POSITION | TECHNOLOGY LAW AND SUBSTANCE POLICY | REACH

EU chemicals legislation: Restriction of PFAS

Evaluation of the envisaged restriction procedure

08 September 2021

1. General

Background/proposal on the restriction of PFASs

On 14 October 2020, the EU Commission adopted its sustainability strategy for chemicals. In this strategy, the Commission presents a comprehensive package of measures to regulate the substance class of per- and polyfluoroalkyl substances (PFAS). The declared aim is to restrict the use of PFAS and the placing on the market of products containing PFAS in the EU as far as possible. Exceptions are only to be made for essential uses, which are still to be defined as part of the restriction process.

The authorities responsible for REACH in the Netherlands, Germany, Denmark, Sweden and Norway have already started preliminary work on the preparation of a corresponding restriction dossier and published their intention to submit a PFAS restriction proposal on 15 July 2021. The exact scope of the PFAS restriction proposal has not yet been determined, but as things stand at present it includes all substances with at least one aliphatic CF2 or CF3 group in the molecular structure. According to the current OECD list for PFAS, this definition includes at least 4,700 chemical compounds. However, as this list does not include all relevant substances, a much higher number of compounds can be expected in reality. The planned comprehensive restriction of PFAS is primarily justified by the high persistence of many representatives of the substance group. Further reasons given are the high mobility and bioaccumulation potential of some PFAS substances.

BDI fully supports the aim of the sustainability strategy for chemicals to improve the protection of people and the environment against risks from chemicals and at the same time to increase the competitiveness of EU industry. Within the framework of sustainable chemicals regulation, substances that pose uncontrollable risks due to their properties and use profile should be restricted or regulated on the basis of scientific assessments. However, the BDI rejects the broad regulation of entire groups of substances - in the case of PFAS, several thousand substances - irrespective of their actual risk. In this position paper, the BDI comments on various aspects of the planned PFAS regulation.

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Objectives of the position paper

The aim of the position paper is to present the significant impact on the entire industry of a comprehensive PFAS restriction. In order to ensure a uniform understanding, a practice-oriented classification of PFASs is first undertaken in Part1. On the basis of various overviews, we then explain in Part 2 which PFAS are used in which industrial sectors and branches, and present the significance of the group of substances for innovations and technological developments in industry. Finally, we will highlight a few application areas and explain the role that PFAS play in the implementation and achievement of efficiency and environmental goals as well as for future technologies.

There is explicitly no classification into essential and less essential applications in which PFAS are used. The reason for this is that such a classification would represent an uncalculable challenge and would have far-reaching negative consequences both for society and for Europe as a business location. This will be demonstrated by means of the points mentioned above.

Furthermore, this position paper (Part 1) deals with the fundamental aspects of the proposed regulatory approach. From the industry's point of view, it is particularly critical that the EU regulatory authorities want to combine and restrict all PFAS in one group in order to simplify and accelerate the regulatory processes. This ignores the fact that the PFAS definition covers substances with different properties and that neither all PFAS are equally persistent nor equally mobile or bioaccumulative. The planned concept of merging all PFAS into one group of substances to be regulated will lead to great regulatory complexity in the implementation phase. Furthermore, virtually risk-free chemicals will be equated with substances of very high concern ("SVHC") with properties requiring regulation. Instead, EU policy makers should ensure that a differentiated approach is taken between the various PFAS. This should take into account whether a PFAS substance poses an unacceptable risk to the environment or human health. Otherwise, there would be a risk, for example, of driving chemicals off the market that have a crucial role to play in helping our industries move towards a decarbonised economy.

BDI is concerned that the restriction of PFAS as currently planned will be disproportionate and unworkable. Moreover, it is to be feared that this will hinder the achievement of both economic goals and goals of the EU Green Deal.

In summary, the main concerns are as follows:

- General regulation of thousands of PFAS substances as a group has no sufficient scientific basis and would be disproportionate for that reason alone.
- The aggregation of thousands of PFAS substances carries the risk that regulation would be too complex for enforcement authorities and thus not feasible.
- The regulatory PFAS approach being planned is in contrast to generally accepted REACH principles, such as that there should only be restrictions in the case of unmanageable risks.
- The impact of a broad PFAS regulation on industry, but also on product diversity, would be significant. A ban on production and use across the board but also of specific

PFAS would considerably restrict the innovative capacity of German industry. Germany's and the EU's economic goals and the goals of the EU Green Deal would be hindered or jeopardised.

- A lack of viable alternatives to PFAS substances means high socio-economic costs in trying to replace them.
- Due to the often highly complex international supply chains and the associated difficulty in analysing and preparing for the exact impact of a ban on many thousands of substances, there is a great risk of unforeseen interruptions to supply chains with all the associated economic consequences. A precise impact analysis per substance therefore requires sufficient time, which unfortunately is not currently granted.

Types, properties and uses of PFAS

Due to their unique property profile, PFAS are used today in a wide range of mainly industrial products, often because of their high thermal and chemical resistance, the fact that they have a very low surface tension and are thus water and oil repellent at the same time, as well as their abrasion and wear resistance.

Depending on the size of the molecule and the chemical structure, however, the chemical, physical and ecotoxicological properties and thus the hazard potential of the representatives of this very extensive group of substances differ considerably: PFAS can be gaseous, liquid or solid; some are water-soluble; some are mobile, others bioaccumulate, some are toxic, others are physiologically harmless and many are persistent in the environment.

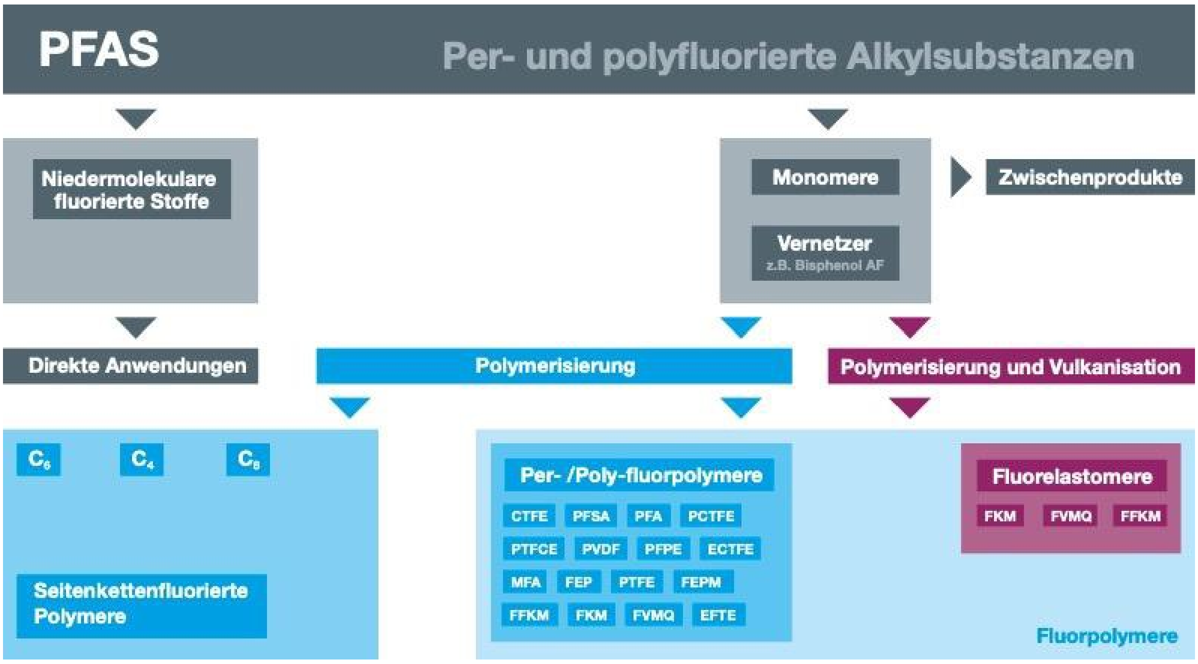
In the past, some PFAS have repeatedly been released into the environment, have accumulated in soil and water and can now also be detected in the human body. In recent years, the industry has already made considerable efforts and established comprehensive environmental protection measures in production. Toxic and particularly harmful substances from the PFAS group (e.g. PFOA and PFOS) have been substituted and production processes have been modified. As the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) reports on its website (www.bmu.bund.de) and as analyses of the federal environmental sample bank show for some compounds, the exposure of the population to PFOS (perfluorooctane sulfonic acid, C8) and PFOA (perfluorooctanoic acid, C8) has also decreased significantly in recent decades. The measured values were highest in 1986. Today they are about 10% for PFOS and about 30% for PFOA compared to the values at that time. This trend is mainly due to the success of the considerable investments made by companies in the EU. The primary sources of emissions to the environment (e.g. from aerosols in Teflon production, fire extinguishing foams or fire training areas, etc.) have already been recorded and controlled in the Member States and are largely eliminated (or are in the process of being eliminated) through continuous technological development and dynamic operator obligations to comply with the state of the art in the EU.

However, there is no doubt that PFASs are needed for many high-tech applications (such as special protective clothing or essential innovations like fuel cells with suitable membrane technology). Furthermore, it is not foreseeable which future applications will rely on the unique properties of fluorochemical-based polymers. If PFASs are banned in the EU for many important applications, this will not change the extensive use of PFASs.

Demand for products with the advantageous properties of PFAS applications. Future innovations and further developments of PFAS technology will be important, but then no longer possible in the EU.

For a better understanding of the diversity of substances and for differentiation purposes, PFAS are divided into the following subgroups (see Figure 1):

Figure 1: **Systematic presentation of the different PFAS categories (with exemplary substance examples)**



Source: BDI

Fluoropolymers with the subgroup of **fluoroelastomers** comprise fully (per-) and partially (poly-)fluorinated plastics. These are generally high-performance plastics whose chemical backbone consists of carbon atoms and which have a high proportion of fluorine atoms in their chemical structure. Their high resistance to extreme temperatures, aggressive chemicals and wear, as well as the physiological harmlessness of fully fluorinated types define their areas of application, such as anti-stick coatings for products (e.g. plain bearings in the process industry) or medical products (e.g. catheter hoses or oil- and fuel-resistant seals).

The basis of many high-performance lubricants are liquid perfluoropolyethers, which are also a class of compounds within the fluoropolymers. They are mainly used under extreme conditions (very high temperatures, chemically aggressive environment) and for the lubrication of machines in the food sector, as they are non-toxic.

Side chain fluorinated polymers (SCFP), which have a comb-like structure and in which the fluorine atoms are located in the side arms of the polymers, also belong to the fluoropolymers. A frequent field of application for this class of polymers is oil, dirt, water and chemical resistance.

cially repellent finish of surfaces. Side-chain fluoropolymers are also used as coating materials for a variety of components in electrical and electronic devices.

In addition, there is the large and extremely diverse group of gaseous and liquid **low-molecular organic fluorine compounds.** Here, too, a distinction is made between perfluorinated and polyfluorinated types. Gaseous representatives are used, among other things, as coolants (F-gases) and as insulating gases in electrical switch cabinets. Many liquid low-molecular PFAS are surface-active and therefore serve as surfactants and wetting agents (e.g. in fire extinguishing foams and as a component of release agents) but also as auxiliary chemicals in a wide variety of processes (e.g. in the semiconductor industry or fluoropolymer synthesis). The basic building blocks of fluoropolymers, the fluorinated monomers, also belong to this group of substances.

Part 2 of the position paper explains which PFAS are currently used in which industries, why they are urgently needed and how they can be used safely.

Evaluation of the proposed restriction approach

Application of the group approach to the restriction of PFASs

From the point of view of German industry, a blanket restriction of the entire PFAS substance group without a differentiated, substance- and application-specific risk assessment and solely due to the persistence of many PFAS is not appropriate. In order to ultimately achieve a sustainable overall balance of resource conservation and environmental impact, a restriction is only justified in cases where the risks to humans and the environment cannot be controlled.

It should be taken into account that the PFAS definition covers substances with different properties and that not all PFAS are equally persistent, mobile or bioaccumulative. This puts almost risk-free chemicals on an equal footing with substances of very high concern ("SVHC") with properties that require regulation. A differentiated approach must urgently ensure that only substances whose use poses an unacceptable risk to the environment or human health are banned. Otherwise, there would be a risk, for example, that chemicals that play a crucial role in innovative technologies would be driven out of the market.

In addition, legal regulations already exist for certain substances from the extensive family of fluorocarbon compounds in the POP Regulation and under REACH (e.g. PFOS, PFOA). In the context of the regulation of these compounds, their properties, restrictions and exemptions have already been discussed extensively. This discussion should not be repeated. In addition, there would be double regulation, e.g. in the area of refrigerants (F-gases), as their use is already regulated by the F-Gas Regulation (EU) No. 517/2014.

Application of the "essential uses" concept to PFASs

The concept of "essential uses" will play a key role in the overall restriction process for PFAS. This concept is also an important element of the EU Commission's chemicals strategy. The PFAS restriction is to be the "model" for this within the framework of the chemicals strategy. According to the concept of "essential uses", only those uses that are indispensable - i.e. "essential uses" - are to be excluded from a group ban on the "most harmful chemicals". The specific criteria for "essential uses" are to be defined at EU level on the basis of the Montreal Protocol's definition of the ban on ozone-depleting substances1. According to the Montreal Protocol, a use is "essential" only if it is necessary for health or safety or critical for the functioning of society and there are no environmentally and health compatible alternatives.

In addition to the concept of "essential use", the EU Commission announces in the Chemicals Strategy for Sustainability that it intends to accelerate restriction procedures to ban hazardous substances in consumer products and to apply the "generic approach to risk assessment" as a standard option.

From BDI's point of view, both the concept of "essential use" and the "generic approach to risk assessment" are to be critically assessed. By extending the scope of restrictions based on the precautionary principle, the Commission would abandon the proven principle of substance-specific risk-based assessments. An extended application of the precautionary principle is not justified from an industry point of view and contradicts the regulatory system of the REACH Regulation, which is designed to regulate substance-specific uncontrollable risks. We therefore advocate the retention of the risk-based approach to assessment for the regulation of chemicals in the EU. It must continue to be possible to use hazardous substances in the future if they can be used safely and do not pose an uncontrollable risk. This is the only way to preserve the diversity of substances and thus the innovative strength and future viability of European industry.

Furthermore, a discussion on "essential uses" is premature at this stage. Rather, the benefits to society as a whole of a risk-based approach should be discussed and highlighted. The fundamental question is whether the concept of "essential use", which was developed for a very limited group of substances with proven fatal global effects on the ozone layer, can be applied to such a large group of substances, only some of which have more precise knowledge of hazards and risks and some of which have no harmful properties at all.

We also see the danger here that restrictions of entire groups of substances to "essential uses" violate the principle of proportionality. According to this principle, only those measures may be taken which are suitable and necessary for the achievement of the objective (in this case: health and environmental protection) and which do not lead to unreasonable effects. In any case, this excludes the prohibition of uses that do not lead to relevant exposures, even if they are not considered "essential". These include, for example, uses of PFASs as process chemicals, intermediates under strictly controlled conditions and substances in closed systems.

[1] https://ozone.unep.org/treaties/montreal-protocol/meetings/fourth-meeting-parties/decisions/decision-iv25-essential-uses

that can be disposed of in a proper manner. Furthermore, it does not appear necessary to ban the entire group of PFAS in general, except for essential uses. Individual environmental protection measures and disposal strategies can be used to prevent their entry into the environment. Restricting the permitted use solely to uses that are necessary for the functioning of society (a term that is hardly tangible) would exclude uses that are of great benefit to society (e.g. by increasing the durability and energy efficiency of products and articles).

In principle, the political restriction to essential applications also leads to an inhibition of future developments, as it is not an objective scientific method and does not allow for planning certainty. What is not considered essential today has no chance of being developed as an essential application at all at a later date, as this would subsequently undermine research and development in this area due to internal company compliance requirements. If the EU wants to continue to be a driver of innovation together with its industry, such a static concept cannot be effective.

Importance of PFAS for innovative technologies and products

In order to avoid misregulation and necessary amendments, restrictions on PFAS must be examined and implemented carefully and gradually. Complex chemical compounds for specific applications cannot be regulated simply and comprehensively without causing considerable obstacles and damage to Europe as a location for technology and business. It is imperative that regulation also assesses the risk and necessity of use and cannot be limited to intrinsic substance properties alone, which in some cases do not even apply to all PFAS.

The industrial use of PFASs has significantly contributed to the further development of technologies and thereby
z. The use of PFAS has also led to an improvement in climate protection, for example, as components have been designed to be more resource-efficient and with less mass, their service life has been increased and maintenance intervals have been reduced. PFASs are therefore an essential building block for the current innovative strength of industry, which will also be important in the future. This development would be set back by a broad ban on PFAS-based applications and products. Non-European manufacturers and their technological developments as well as sales and market shares would receive an unassailable boost and lead, as entire production chains would no longer be possible in Europe.

Without the use of PFASs, new future-oriented and sustainable technologies for private and industrial applications are not possible according to current knowledge (see Part 2). The marketing of certain products containing PFASs with high safety relevance and key functions in industrial applications would also no longer be possible in the EU.

In this respect, it should be emphasised once again that German industry supports regulations that prevent the release of PFASs into the environment. However, a general ban on all applications involving PFASs does not appear to be a suitable way of achieving the objective, as this would also jeopardise future technologies with high innovation potential in Europe as a location for technology and business, or make them impossible.

2. Examples from practice

Affected industries and areas of application

Per- and polyfluorinated substances are used in many industries primarily when increased ambient temperatures, reduction of frictional resistance or chemical inertness require it. PFAS are therefore often not replaceable by alternatives in many application areas due to the requirements. They are used for the efficient and resource-saving manufacture of products, as well as for increasing service life and reliability. PFAS thus make a decisive contribution to the longevity and safety of products. PFAS enable many innovative technologies that contribute to a sustainable European economic system. In many areas, PFAS are necessary for the fulfilment of official regulations, especially in safety-relevant areas in the plants. Only PFAS such as Teflon and PVDF are sufficiently pure and inert to enable the manufacture of high-tech products.

Often it is the key components that are inconspicuous for the functionality of products, such as z. e.g. seals or membranes, in which PFAS are used. These "key components" are not only needed in products themselves, but also for the manufacture, transport or storage of other products, and this across all industries. In almost all industrial sectors, lubricants are used on moving parts to minimise friction and therefore minimise energy loss. These have to withstand extreme conditions and remain functional over the entire service life (e.g. of industrial plants), which is made possible by the use of PFAS.

PFAS are also widely used in important future technologies such as lithium-ion batteries, fuel cells, hydrogen technologies or innovative medical devices, which will play a key role in achieving sustainability and environmental protection goals, as well as in healthcare. In the absence of suitable alternatives for these applications, PFAS are essential to achieve the goals of the EU Green Deal and to further increase the sustainability and efficiency of products and technologies. In the area of food contact and medicine, PFASs offer the prerequisite for the necessary hygiene by allowing the use of appropriate cleaners and minimizing residues on the material.

The following table gives an overview of the affected industries and exemplary applications of PFAS.

Table 1: Use of PFAS in various industrial sectors

Industry	Applications (exemplary)
Automotive industry	Components and systems containing PFAS are an integral part of current and future vehicle technologies; neither battery electric fuel cell drives nor automated driving functions work without PFAS.
Electrical industry	Due to the variety of products, PFAS are used in the electrical industry in a wide range of applications, e.g.: ▪ Cable sheathing of sensor systems in process engineering plants ▪ Sliding and sealing systems in production plants and (electric) motors ▪ Coating materials for a wide range of components in electrical and electronic devices ▪ Insulating gases as a substitute for SF6 (which is one of the most climate-damaging greenhouse gases) ▪ Spark gaps for the realization of smallest dimensions (due to the very good insulating effect in combination with high thermal resistance) ▪ Lubricants to increase the reliability of electrical connections (e.g. in modern traffic systems and plant engineering). ▪ Electrode components of lithium ion and lithium primary batteries, which are used as energy sources in numerous electrical devices. ▪ further applications in power generation, semiconductor manufacturing, kitchen appliances, medical technology and the heating industry (see below).
Power generation	The use of fuels in engines or turbines requires a high resistance of the materials (of hoses and seals), e.g. to very high and very low temperatures, to fuels and oils containing alcohol and non-alcohol.
Renewable energies	In connection with the Green Deal and the reduction of CO_2 emissions, the storage of sustainably generated electrical energy (e.g. through photovoltaics and wind power) will play an increasingly important role. This concerns both stationary storage (e.g. in houses with photovoltaic systems) and in vehicles (electric mobility). In this context, both lithium-ion batteries and fuel cells are becoming increasingly important. PFASs are required for both lithium-ion batteries and fuel cells and cannot be replaced by other substances.
Semiconductor Manufacturing	Special formulations containing PFAS are used in photolithography, the central process step in semiconductor production, due to their high technical functionality and chemical properties. Perfluorinated and polyfluorinated gases are used in the semiconductor industry for etching processes to structure wafers and for cleaning production equipment.

	For micromechanical semiconductor components (MEMS), fluoroalkylsilanes are used as an anti-adhesion coating of the moving microstructures in the chip to prevent functional failures due to adhesion of these structures to each other. In various production facilities of the semiconductor industry, PFAS-containing materials are necessary as components as well as vacuum or liquid seals for permanent use in aggressive environments (reactive gases or chemicals, plasma, high temperatures).
Food and beverage industry	In the area of food contact PFAS offer the prerequisite for the necessary hygiene, because they allow the use of partly aggressive cleaning agents and minimize residues on the material (with simultaneous approval as food contact material).
aerospace	In safety-relevant components, PFAS play a major role, e.g. with regard to the durability of products.
mechanical and plant engineering	PFAS-containing seals are used in various machines, which in addition to the sealing function also keep frictional resistance low, e.g. in rotating objects such as injection moulding machines, presses or excavators and are used under extreme conditions in safety-relevant components. PFAS-containing seals, but also coatings, play an important role in many other product areas, such as pumps that convey various media. Many applications mentioned under other sectors such as the electrical industry, energy production, the lubricant industry, the food industry or air-conditioning technology are also of essential importance for mechanical engineering.
Medical Technology	The requirements for the necessary hygiene in the manufacture of medical products, but also in the use of medical products themselves, are very high. The materials used in the products must not be damaged during cleaning processes. In addition to the hygiene aspect, the physiological harmlessness of many PFAS (polymers, especially PTFE) is an essential reason for the use in the field of medical products without alternative.
Lubricants industry	PFAS-based lubricants save energy and CO_2 emissions and conserve resources through extreme durability (lifetime lubrication), which cannot be achieved otherwise. Their use is also indispensable for lubrication in extreme environments (aggressive chemicals/extreme temperatures/vacuum).
Textile industry	Technical textiles and safety clothing as well as medical textiles are subject to various requirements which can only be met by PFAS (e.g. in the area of water, oil, dirt and chemical repellent and temperature resistant properties).
Heating, air conditioning and refrigeration technology	The refrigeration circuits of various heating, air conditioning and refrigeration products are based on hydrofluoroolefin (HFO) refrigerants. These refrigerants do not damage the ozone layer and have a low greenhouse potential. They are a result of the implementation of the European F-Gas Regulation (EU 517/2014) and are essential for the safe and efficient operation of the systems.

Table 2 below provides an overview of the types, properties and diverse uses of selected PFASs, as well as the requirements for the substances used. In the following, selected application examples are used to describe the role played by the use of PFASs in particularly innovative technologies and applications. In particular, we address future technologies and applications that are important for achieving efficiency and environmental goals as well as for future developments.

Table 2: Overview of the types, properties and multiple uses of PFASs

Selection of key components	Selection of industries/applications/pro ducts	Properties/requirements in relation to the materials used
Fluoropolymers (per-/polyfluoropolymers (fully or partially fluorinated polymers and fluoroelastomers) Per-/Polyfluoropolymers have a carbon backbone, fully or partially fluorinated and are: Inert, repellent, temperature resistant, chemical resistant, abrasion resistant, pressure resistant and have a mechanical resistance. Elastomers are also used in applications where, in addition to the above-mentioned properties, the material is subjected to different pressures, e.g. when pressure is applied and removed, due to the property of deformability.		
▪ Seals ▪ Hoses ▪ Cable insulation ▪ Components of the chemical process technology ▪ Sliding bushes ▪ Solid components to ensure the technical switching function ▪ Sealing rings ▪ Filter z. e.g. from the per-/polyfluoropolymers z. B. PTFE, CTFE, FEP, ETFE, MFA, PFA and Fluoroelastomers z. B. FKM, FFKM, FVMQ	Production, transport, storage, treatment, preparation of liquids, gases and solids Affected products are e.g.: ▪ Machines or process plants for the production ▪ Pumps for transport ▪ Motors as drive ▪ storage tanks	Requirements for materials: ▪ Resistance to acids and alkalis; resistance to solvents and physical effects (heat, cold, abrasion etc.) **Food/Drinking Water:** ▪ Fulfilment of hygienic requirements for materials in the area of drinking water and food contact ▪ Resistance to aggressive cleaning agents (e.g. hydrogen peroxide in aseptic applications) and fatty foodstuffs. ▪ Prevention of aroma carry-over (due to their inert properties, perfluorinated materials do not take on the aroma of the filling material) **Fuels:** ▪ Resistance of materials in combustion engines to various fuels (including those containing alcohol) ▪ Resistance of materials in turbines to fuels and low-viscosity oils in combination with very low temperatures (- 60 °C) **Lubricating oils and hydraulic fluids:** ▪ Resistance to engine and gear oils as well as hydraulic fluids in the case of

		often high temperatures and simultaneous wear resistance due to low coefficients of friction in dynamic sealing applications **Sewage:** ▪ Resistance to fluctuating compositions with extreme pH values **Gases/exhaust:** ▪ Gas tightness in combination with very high or very low temperatures and extreme chemical conditions ▪ Resistance to high temperatures and the presence of aggressive gases
	Medical devices that come into contact with the human body (implants, endoscopy, catheters, dialysis, respirators, anaesthesia equipment), care and surgical textiles).	▪ Resistance to concentrated oxygen and anaesthetic gases ▪ Hygiene requirements ▪ Biological compatibility must be present
	▪ NOx sensors/catalytic converters/sensors ▪ SCR heating cable for the Ad- blue supply lines ▪ BVA (Brake wear indicator) ▪ Cables (e.g. in the gearbox, often immersed in hot, aggressive gearbox oil) ▪ Heating of the windscreen washer system to prevent the windscreen washer system from freezing.	▪ Reliability with large mating cycles ▪ Requirements for low contact resistance, chemical resistance, temperature resistance and mechanical friction reduction
	▪ Wet Chemistry ▪ Process equipment ▪ Railway technology ▪ Manufacturing Technology ▪ Kinematic chains	▪ Resistance to high temperatures ▪ Resistance to chemicals ▪ Requirements for low transition resistance and mechanical friction reduction
	Gearboxes and motors	Fluoroelastomers (e.g. FKM) have the following properties in sealing rings compared to alternative materials such as nitrile butadiene rubber (NBR): ▪ better temperature and chemical resistance ▪ better wear resistance at high speeds ▪ High resistance to environmental influences, e.g. ozone radiation ▪ higher ageing resistance and lower maintenance intensity

Membranes Proton conducting material z. e.g. made of PTFE, PFSA and gas diffusion layers z. e.g. from FEP	▪ Fuel cells ▪ Electrolysis cells ▪ Breathable protective membranes	▪ highest demands on chemical and thermal resistance ▪ Gas tightness requirements ▪ Use of sealing materials in fuel cells, which seal gas and water paths and must withstand all chemical and thermal conditions in the cell.
(non-stick) coatings	▪ Plain bearing ▪ Housing ▪ Tubes ▪ Hoses ▪ Conveyor belts	▪ Requirements for chemical, mechanical and thermal resistance ▪ Requirement for a friction-reducing effect ▪ Compliance with hygiene requirements
Lubricants and lubricants, Bearings, gears, compressors electrical contacts z. e.g. made of PTFE, PFPE	Contact lubrication is used in a wide variety of industries: ▪ Mechanical Engineering ▪ Automotive industry ▪ Food production ▪ Gas/oxygen production ▪ Textile industry ▪ Shipping industry ▪ chemical industry ▪ Aviation ▪ Medical Technology ▪ electrical contact technology	Lubricants are used in all moving parts to minimize friction and thus energy losses. The lubricants must withstand extreme conditions and meet the following requirements: ▪ Substances must be non-toxic and non-flammable. ▪ Resistance to decomposition must be guaranteed over many years. ▪ Resistance to high and low temperatures (note pour point) ▪ Resistance to aggressive media must be given. ▪ Resistance to high mechanical loads must be guaranteed. ▪ Substances must be compatible with the requirements of food and medical technology. ▪ Ensuring lubrication throughout the life of a bearing or other product ▪ Increasing the number of mating cycles and extending the service life of electrical components
Electrode material, Cooling hoses z. e.g. made of PVDF, PTFE	▪ lithium-ion batteries ▪ Lithium primary batteries ▪ Fuel cells ▪ HV transformers	▪ Prerequisite for efficient and long-lasting lithium batteries and fuel cells due to high material resistance in the electrochemical environment
Insulating panels z. e.g. made of PTFE	▪ Spark gaps of overvoltage protection devices	▪ Realization of extremely compact designs due to the very good insulating properties and thermal resistance

Solid lubricants z. e.g. made of PTFE/PFPE	▪ Use in high vacuum applications	▪ The reason for using PTFE in lubricants for high vacuum applications is the vapour pressure curve. The lubricants are still liquid at low pressures.
Side chain fluorinated polymers (SCFP) SCFP have fluorinated polymer side chains on a carbon backbone and are: inert and substance-repellent		
Textiles	▪ Protective textiles ▪ technical textiles ▪ Filtration media ▪ Medical textiles	▪ Materials must have oil, dirt, water and chemical repellent properties. ▪ Barrier against bacteriological, viral and other biological influences
Coatings	▪ electrical and electronic components/devices	▪ inert, fabric repellent, good dielectric properties
Low molecular weight fluorinated substances		
Surfactants and wetting agents	▪ Release agent ▪ Paints and varnishes ▪ Paper and packaging	▪ Surfactants and wetting agents are partly surface-active and partly reactive ▪ Requirements for a wide range of physical, chemical and electrical properties
Waterproofing sprays		▪ Fulfillment of fabric and water repellent properties
Extinguishing foams	▪ Extinguishing fires, e.g. in large mineral oil tanks and their containment areas.	▪ Use of simultaneously oil- and water-repellent surfactants ▪ high flow rate, high range and good temperature resistance of the foam required
Process materials	▪ Additives for the preparation of fully and partially fluorinated polymers	
Use in the photolithography process of the semiconductor industry	▪ key process step in the semiconductor industry	▪ The technical requirements of the photo-lithography process are a specific combination of surface properties, with specific refractive indices and chemical and thermal resistance.
Fluoroalkyl silanes	▪ Anti-stick coatings for micro-mechanical components (MEMS, especially sensor chips) in the semiconductor industry	▪ Minimization of surface energy, adhesion forces and friction to reliably prevent stiction of the microstructures during the entire product life. ▪ at the same time high temperature stability of the anti-adhesive layer (> 400 °C during processing)

		▪ Hydrophobization of surfaces in MEMS products with contact to the surrounding medium (e.g. microphones)
Per- and polyfluorinated gases (insulating gases, process gases)	▪ Electrical industry, medium and high voltage switchgear, etching and cleaning processes e.g. in the production of solar cells, printed circuit board and semiconductor industry	▪ Requirements for very good dielectric properties with low greenhouse potential (substitute for SF6) ▪ Use as etching gases (e.g. for structural etching and for chamber cleaning of coating machines) due to the unique combination of performance and work safety with the specific release of the fluorine atoms required for the etching reaction.
Wetting agent z. E.G. 4H-PFOA	▪ Use in chrome baths	▪ 4H-PFOA is a substitute for perfluorooctanoic acid (PFOA), which is restricted by the POPs Regulation. Compared to PFOA, F atoms have been replaced by H atoms.
Refrigerant z. e. g. R1234 yf	▪ Use as a refrigerant for heat pumps, air conditioning and refrigeration applications. ▪ Use in refrigeration technology and by heating appliance manufacturers.	Tetrafluoropropene known as R1234 yf (HFO Blends) from the substance group of hydrofluoro- lefins (HFO) fulfils the following properties: ▪ low global warm potential ▪ low residence time in the atmosphere; decomposition products (TFA) possibly persistent, but high background level of natural origin ▪ Normally, refrigerant is not released but largely recovered and recycled. ▪ Alternative refrigerants with low GWP are explosive, therefore associated with increased risk, especially in the domestic environment.

Monomers

Monomers are intermediates without whose use the production of polymers (fluoropolymers, side-chain fluorinated polymers) would not be possible.

Selected application examples

Protective textiles in the field of personal protective equipment (PPE) for fire brigades, security and rescue forces and in medicine.

Protective textiles for the protection of employees in action are used by the police, customs, the Federal Border Guard, the fire brigade and the Federal Armed Forces, but also in private institutions such as security services or aid organisations (e.g. the THW in Germany). Among other things, chemical protection suits are used to avert danger in the event of accidents and environmental damage. Special protective equipment is also necessary for workers in the chemical industry or fishermen.

This requires numerous highly innovative special products with a combination of different properties: The textiles must often be simultaneously non-flammable, water-, oil-, chemical- and dirt-repellent. These properties must remain undiminished during the entire period of use and even after several industrial washes. The finish required for the longevity of the textiles makes an important contribution to sustainability. The combination of a water, oil, stain and chemical repellent finish can only be achieved with fluorinated polymers. No fluorine-free alternatives are yet available for the combination of an oil-, stain- and chemical-repellent finish.

PFAS remain indispensable in many medical applications. Every operation in Europe must be performed covered. In Germany alone, more than 19 million patients are treated each year, of which approx. 40 % are operated on, according to Destatis. For example, membrane laminates are used for reusable medical products such as surgical gowns and drapes, as well as narrow-meshed microfilament fabrics, which must be equipped with PFAS to prevent the penetration of certain liquids that occur in the operating room. There is no adequate alternative to C6 or C8 textile auxiliaries to achieve the appropriate performance of these fabrics. Consequently, the entire sector of reusable surgical textile products in Europe is affected. Also plasters, which are offered as medical devices, are partially permitted with PFAS (C6 chemicals). This applies in particular to plasters and plaster fabrics that are offered rolled and must also function at warm ambient temperatures.

Sun protection systems (e.g. awnings, sun sails, textile building envelopes) that are protected against weathering and biological infestation over the long term prevent rooms from heating up, they avoid the need for energy-intensive cooling and thus reduce energy consumption. They thus make a significant contribution to climate protection and to achieving the European climate targets.

Filtration media (exhaust air and waste water treatment, clean rooms, pollen filters etc.)

Filter media for dust separation in industrial processes are required for numerous important industries, from aluminum to cement production, from waste incineration to power generation and also in the food industry. The demands on the mechanical and chemical resistance of the filter media in particular are high, as they must provide their function undiminished over a long period of time in order to protect people and the environment from emissions. In order to maintain the filter effect even against different and changing pollutant flows, the filter is impregnated. A fluorine-free substitute for the impregnation is currently not available in the same quality, and the service life of alternatively impregnated systems is significantly shorter.

Semiconductor

The use of PFAS-containing special formulations in the central process step of semiconductor manufacture, photolithography, is essential due to their high technical functionality and chemical properties. PFAS-containing process chemicals are, for example, photoresists and anti-reflective coatings, which are used in photolithography to create the structures on the silicon wafer. PFAS components are used in low concentrations (typically less than <1
%) are used in these special formulations. Photolithography processes are repeated several times (up to 60 times, depending on the technology) in the entire semiconductor manufacturing process, in order to create structures before applying further layers, which in total finally form the transistors and connections of the finished microchips on the silicon wafer.

The use of fluoroalkylsilanes is essential for certain micromechanical semiconductor components (MEMS), in particular for MEMS acceleration sensors, due to their unique properties (formation of very thin layers with extremely low surface energy and correspondingly low adhesion forces combined with very high temperature stability). Anti-adhesion coatings based on fluoroalkyl silanes enable the fabrication of very precise sensors of small size with the required reliability. Such MEMS acceleration sensors are indispensable for automotive safety systems (airbag, ESP driving dynamics control) as well as for automated driving and other vehicle assistance systems. They are also used in a wide range of consumer electronics applications (smartphones, tablets, wearables).

PFAS-containing process chemicals (PFHxA-related substances) remain in the finished product in some specific applications (MEMS, CMOS image sensors in automotive and medical technology, cameras, mobile phones, computers), but are encapsulated.

Perfluorinated and polyfluorinated gases are used in the semiconductor industry for etching processes to structure wafers and for cleaning production equipment.

The semiconductor industry has risk and safety management measures (e.g. closed production facilities) to prevent the release of chemicals at all stages of the manufacturing process. Waste from photolithography containing PFAS is usually collected on site and sent for proper disposal.

There are no known alternatives for PFAS-containing special formulations in photolithography that have the same unique properties. Due to the high purity requirements in the production process, the use of fluoropolymers in the production equipment is necessary.

The continued availability of PFAS in the production process is a fundamental prerequisite for the manufacture of semiconductors as a key technology and thus essential for the existing production supply chains (e.g. automotive) and the future innovation capability in Europe.

lithium-ion batteries

Rechargeable lithium-ion batteries, especially for use as traction batteries in vehicles, must meet high demands with regard to service life, charging speed, high energy density and permanent charging capacity. The materials used in lithium-ion batteries are therefore carefully selected so that they are stable at different ambient temperatures and high currents or energies. Fluorocarbon compounds are indispensable for meeting these requirements due to their stability.

A long service life of the lithium-ion batteries and thus the long-term stability of the materials used are also of decisive importance with regard to the secondary use of traction batteries as stationary energy storage systems, as envisaged in the Green Deal and the new EU Battery Regulation currently being drafted.

The durability of the materials used also plays a decisive role for lithium primary batteries, which are often permanently installed in electrical devices and provide energy for operating times of up to 20 years.

Currently, there are two main PFAS applications in modern Li-ion batteries:

1. PVDF (polyvinylidene fluoride) and PTFE (polytetrafluoroethylene) as binders for coating the cathode with active materials such as metal oxides.

2. Fluoro-organic additives in the electrolyte to improve the service life of the battery cell.

Emissions of the PFAS compounds used into the environment are excluded during normal operation or when used as intended and are limited to malfunctions or accidents. The PFAS compounds are used in the manufacture of the battery cell in closed systems, are encapsulated in the battery cell during the use phase and are decomposed during recycling and the resulting fluorine compounds are removed via gas scrubbers.

Fuel cells/electrolysis cells

PFASs are used in various key components in fuel cells and electrolysis cells. This includes, for example, the proton exchange membrane, gas diffusion layer and sealing materials for gas, water and air paths.

The proton exchange membrane consists mainly of PFSA-like ionomers with a reinforcement of PTFE. PFSA is the proton conducting material in the fuel cell membrane and electrode and enables the electrical transport of protons in the electrodes and membranes. This separates reactants and gases and ensures the electrical insulation of the half-cells. The proton membrane is the main functional unit and therefore mandatory for the functionality of a polymer electrolyte fuel cell. In the gas diffusion layer PTFE and FEP are used as hydrophobic agents to stabilize the water management and to separate the water circuits in the single cells of a fuel cell stack. PFAS are also used to seal the chambers within the fuel cell. Chemical and thermal stability are particularly important here.

Currently, no alternatives are available for use in these key components, since, for example, only PFSA ionomers have reached technological maturity for use in proton exchange membranes for these functions in the harsh environment of a fuel cell.

In gas diffusion layers, PTFE and FEP are required as electrochemically stable binders that can withstand the acidic conditions in the vicinity of the catalyst or the membrane of a fuel cell. The superior electrochemical stability of PTFE under different conditions in a fuel cell is of particular relevance here. There are currently no alternatives for this either.

Compressed gas metered dose inhalers for the treatment of lung diseases

Compressed gas metered dose inhalers are used for the targeted administration of drugs via the lungs. For these highly effective drugs, precise dosing in the microgram range is necessary. In addition, this form of administration with propellant gas allows children and elderly patients to inhale life-saving drugs, among other things. Many patients would not be able to take other dosage forms due to their lung disease.

In these pressurized gas metered dose inhalers PFAS are contained both as propellant gas and in the coating of the aluminum pressure container. During application, the propellant gas used must generate a pressure that allows fine distribution of the active substance and transports the active substance into the lungs. At the same time, the pressure must not cause any damage to the lungs. Only fluorinated propellants have this property.

The inner coating of the aluminium pressure vessel must have as low a surface energy as possible in order to prevent the active pharmaceutical ingredient from adhering. Only in this way can a uniform dosage be achieved. This eliminates the risk of under- or overdosing for the patient. This can only be achieved by PTFE, FEP or PFA coatings.

Food sector

PFAS and especially PTFE are used in numerous components and assemblies in systems and equipment for the production and preparation of food. In most cases this is due to the special material property combination of high temperature resistance and approval for food contact. The combination of high temperature resistance/lubrication effect is the reason for its use in seals and plain bearings.

An important application of PTFE is the use in hoses and pipes for the transport of liquids. These liquids are, for example, drinking water, coffee, milk and also steam. Some of these transported liquids are under a pressure of up to 12 bar in normal operation and must be able to withstand pressures of up to 20 bar in the event of a fault. The operating temperature can be assumed to be between 0 °C and 160 °C in normal operation. In case of need, temperatures of up to 200 °C can occur. In some cases there is even a combination of 20 bar and 200 °C. PTFE has proven to be an ideal material for such applications. But also in the area of food contact, PTFE materials are characterized by their very good compatibility in contact with food. At present, there are no alternative materials for safe use in contact with food. Switching to other materials would result in an earlier failure of the components.

Heat pumps

In order to achieve the European climate targets, the switch from fossil fuels to electrically driven heat pumps is one of the decisive measures. With the implementation of the F-Gas Regulation (EU 517/2014) in recent years, there has been an almost complete conversion of components and equipment concepts to new synthetic refrigerants (HFOs). Additional restrictions on the use of refrigerants via PFAS regulation would make it impossible to achieve the EU climate targets for 2030.

In Europe, a broad renovation wave is underway in the building sector. The focus is particularly on multi-family houses. The heat pump industry has just started to implement heat pumps in this sector and has adapted the necessary properties and performance sizes of the products for use in these buildings. To ensure safe and efficient operation of the heat pumps, the use of HFOs is necessary.

A widespread use of natural refrigerants as an alternative cannot currently replace the use of HFOs for technical reasons due to safety requirements and the desired efficiency requirements.

Paints and varnishes

Fluoropolymers, especially PTFEs, are also used in paints, coatings and printing inks. They help to give the coatings important properties such as scratch and abrasion resistance as well as thermal and chemical resistance, which are essential for the specific end uses. In some cases, the compounds are only used in very small quantities, but are of great technical importance. This applies, among others, to the fields of powder coatings, industrial coatings, automotive, corrosion protection and printing inks.

Safety-relevant fasteners (e.g. screws, nuts, washers, clips, etc.), whose functionality can only be guaranteed by coatings with fluoropolymers according to the current state of the art, are used, for example, in the assembly of chassis and tires. The coating ensures that the required defined assembly conditions (including pretensioning force and clamping force) are fulfilled so that the connection maintains its function and the necessary safety. Coatings containing fluoropolymer are also essential for the function of seat belt restraint systems in cars, for example. They prevent the belt from sticking to the components in the event of an accident due to the high thermal energy involved, thus guaranteeing that the belt remains functional. Furthermore, this coating ensures that the belt buckle can still be operated and opened under load after an accident.

In the case of printed products, especially in offset printing, various problems and qualitative impairments can occur without suitable rub protection. On the one hand, there are visible rubbing problems in the printed product, for example scratches, "smearing" and depositing ink on surfaces that are actually unprinted. These rubbing problems can impair the quality of the printed product to such an extent that it can no longer be sold, which can result in considerable financial damage. On the other hand, contamination and deposits also occur in the press and in finishing, especially on chill rollers, formers and spiral bars, which lead to significantly more waste and result in increased cleaning effort, which is often very time- and solution-intensive.

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