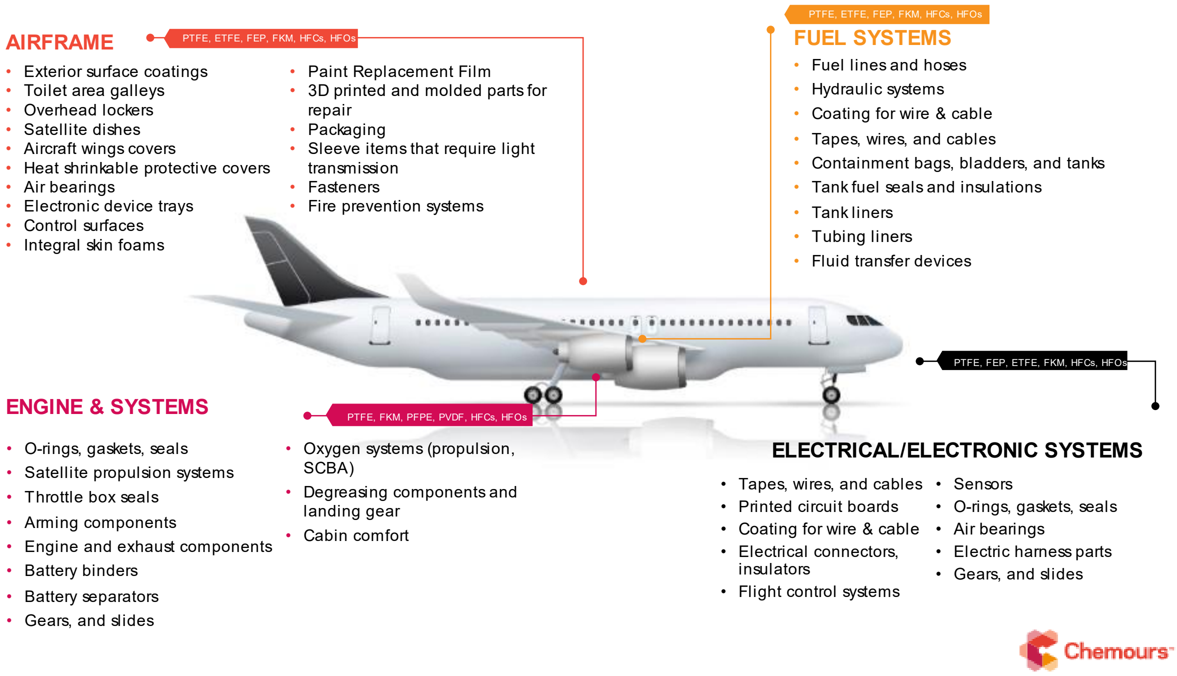
[62] RECHARGE (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 2 ref 3925, pages 8-10. And 2nd submission in August/early September

[63] RECHARGE (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 2, Ref 3925 page 14

2.1.5 Transportation: Aerospace

In the aerospace industry, equipment and materials must meet a whole range of specific and stringent performance requirements, such as resistance to pressure, weight, load, vibration, extreme temperatures, rapid temperature changes, and high durability. Given the unique set of properties and characteristics of fluoropolymers that help to meet these different performance requirements, fluoropolymers are used in numerous applications on an airplane, as Graphic 7 illustrates.

Graphic 7: Aerospace components containing fluoropolymers



- In many airplane components, fluoropolymers are used as **lubricants** and **hydraulic fluids** as they are highly durable and reliably, can withstand extreme temperatures changes, and reduce friction in various mechanical devices.[64] There is no alternative material that can provide similar properties to meet this range of very specific performance requirements.[65]
  - Fluoropolymers are often used as lubricants to ensure reliable operation of airplane devices such as **doors, flaps, and windows**.
  - In **flight control systems, flight surface actuators, aircraft landing gear and actuators** in defense systems, fluoropolymers are further used as hydraulic fluids, as they are also compatible with other materials used to make lubricated parts.
  - Fluoropolymers are also important in high-performance lubricating oils that can withstand pressure and heat and minimize wear in **engines and transmissions**.
  - They are also used to lubricate **bearings** and moving parts in specialized applications.

[64] ASD (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 17 ref 4419, appendix page 3-6.
[65] ASD (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 17 ref 4419, appendix page 7.

- Given the extreme operating conditions in the aerospace sector (hear and temperature fluctuations, corrosion, pressure, etc.), fluoropolymers, due to their unique set of properties, are used in a number of **sealing applications** such as **sealants, mastics and resins**, as well as in molded products such as fluorocarbon **O-rings** and **gaskets**. These different forms of sealants are used as high-performance sealants, particularly in airfoils: for **coating fasteners, filling voids, joining airfoils, filling gaps, and for wet-assembly fasteners**.[66] In these applications, fluoropolymer-based sealants perform a critical function in aircraft to seal aircraft components from moisture or liquids (e.g., fuel) as well as from air, gases, and air pressure differentials; to provide water, fuel, and air tightness; to minimize contamination of aircraft structures and systems and corrosion of aircraft in service; to improve aerodynamics; and as friction protection to prevent abrasion between surfaces due to the moving aircraft structure.[67] Without these high-performance, high-resistance sealing applications, the safety and reliability of many of the sector's products could not be guaranteed. Moreover, as the aerospace sector in particular is highly regulated, finding and introducing any alternatives offering the same levels of safety and performance guarantee will require considerable time that is not yet possible to adequately estimate. For reference, it took the aerospace industry 32 years to develop an alternative to hexavalent chromium.[68]

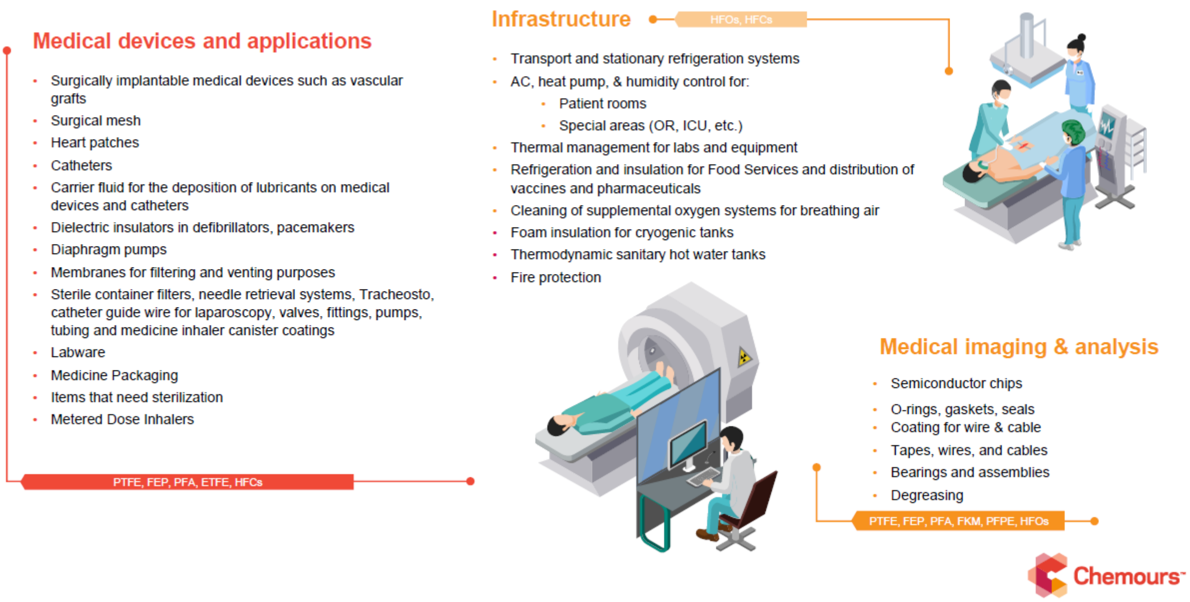
- In the aerospace industry, fluoropolymers, especially PTFE and FEP, are also used in **(high voltage) electrical cabling** due to their exceptional electrical properties at high voltage and high signal frequencies and resistance properties, as well as fire and flame retardancy and reduced smoke generation. Fluoropolymers offer property retention under a wide range of temperatures and exposure to specialty fuels that may be chemically aggressive. An example of such an application is the coaxial cable EN 4606-008 WD for high frequency radio communications in aerospace, which serves as a European standard product due to its thermal resistance and simultaneous flexibility.[69] Potential alternatives, such as engineering plastics (such as PVC and PE) combined with HFFR, PEEK, or ceramics are all inferior to fluoropolymers as they only provide a subset of properties and characteristics but fail to provide chemical resistance, temperature resistance, and flexibility at once, leading to significant performance disadvantages.[70] The fatal consequences that can result from inadequate use of materials for electric cabling in the aviation sector are illustrated by the crash of Swiss flight 111 in 1998. According to the Transportation Safety Board of Canada (TSB), an electrical arcing event in electric cables above the cockpit ceiling had most likely caused a fire, which ignited the flammable deck material on nearby thermal insulation covers used in the aircraft structure, thus allowing the fire to spread beyond the crew's control.[71] It was determined that the circuit breakers used in the aircraft were not capable of protecting against all types of arcing events in electrical wiring. Subsequently, standards for flammability for aircraft wiring and electrical systems were reviewed and updated to higher requirements.

[66] ASD (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 17 ref 4419, appendix page 18.
[67] ASD (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 17 ref 4419, appendix page 17.
[68] ESA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20 ref 4472, appendix page 11.
[69] Ref I - Nexans (2018). EN 4604-008 WD (Datasheet).
[70] Ref D - Chemservice (2022, July 19). Technical Report. Chapter 3.4.1. Application 4.1: Use of PTFE and FEP in the production of electrical cabling for use in aircrafts.
[71] Transportation Safety Board of Canada (2023). Swissair 111 Investigation Report – Executive Summary. https://www.tsb.gc.ca/eng/medias-media/fiches-facts/a98h0003/sum_a98h0003.html

2.1.6 Medical & pharmaceuticals

In the medical industry, fluoropolymers are used in a number of different applications in different medical segments, including medical devices, medical and pharmaceutical infrastructure, and medical imaging and analysis (please also see Graphic 8 below). In this context, fluoropolymers' low surface energy and barrier properties, lubriciousness, temperature and chemical resistance, mechanical strengths, flexibility and high product purity help to create a highly sterile environment and protect medical devices, equipment, and drugs against contaminants. As such, fluoropolymers are used, amongst others, for chemical reactors, in vials, membrane filters, gaskets, liners, O-rings, tubing and piping for a number of medical devices. To further illustrate the functions and benefits of fluoropolymers in the medical sector, in the following we highlight certain uses of fluoropolymers in specific medical applications in more detail.

Graphic 8: Medical components containing fluoropolymers



Medical devices

- Polytetrafluoroethylene (PTFE) is used as a seal for **chemical reactors**, in **vials, membrane filters, gaskets, liners, O-rings, tubing** and **piping** for a number of medical devices. Here, PTFE's resistance to varying temperatures, mechanical strength, and non-stick and non-leaching properties prevent crucial medicines and vaccines from contamination against other surfaces that equipment or drug products touch in the manufacturing and delivery process.[72]

- Fluoropolymers are used in medical tubing and piping systems, and as films applied to the various pieces that make up drug delivery systems. In this context:

[72] Animalhealth Europe (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 24 ref 5390.

- Fluoropolymers' high product purity is specifically critical in equipment used in **vaccine and medical production** because impurities or contact with other materials risk the possibility of contamination.[73]
- In **catheters**[74] and **IV cannulas**[75], PTFE acts as an inert, non-toxic, and biocompatible material that can attach to tissue and enable cell adhesion to effectively mitigate patient ailments. For example, in PTFE etched liners used for catheters, PTFE's low coefficient of friction enables the continuation of flow and its ability to pass residue as the inner diameter engages directly with the body.[76]
- Fluoropolymers are also used to allow medical tubing to withstand high temperatures and prevent adhesion in **flexible and protective processing aids for surgical devices**, which are for instance frequently used for **catheter shafts** and **surgical instrument jacketing**.[77]

- PTFE is also used in various life-saving medical devices such as cardiovascular grafts, hernia mesh, stents, ligaments, and etched liners. Here, PTFE's unique properties allow for sterilizability that helps to prevent any form of contamination to allow for the effective and safe use of the devices.[78]

Medical packaging

- In **metered dose inhalers**, fluoropolymers are used in the inhaler coating to ensure the ingredients of the inhaler do not adhere to other materials of the container.[79]

- Fluoropolymers are also used to laminate **rubber stoppers** to plug drug material in vials and syringes. Fluoropolymers unique properties of lubricity, low coefficient of friction, resistance to varying temperatures, and their sterilization effect also help to protect drug content inside **vials and syringes** from contamination from external sources or from container material.[80]

2.1.7 Industrial machinery

Even though rarely explored in the space of industrial machinery, fluoropolymers take on a critical role in the industrial machinery sector. Industrial machinery and plants are intended to last decades, meaning that they must be protected against external factors such as extreme temperatures, weather, and corrosion. The anti-corrosive properties of fluoropolymers coupled with their ability to withstand a wide range of temperatures makes them the optimal solution to ensure longevity of the machinery.[81]

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[73] Ref D - Chemservice (2022, July 19). Technical Report.
[74] B. Braun Medical Inc. (2023), https://www.bbraunusa.com/en.html
[75] Raumedic (2023). Peripheral indwelling venous cannulas for parenteral infusion, https://www.raumedic.com/competences/manufacturing/extrusion/iv-cannulas
[76] Ref D - Chemservice (2022, July 19). Technical Report.
[77] Optinova, FEP Heat Shrink, https://optinova.com/app/uploads/2022/08/optinova-fep-heat-shrink-copy.pdf
[78] Ref D - Chemservice (2022, July 19). Technical Report.
[79] H&T Presspart (2022). Drug Delivery Solutions, https://presspart.com/drug-delivery-solutions/
[80] West Pharmaceuticals (2023), Vial Containment Solutions, https://www.westpharma.com/products/vial-containment-solutions
[81] VDMA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc20. Reference 4471. Appendix page 3.

Based on their unique set of properties, fluoropolymers are currently the only solution on the market to ensure industrial machinery to function seamlessly.

In its current form, the PFAS restriction proposal, with entry into force, would almost entirely ban the use of fluoropolymers in industrial machinery. [82] As the industrial machinery space works to develop next generation technologies, however, it has yet to discover drop-in alternatives to fluoropolymers, as no alternative is able to adequately replicate the combination of properties of fluoropolymers. [83]

Seals and gaskets
PTFE seals and gaskets are used across a broad range of industries that utilize harsh chemicals. Adequate sealing of machinery and equipment poses an upmost importance, resulting in a need for materials that are reliable and can withstand extreme temperatures, mechanical strength, and interaction with other chemicals.[84] Replacing PTFE would result in downgraded performance of the industrial machinery, resulting in a reduction in competitiveness for the EU on a global scale.[85] Over the years PTFE based seals have been replacing asbestos has better alternative due to asbestos carcinogenic properties. As this example shows, alternatives to fluoropolymers are not necessarily safer and better, even if they can meet all property requirements.

2.2 Uses of fluoropolymers across sectors and industries

Section 2.1, describes just a few examples of critical uses of fluoropolymers in industrial and professional applications; there are many more as has become visible by the many submissions during the public consultation of the PFAS restriction dossier proposal
When looking at the numerous uses of fluoropolymers in different applications, it is important to consider the links between industries as well as cross-industry dimensions of these uses. Furthermore, it is important to keep in mind that the application sectors outlined above are only intended to serve *as examples*, while the vast range of applications for fluoropolymers extends into many more other sectors and applications outside of the examples presented – and the complexity of the interconnectivity between uses also goes beyond what it is described here.

First, there are many common fluoropolymer applications in industrial and professional uses across different sectors. For instance, fluoropolymers are used for valves, O-rings, seals, fittings, pumps, pipes, filters and vessels in numerous contexts in all sectors described above. As mentioned before, Chemours alone provides fluoropolymers to over 1,400 different combinations of different sectors and their applications in the EMEA region. Where these applications are used, they generally provide important safety and performance benefits, as downstream users have an inherent economic incentive to use comparatively cheaper alternative materials wherever possible. However, in practice, alternatives are not used. For instance, because of their unique combination of properties, fluoropolymer based seals are distributed to downstream users in a variety of industries, including mineral extraction, chemical and petrochemical, power generation (incl. nuclear) and utilities,

[82] VDMA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20. Reference 4471. Appendix page 1.
[83] VDMA (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 20. Reference 4471. Appendix page 3.
[84] Ref D - Chemservice (2022, July 19). Technical Report, page 11.
[85] Ref D - Chemservice (2022, July 19). Technical Report, page 13.

automotive, aerospace, marine, potable and wastewater, , pharmaceuticals, food and beverage, HVACR (Heating Ventilation, Air-Conditioning and Refrigeration)

A number of applications that require the use of fluoropolymers are used in products which in turn are part of another product, and which are indispensable in this second product. In other words, fluoropolymers are often used at the beginning of a value chain, but the downstream value chain relies on this initial use of fluoropolymers – at least to a certain degree. We have also seen that articles that comprise fluoropolymers (I.e., for sealing, lubricants and cabling) can, once they are combined into other products, have value chains that span different sectors. This interconnectivity between sectors, applications and articles makes it very complicated and likely not practical (manageable) to implement or enforce derogations for continued uses of fluoropolymers by specific sectors or application, as proposed by the Dossier Submitters. The examples below demonstrate the connectivity and criticality of fluoropolymer-containing across sectors:

- As demonstrated above, the use of fluoropolymers in the manufacture of semiconductors is critical; as fluoropolymer tubing, injection molded parts, seals, and lubricants are used. The chemical industry, meanwhile, must be able to produce the many materials and chemicals used in the semiconductor industry. Semiconductors, in turn, are indispensable components in the automotive industry, aerospace (almost all electronic equipment), the energy sector, and high-end medical devices, to name a few. The energy sector, oil and gas production, solar energy production or renewable energy storage using hydrogen, in turn forms the basis for the enormous energy requirements of all industrial sectors.

- Fluoropolymers are important for the production of green hydrogen, both in fuel cells as well as in electrolyzers. The cost-effective production of renewable hydrogen, in turn, is vital for viable industrial production in the EU, for example the automotive sector. The materials used for construction, meanwhile, come from the chemical industry, which is dependent on access to reliable industrial machinery and equipment.

- Fluoropolymers are a key component in high-performance batteries in various applications (please see above for a detailed explanation). The availability of high-performance batteries is necessary in electric vehicles as well as a whole range of other electronic and industrial applications.

- As we have shown above, fluoropolymers play a key role in the medical and pharmaceutical sectors. The required pharmaceuticals and materials are produced by the chemical industry, which in turn also relies on fluoropolymers. The healthcare sector is also heavily dependent on electronic components, while transportation is key to the sector's whole supply chain. The products of the automotive industry, on the other hand, also rely on fluoropolymers. This is to show that mutual dependence on the products of each other industrial sectors is endless.

As such, it is misleading to assess the functions and benefits of fluoropolymers within the scope of individual applications. **<u>Instead, it is important to also consider the use of specific fluoropolymer-containing applications within and across industries and value chains.</u> For this reason, the only practical way to regulate the use of fluoropolymers in the restriction dossier is to exempt them or, if this is not possible, to provide a very broad derogation for fluoropolymers in industrial and**

professional use. Such an exemption would thereby also be justified by controlling any possible risks throughout the lifecycle, as we will address in the next chapters 3 and 4.

2.3 Considerations around use-specific derogations

As demonstrated in this chapter, the unique set of properties of fluoropolymers and their characteristics make them vital for numerous applications in various industries. This holds true for uses of fluoropolymers within industries, as well as uses of fluoropolymer-containing applications across industries. In addition, it is necessary to take into account the relevance of a certain fluoropolymer-containing application in the context of downstream uses or connected value chains and their articles. Thus, if fluoropolymers were only allowed in certain industries and not in others, governance and implementation of the restriction would become excessively complicated.

In this context, it is important to note that there are thousands of individual applications of fluoropolymers. As mentioned before, Chemours alone provides fluoropolymer to over 1,400 applications in the various sectors.

Considering this very high amount of individual uses of fluoropolymers as well as their relevance within and across industries, Chemours urges ECHA to reconsider the proposed approach of use-specific derogations for regulating the uses of fluoropolymers. We believe that, in the context of fluoropolymers, the approach of use-specific derogations is not appropriate to provide for an effective regulatory framework based on both risk and socio-economic assessments:

- This approach would result in a need for potentially thousands of individual use-specific derogations, given the high number of individual industrial and professional uses for which currently no suitable alternative materials exist. Therefore, the consideration of these derogations cannot be properly evaluated by the ECHA Scientific Committees in the tight time-period given to them by the EU legislators. Equally, the implementation and enforcement of thousands (or even hundreds) of derogations will also not be practical.

- This approach would risk phasing out uses because of not considering (A) all of the applications that require these uses (e.g. fluoropolymer-based wiring) or (B) the importance of individual fluoropolymer-based applications for subsequent value chains. In such a case, this could lead to large disruptions in the European market.

- In addition, there is a genuine possibility, in the absence of comprehensive analysis of alternatives, that restricting the manufacture, placing on the market or use of fluoropolymers could lead to the use of alternatives that do not perform as well as fluoropolymers, are less durable, as well as proving to be hazardous and thus unable to meet stringent industrial safety standards (resulting in regrettable substitution). Such hazardous materials may pose their own health risks. This submission emphasizes the importance of a comprehensive safety evaluation of substitutes before they are widely introduced to ensure that they can indeed serve as a suitable alternative.

- Evaluating and implementing a large number of specific use or sector-specific derogations would require significant time and administrative effort on the side of both industry as well as enforcement authorities, which in turn would be likely to create high regulatory uncertainty within industries, which could result in investment decisions being delayed and hindering innovation within the EEA.

Such uncertainties – due to limited data available or knowledge about the specific links between uses and industries – are likely to result in significant socio-economic costs. For instance, if fluoropolymers were to be absent from electrical wiring, it would seriously affect the performance of a wide range of industrial applications, including semiconductors, batteries, medical and electronic devices, which could lead to higher maintenance costs, lower reliability, and ultimately higher risks to human health (e.g., fires) and the environment.

Furthermore, it is important to take into account that the individual applications and sectors that rely on fluoropolymers are in many ways crucial for the sustainable transformation envisaged in the European Green Deal, the European Chips Act, RePowerEU, and other ambitious European policy programs. As emphasized above, where alternatives for industrial and professional uses exist, companies either already have an inherent economic incentive to use those alternatives or the alternatives come with significant performance sacrifices. Therefore, if the use of fluoropolymers is to be banned or would become significantly more costly and difficult, the EU risks losing currently domestic production to move to outside the EU, increasing geopolitical dependencies of the EEA as EU industry would be forced to import those applications derogated from the scope of the restriction from outside of the EEA. Moreover, many of the fluoropolymer-containing applications outlined in this chapter, which are key for the transformation of the EU economy and society, would not be available anymore – leading to significant economic disadvantages for European companies and the EEA as a whole.

3. Emission Control and Abatement

As outlined above, one of the aspects Chemours wishes to emphasize with this submission is that concerns associated with industrial or professional uses of fluoropolymers can be minimized and controlled throughout their lifecycle by means other than a ban. To underline this argument, we intend to demonstrate that fluorinated emissions generated during the conversion process of fluoropolymers to articles, namely emissions through air or water, can be prevented or minimized using appropriate available sufficiently effective abatement technologies for each specific situation.

For emissions generated during the use-phase (service life) of fluoropolymer-containing applications, the dossier submitters in their Annex XV report raise that the main concern for dispersive use applications, is consumer related. Industrial and professional applications are rarely dispersive, as such don't pose a risk for emissions of fluoropolymers. We also refer to data on the stability and durability of fluoropolymers during their use, which demonstrates very low levels of or other degradation. For more in depth scientific justification, we refer to response to comments # 6167 by W.L. Gore and Associated in RCOM Volume 31[86].

[86] WL Gore Submission to consultantion for REACH PFAS restriction document RCOM31, reference 6167

3.1 Emissions control throughout the conversion of fluoropolymers to articles

Fluoropolymers initially often have the form of powders, granules or aqueous dispersions before they are converted to final, application ready articles (for Chemours, product groups include Viton™, Krytox™, Teflon™, and Nafion™). This conversion process often includes forms of extrusion or injection molding and could generate air and water emissions containing fluorinated residues. These fluorinated emissions, however, can be managed by applying highly effective abatement technologies.

The emissions created during the conversion process of fluoropolymers substances to articles are very different from fluoropolymer manufacturing; meaning that standard emission control technologies, like carbon beds, ion exchange resin, thermal converters, can be used to capture them.[87] The detailed requirements and emission control configurations are defined by each converter process, setup and local authority requirements.

For example, at the Chemours Discovery Hub, our recently opened state of the art research and technical service facility in the US, where we simulate our customer's processes, we successfully use standard carbon beds to absorb any residue from the used water streams.

Plastics Europe's Safe Handling Guide of Fluoropolymers, recommends methods for safety to the employees, like, employees have to wear adequate personal protective equipment and use of appropriate ventilation. These measures help to ensure occupational safety to the highest degree possible.[88] . The Management Committee of the FluoroPolymer Product Group under Plastics Europe, who is responsible for Safe Handing Guide, agreed to update this guide with also recommendations for emission controls. This document is envisaged to be available in 2024.

3.2 Fluorinated emissions throughout the use of fluoropolymer-containing applications

As demonstrated above, fluoropolymers are used in many different applications across numerous industrial sectors. In this context, however, it is important to understand that a key reason for using fluoropolymers is their durability and stability (please also see chapter *2. Critical uses of fluoropolymers*). In the many applications in which fluoropolymers are used, they typically reliably function over the applications' entire life cycle, not changing their structure, properties, or performance.[89] The high stability of fluoropolymers and its consistent structure and properties over time imply that the wear and degradation of fluoropolymers is very limited, which in turn implies that fluorinated emissions resulting from the use of fluoropolymer-containing applications are very limited as well. In the Annex XV the dossier submitters share that the main emission of fluoropolymers from the use phase is linked to dispersive applications, which are very rare for industrial and professional use, as examples in section 2 have demonstrated.

An example of the stability of fluoropolymers is the stability of PFA used for heat exchanger tubing in the flue gas section of coal fired power plants. The operating condition is 260 °C, and the lifetime of the heat exchanger can be 90,000 hours. The lifetime is determined by the amount of flue gas that

[87] Interstate Technology Regulatory Council. (2023). PFAS – Per- and Polyfluoroalkyl Substances – 12 Treatment Technologies. https://pfas-1.itrcweb.org/12-treatment-technologies/

[88] Plastics Europe. (2021). Guide for the Safe Handling of Fluoropolymer Resins. https://fluoropolymers.plasticseurope.org/application/files/5116/3671/1909/Fluoropolymers_Safe_Hand_EN_2021.pdf

[89] Ref B –Chemours Fluoropolymers Introduction– [too large for attachment, can be provided upon request]

gets collected that overtime reduces the capacity of the heat exchanger. This example is described in more detail in the recycling section 4.1.

The PFA can be recovered when the heat exchanger is removed, an indication for stability of the material is the use of ThermoGraphic Analysis (TGA). This is a method that shows the thermal stability of a substance as function of temperature[90]. When a substance is very stable there is very little weight loss at targeted temperatures, or to observe a certain weight loss temperature are high. The Table 2 below shows the typical value for virgin PFA and also the PFA after 90,000 hours at 260C. This is data generated by Chemours based on samples received from our partner. What is clear is that there is no difference in temperature for a certain level of weight loss, meaning the PFA is as stable after the extensive and aggressive use, as it was virgin resin, demonstration no degration of the PFA after extensive use

Table 2: PFA thermal stability comparison virgin versus end of life

	Temperature 1% weight loss in air	Temperature 50% weight loss in air
Typical value PFA virgin resin	477°C	542°C
Typical value PFA recovered from flue gas heat exchanger	475°C	544°C

3.3 Conclusion: Emissions from Fluoropolymers conversion and use associated risks can be controlled and minimized

Based on the elaborations above, Chemours argues that fluorinated emissions generated throughout the conversion of Fluoropolymers can be controlled and minimized using standard abatement technologies. During the use phase, Fluoropolymers are stable, and as such, there is no risk and thus no need for their restriction

[90] https://en.wikipedia.org/wiki/Thermogravimetric_analysis

4. Waste and end-of-life management

In addition to stringent emission controls during manufacture and use, appropriate management of fluoropolymers at the end of their life, including as waste, will ensure that they are used safely. The Annex XV dossier points to the end-of-life phase as one of the main concerns of fluoropolymers. Since the publication of the 2021 ETC/WMGE report [91], several studies regarding industrial and professional waste handling have been conducted or are ongoing which may alleviate some of the concerns expressed in the report and referenced in the Annex XV dossier. In this chapter we would like to argue that an unacceptable risk has not been demonstrated, and that any remaining concerns can be addressed using existing EU vertical legislation outside of REACH, as such a restriction is not the appropriate way to manage the risk.

In this context, we highlight existing comprehensive EU Waste regulation, which we believe provides an ample regulatory framework for managing fluoropolymer-containing waste. In addition, we highlight elements of existing waste legislation that could, if necessary, be updated to further strengthen provisions around the end of life of fluoropolymers .[92]

Additionally, there are numerous recycling, incineration, and landfill processes and methods in place, well suited to address end-of-life concerns. Both existing waste directives as well as recycling, incineration, and landfill standards and practices that demonstrate that effective mitigation measures are already in place or more specific can be added to address risks associated with the end of life of applications containing fluoropolymers.[93]

In general, we believe that the socioeconomic benefits of using fluoropolymers (as demonstrated in the previous chapter section 2) outweigh the concerns of the Dossier Submitters for an eventual phase out of them purely based on hypothetical emissions during the waste phase and end of life management of fluoropolymers. The entering of fluoropolymers in the waste phase is one of the main concerns of the Dossier Submitters since the durability of them implies that fluoropolymers wear and erosion is very limited in the use phase.. Therefore, the concerns on fluoropolymers associated with their fate in the waste phase would be more appropriately dealt within the relevant Regulatory framework already in place in the WFD, and possibly enhanced with slight modifications/amendments to specifically address fluoropolymers incorporated in articles.

In 2020, around 40 kt of fluoropolymer materials were sold to EU fluoropolymer product manufacturers. approximately 23.5 kilotons of fluoropolymer waste were collected in Europe, with 20.4 kilotons being either incinerated or thermally destroyed. Another 0.8 kilotons of fluoropolymers were collected and exported for proper recycling to other countries, as further demonstrated in the graphic below. [94] Notably, Chemours is listed in the graphic below as maintaining end of life management for fluoropolymers following consumer use.

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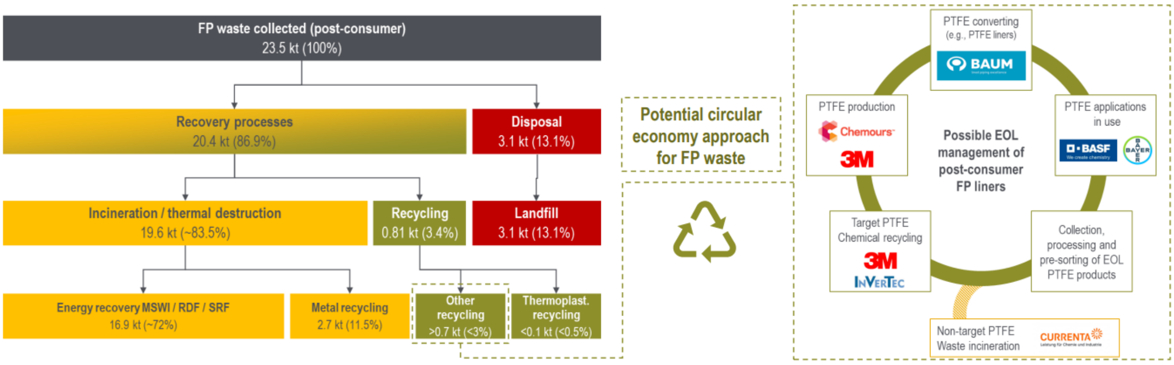
[91] ETC/WMGE Report 9/2021: Fluorinated polymers in a low carbon, circular and toxic-free economy

[92] EU Commission. (2023). Waste and Recycling. https://environment.ec.europa.eu/topics/waste-and-recycling_en

[93] Conversio (2020) Fluoropolymer waste in Europe 2020 (https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf)

[94] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdfF

Graphic 8: Recycling of fluoropolymers and end-of-life management[95]



4.1 The recycling of fluoropolymers

With Fluoropolymers being very stable in aggressive environment, they are very suitable for recycling. Several companies in the industry are looking for ways to recycle fluoropolymers where large quantities can be collected at end of life. Where small quantities are being used, especially as parts in larger non-fluoropolymer assemblies, incineration is a more appropriate way to manage the end of life, which is covered in section 4.2. The combination of recycling and incineration is a very effective way to manage the risk, and a restriction is not needed.

In this section we share a few examples of recycling activities.
Most melt-processable fluoropolymers are recycled through conventional melting processes, also often used in mechanical recycling.[96] [97]

Fluoroplastics like FEP and PFA, that are melt processable, suit themselves for recycling when they can be effectively collected. A good example is the use of PFA from heat exchanger tubing[98].
After a long time in operation, the heat exchanger collects a lot of flue gas which reduces its capacity, and requires it to be changed. The PFA tubes can be extracted from the heat exchanger and recycled to PFA resin that can be reused again.

Figure 10 different recycling stages of the flue gas heat exchanger from coal fired powerplants

[95] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022.
https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdfF
[96] https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/fluorinated-polymers-in-a-low-carbon-circular-and-toxic-free-economy
and toxic-free economy Technical Report. September 2021.
[97] Yi Ji et al
Decomposition of PVDF to delaminate cathode materials from end-of-life lithium-ion battery cathodes. Journal of Cleaner Production. 367 (2022) 133112 https://doi.org/10.1016/j.jclepro.2022.133112
[98] Ref J – Powerplant PFA to Industrial pellets (FluoroPolymer Resource presentation)

In Figure 10 from left to right it shows the following views

1) New PFA heat exchanger for a coal-fired power plant
2) Section of heat exchanger after 90,000 hours of use at 260°C after capturing flue gase
3) Recovered PFA tubes after grinding
4) The ground PFA after a purification step

The properties of the recovered PFA are very similar to virgin material, as indicated in section 3.2

Table 3: comparison TGA results virgin and recovered PFA

	Temperature 1% weight loss in air	Temperature 50% weight loss in air
Typical value PFA virgin resin	477°C	542°C
Typical value PFA recovered from flue gas heat exchanger	475°C	544°C

ThermoGraphic Analysis (TGA) is a method that shows the thermal stability of a substance as function of temperature[99].When a substance is very stable , there is very little weight loss at targeted temperatures, or to observe a certain weight loss temperatures are high. For virgin and recovered PFA we see the same temperatures, showing stability has not changed over the life time of the PFA.

Chemours has collaborated with our partner FluoroPolymer Resources (https://frlusa.com/) to demonstrate that the same recycling process can be used for PFA parts from semi-conductor fabrication plants.

The company FluoroPolymer Resources[100], also recycled FEP cabling and other fluoroplastics (https://frlusa.com/)

While challenging, efforts are being done to make the life cycle of fluoropolymers circular. Several respondents to this consultation have also provided information on this (see the, for instance, the Responses to Comments # 4463, 4487, and 6056).

Another application, where recycling is currently actively investigated, is in the Hydrogen Economy and Water Electrolysis application. Recycling is already happening to capture the metals, but now also

[99] https://en.wikipedia.org/wiki/Thermogravimetric_analysis

[100] Website: https://frlusa.com/

studies are active in industry consortia for the fluoropolymer. For example, Chemours is actively working on this and has shared these activities externally[101] as well as by a Case study paper[102] Good progress is being made , demonstrating successful lab scale results and currently scaling up the technology.

In the case of the recycling of highly heat-resistant fluoropolymers that cannot be converted back to their original form, such as PTFE, production scraps are ground into fine powder and compressed under pressure.[103] The resulting recycled PTFE possesses a different structure compared to the initially produced PTFE. Recycled PTFE can be applied to uses such as rods, tubing, tape, and others.[104] . Another process that was used in the past was irradiation of PTFE, but that process generated C9-C14 residues, which are now subject to the restriction for these substances. The complexity to remove these residues has resulted in several companies not using this process anymore.

Another process to recycle fluoropolymers is called pyrolysis. Pyrolysis is a high temperature conversion process applied to organic, carbon-based products that result in break down and separation into smaller products through a heating process that takes place in the absence of oxygen.[105] In this process, fluoropolymers are broken down into monomers of TFE and HFP which, according to various studies, have a recyclability rate of 90-95%.[106] This process is typically integrated into an existing plant that produced fluoromonomers , leverage its emission control facilities

Once the fluoropolymers are incorporated into larger assemblies, cost-effective recycling becomes more cumbersome, however, this issue is not unique to fluoropolymers and will likely be the case for any non-PFAS alternative.

4.2 Incineration of fluoropolymers

In general, incineration is a highly effective method of waste disposal and thermal utilization in which the organic substances contained in the waste are burnt at high temperatures and converted into ash, flue gas and heat (energy). In the past years, two large scale studies conducted by the Karlsruhe Institute of Technology (KIT) have demonstrated that complete degradation of fluoropolymers through incineration is possible without the formation of short or long PFAS by-products. A 2019 study tested PTFE[107] and is well described in the submission by WL Gore[108]. The report of the most recent study can

[101] Chemours presentation - https://www.energy.gov/sites/default/files/2022-07/h2-mach-16-park.pdf
[102] Ref N - Chemours Nafion[tm]_Circularity_CaseStudy_FINAL
[103] https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/fluorinated-polymers-in-a-low-carbon-circular-and-toxic-free-economy
[104] Lakshmanan, A., & Chakraborty, S. K. (2015, April 1). Recycling of polytetrafluoroethylene (PTFE) scrap materials. IntechOpen. https://www.intechopen.com/chapters/47771
[105] https://www.biogreen-energy.com/what-is-pyrolysis
[106]https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/fluorinated-polymers-in-a-low-carbon-circular-and-toxic-free-economyand toxic-free economy Technical Report. September 2021.
[107] Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas. Alexandrov et al Chemosphere 226 (2019) p 898-906 https://doi.org/10.1016/j.chemosphere.2019.03.191
[108] Submission by WL Gore to REACH PFAS Restriction consultation part 31 reference 6167 page 18-27

be found in in the submission by GFL[109]. Moreover, a recent study by the German consultancy Conversio had shown that about 85% of all fluoropolymers are incinerated at the end of life. In combination, these studies underline that it is possible to control and minimize risks of fluoropolymers at the end-of-life through effective incineration.

The KIT study was carried out at pilot scale under operational conditions similar to those in European waste incinerators where fluoropolymer-containing products are normally burnt. The 2019 test mentioned was using PTFE as the fluoropolymer feedstock, the 2022/2023 test used post-use samples of the main applications of the four most commonly used fluoropolymers (PTFE, PVDF, PFA and FKM), which account for more than 80% of commercial production were tested. The samples were supplied as a mixture in relative proportions corresponding to the mass proportions sold on the European market. The samples were thus representative of a wide range of different post-use applications.

Both tests showed full destruction of the Fluoropolymers. The results of the latest KIT study indicate that no statistically significant uncontrolled emissions of PFAS substances were measured at levels that could pose a risk. The vast majority of samples (>98%) taken from the flue gas, liquids and residues after each run were at or below the reporting limits. No significant emissions of long-chain PFAS were measured in the samples. Similarly, no emissions of TFA or volatile fluorocarbons such as CF_4 or C_2F_6 were detected. The inorganic fluorides detected were hydrogen fluoride. The study therefore provides strong evidence that incineration of a mixture of fluoropolymers under municipal waste combustion conditions results in complete mineralization of the C-F bonds; as the fluoropolymers are converted to inorganic fluorides and carbon dioxide.

As already noted in the RAC opinion on PFAS in firefighting foams[110] hazardous wastes containing more than 1 % PFAS fall under the Industrial Emissions Directive 2010/75/EU and must be incinerated at elevated temperature. An example of a commercial incineration facility specialized in incineration of Fluoropolymers is based the company Indaver in Antwerp Belgium[111],**) meeting all regulatory requirements for state-of-the-art emissions controls[112] according to Best Available Techniques[113] as established under the Industrial Emissions Directive 2010/75/EU.** RAC expects that availability of these state-of-the-art facilities will increase due to higher market demand, and notes that additional disposal techniques may be developed in the future.

From this section it can be concluded that effective incineration of fluoropolymers is possible and commercially available, leading to complete mineralization and hence degradation out of the scope of the restriction. Municipal and industrial incineration according to current BAT guidelines does not pose any risk, hence a restriction is not needed to manage incineration as end-of-life step.

[109] Submission by GFL to REACH PFAS Restriction consultation part 22 Reference 4587

[110] RAC opinion on proposed restriction of PFAS in firefighting foams, available on ECHA website at https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e1856e8ce6

[111] https://indaver.com/locations/belgium/antwerp; https://indaver.com/expertise/safe-sink/rotary-kilns-belgium/sustainable-destruction-of-pfas-waste

[112] https://www.rijksoverheid.nl/documenten/kamerstukken/2023/06/23/besluit-ilt-op-vergunnen-internationaal-afvaltransport-pfas-verdacht-afval-naar-indaver-antwerpen

[113] https://publications.jrc.ec.europa.eu/repository/handle/JRC118637

4.3 Landfilling fluoropolymers

Landfilling involves the disposal of waste materials by burying them underground. According to a study by the German consultancy Conversio, about 13% of all fluoropolymers end up in landfills at the end of their life.[114] In the EU waste hierarchy as defined in the Waste Framework Directive, landfill is considered as the least preferrable option, and the Landfill Directive 1999/31/EC sets targets to reduce the amount of waste going to landfill. As a result, the amount of fluoropolymers going to landfill is expected to decline progressively over time.

A leaching test (Toxicity Characteristic Leaching Potential or TCLP) was performed by ALS Laboratories in Kelso, Washington (USA). This test has been used in the past by EPA to determine the mobility of organic and inorganic analytes in liquid, solid, and multiphase wastes. In this TCLP test, a leachate is generated in a laboratory environment that simulates conditions at a landfill to evaluate potential environmental impacts of uncontrolled landfilling. The TCLP test was passed, implying that leachates into the environment by fluoropolymers from landfills are unlikely.[115]

As has been described in the use section 2, fluoropolymers are used because of the thermal and chemical stability. Since they are stable at these extreme conditions there is no basis to assume they degrade in landfill. An ongoing study by Plastics Europe Fluoropolymer Product Group is designed to generate moredata to support this conclusion; unfortunately the results will not be available before the end of this consultation.

4.4 Relevant waste management legislation and guidelines already in place

As we mentioned in the introduction of this section 4, the concerns on fluoropolymers for industrial and professional use, associated with their fate in the waste phase can be dealt within the relevant Regulatory framework already in place. The Waste Framework Directive (WFD) can possibly be enhanced with slight modifications/amendments. Below we list several of the existing Directives and Regulations that can be built on.

Vehicles

The Directive 2000/53/EC comprehensively addresses any risks associated with the end of life management of vehicles.[116] The scope of the directive (Art. 3) includes vehicles as well as individual components and materials used in their production. The directive covers all steps at the end of the life cycle to allow control of risks throughout each stage of waste processing, be it collection (Art. 5), storage, or treatment (Art. 6). It explicitly stipulates separate disposal of components containing hazardous substances to prevent contamination (Art. 6, point 3b). It also necessitates a permit for handling vehicle waste, and those should only be issued to those waste treatment facilities who can

[114] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022.
https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf
[115] Summary of the PTFE Studies Performed with Independent Laboratories to Investigate Persistence, Degradation, Transformation to or Release of Substances of Concern
[116] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02000L0053-20200306

guarantee professional handling of hazardous waste. Relevant storage sites must also have an impermeable surface that prevents any leakages. Finally, the directive states that any reuse or recycling of vehicle parts must not give rise to any negative environmental risks (Art. 5, point 5). An update could for example include that the remaining waste from car demolition and recycling, which likely contains the use fluoropolymers (typically the shredder light fraction) , since it is only present in a small quantities across many parts, would be incinerated instead of landfilled.

Batteries

Regulation (EU) 2023/1542 on batteries and waste batteries[117] entered into force on 17 August 2023, replacing Directive 2006/66/EC. In Article 6, the legislation explicitly provides for the Commission assisted by ECHA to report on substances of concern present in batteries or used in their manufacture by 2027. In this report, appropriate follow-up measures including restrictions can be proposed, including specific conditions during repurposing of treatment of waste batteries. This mechanism is hence perfectly suited to first assess if any risks from the presence of fluoropolymers in batteries arise at end-of-life, and, if so, how these risks can be mitigated.

Electronics

The Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU[118] addresses potential risks associated with the end-of-life of electrical and electronic equipment. Risks are taken into account at all stages, starting with recyclable design (Art. 4) and extending to requirements for collection, transport, treatment and disposal. The danger of hazardous substances is explicitly addressed, already to be taken into account during collection and transport (Art. 6, point 2). Waste must be properly treated (Art. 8), using best available techniques (Art. 8, point 3), to guarantee compliance with minimum standards of environmental protection (Art. 8, point 5). Disposal without treatment is prohibited (Art. 6). For the executing treatment facilities, the issuance of the operating permit is linked to the capability of fulfilling the aforementioned requirements (Art. 9). In addition, producers must provide financial resources for collection, treatment, and recovery – any disposal is only to take place if environmentally sound (Art. 12). The directive also provides an information obligation for producers to make consumers aware of potential hazardous effects on the environment in case of unintended disposal (Art. 14, point 1d) and to enable treatment facilities to locate dangerous substances contained in electronics. Finally, the directive stipulates inspections for compliance with the rules (Art. 23), as well as penalties (Art. 22) for violations. The directive thus provides a framework to ensure that any risks at the end-of-life in electronic products can be controlled and minimized possibly by minimal additions/modifications or guidance documents.

Medical and Pharmaceuticals

The Medical Devices Regulation (2017/745) provides a regulatory framework to manage end-of-life of medical devices in the EU.[119] The regulation outlines specific, harmonized processes for medical device manufacturers to follow to ensure safe management of their devices throughout each step of the supply chain. As it relates to waste management in particular, manufacturers are required to design medical devices for safe disposal, and their instructions for use must include detailed information for

[117] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1542

[118] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02012L0019-20180704

[119] PlasticsEurope, Guide of the Safe Handling of Fluoropolymer Resins, June 2021, https://www.efpia.eu/media/636866/pfas-position-_-efpia-and-animalhealtheurope-january-2022.pdf

safe disposal. The regulation also implements a Unique Device Identification (UDI) system to ensure post-market waste disposal is both safe and effectively monitored.[120] With already existent clear and measurable standards for waste management compliance, the Medical Device Regulation allows to minimize and control potential risks at the end-of-life of medical devices that contain fluoropolymers.

Chemical Industry

As noted above, fluoropolymers are also used in different applications across the chemical industry.[121] At the end of life of materials containing fluoropolymers, the materials are broken down and then further separated for individual waste treatment. For example, steel pipes including fluoropolymer liners are collected by metal recycling companies to further process the metals and extract fluoropolymers, therefore removing them from the continued use of the metal.[122] Recycling of fluoropolymers in most instances is done by specialized waste management companies who extract fluoropolymers via incineration.[123]

A specific example we can give from our Chemours plant site in France. Fluoropolymer parts like seals are collected and sent for industrial incineration at temperature over 1200°C. Steel parts containing Fluoropolymers are collected as scrap metal and processed by scrap metal companies. This remelting process is performed at temperatures over 1400°C. Based on the incineration studies[124], [125] it is demonstrated that at these temperatures full mineralization occurs and no PFAS is being generated.

Industrial Machinery

Within industrial machinery, end of life fluoropolymer production and processing equipment is used within different sectors. Industrial waste is generated, collected, sorted, and disposed of by sector-specific specialized waste management services.[126] Depending on the sector, fluoropolymer waste is either recycled, incinerated, recovered for energy uses, or disposed of in a landfill.[127] Industries using industrial machinery reliant on the use of fluoropolymers include passenger cars, air crafts, and medical industries.[128] Each industry handles the end of life for the respective machinery within the confines of that given industry.

Energy

[120] Official Journal of the European Union, Regulation (EU) 2017/745, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0745

[121] Conversio. EEU Fluoropolymer waste in Europe 2020. Slide 50. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

[122] Conversio. EEU Fluoropolymer waste in Europe 2020. Slide 50. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

[123] Conversio. EEU Fluoropolymer waste in Europe 2020. Slide 50. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

[124] Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas. Alexandrov et al. https://doi.org/10.1016/j.chemosphere.2019.03.191

[125] Submission by WL Gore to REACH PFAS Restriction consultation document 31 reference 6167 page 18-27

[126] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

[127] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

[128] Conversio. EEU Fluoropolymer waste in Europe 2020. July 2022. https://www.ft.dk/samling/20222/almdel/euu/spm/49/svar/1951975/2698345.pdf

Solar panels have lifespans of up to 30 years, and the waste electrical and electronic equipment directive (WEEE) defines how solar panels are to be handled at the end of life stage. Under this directive, producers of photovoltaic modules have to register in the national WEEE register and annually report their output on the national market. They also have to organize and finance the take-back and waste management of the modules. Furthermore, photovoltaic modules considered household WEEE, have to have an ensured financial guarantee for the disposal operations from the producers.

Also, there are mandatory collection and recycling targets. All products are to be clearly marked with a sign indicating that the module is not to be disposed in household waste, and producers must inform customers on how to dispose old modules. Further down the value chain, treatment facilities have to be informed of the products composition, as well as on potential hazardous materials, to be able to safely treat, recycle, and dispose old module components.[129] [130]

5. Conclusion

With this paper, we set out to explain the uses of fluoropolymers within and across industries, assess potential alternatives, and elaborate on waste and end-of-life management for applications containing fluoropolymers.

We demonstrated that standard emission abatement technologies allow to capture and decompose fluorinated emissions during the conversion process. Moreover, fluoropolymers' high stability over time implies very limited emissions generated during their use phase, yet, clear guidelines for measuring such emissions would enable targeted measures to also control those emissions. Overall, we concluded that risks resulting from fluorinated can be controlled and minimized.

The same holds true for waste and end-of-life management. Existing recycling, incineration, and landfill processes and regulations ensure the professional treatment and disposal of applications containing fluoropolymers industrial and professional use. Such professional treatment and disposal is further ensured through various already existing and very detailed waste directives for different sectors and products.

Ultimately, we outlined numerous uses, functions, and benefits of fluoropolymers, underlining their criticality within and across numerous industries. In this context, we also elaborated why use-specific derogations are inapplicable for fluoropolymers, as they would have to account for not only specific uses but for these uses' role within and across industries and value chains. Furthermore, we explained the shortcomings of potential alternatives, respectively, showing that substitutions, where possible, are either used due to inherent economic incentives or they are bound to significant performance sacrifices, affecting quality as well as safety aspects.

Overall, we demonstrated that risks associated with the use of fluoropolymers – which themselves meet the OECD criteria for polymers of low concern – can be minimized and controlled throughout their lifecycle, considering both emission control as well as waste and end-of-life management. Moreover, considering the variety of uses of fluoropolymers and inapplicability of use-specific

[129] http://www.solarwaste.eu/pv-waste-legislation/producers/
[130] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019

derogations to regulate these uses, Chemours argues that the currently proposed restriction option, namely a phase-out, is disproportionate. As demonstrated above, a phase-out would significantly impact key European industries, resulting in very high socio-economic costs. Therefore, Chemours urges ECHA to consider an exemption for fluoropolymers in industrial and professional use from the proposed PFAS restriction.