PFAS and Electrical Connectors

Annex to the ZVEI comments on the UPPFAS Restriction and el. Connectors

1 ZVEI association

ZVEI e. V., the German Electro and Digital Industry Association, represents an industry with an annual turnover of about 223 bn. Euro and 890 thousand employees in 2024.

2 Relevance in EU and Germany

Connectors are Key Components of an Electrified and Digitalized World

Connectors are essential building blocks for the growing electrification and digitalization of modern systems. They enable the connection of networks and serve as interfaces for electrical and electronic links. Their applications span all areas of electrical engineering and electronics from miniature connectors to large, heavy duty ones. Fundamentally, a connector is a physical interface component used to separate or join lines, allowing systems and components to transmit electrical power, signals, and data. Especially in harsh environments, for example dirt, shock and vibration, a reliable physical connection is indispensable. Connectors are also required for a wide range of applications, from low voltage power transmission at 5 V to high voltage systems exceeding 800 V and several hundred amperes. They form the backbone of connectivity, from power plants to microcomputers.

Depending on the application and required transmission quality, connectors are designed to meet specific technical and economic demands. This includes efficient manufacturing and processing methods, compatibility with current and future technologies, environmental and economic considerations, continuously increasing data transmission rates, and higher performance and reliability. To meet these diverse requirements, connectors are engineered for a broad spectrum of use cases and operating conditions.

The connector market has seen steady growth over the years. While traditional applications have shown moderate but consistent expansion, demand in emerging fields such as e-mobility, renewable energy, and data infrastructure is rising sharply. Although economic downturns have impacted the industry, the sector has remained resilient thanks to its solid structural foundation and strategic technological orientation. Moreover, the ongoing trends of electrification and digitalization, along with the increasing use of sensors and their integration into systems, are driving the growing need for electrical connectivity solutions.

Table: Development of the market for electrical connectors (ZVEI internal survey)

Connector market by regio	2021 Mio Euro	2022 Mio Euro	2023 Mio Euro	2024 Mio Euro	2025 Mio Euro
America	10196	12256	12619	12860	13634
EMEA	8453	9877	10025	9415	9460
Japan	6279	7336	7410	7478	7476
Ais/Pacific	21155	25192	26307	25494	27281
Total	**46082**	**54661**	**56361**	**55246**	**57851**

Table: Development of the market for electrical connectors (ZVEI internal survey)

Around 700 different connectors inside a car [2]

4,1 Mio produced cars in germany in 2023 [1]

<u>4,1 Mio cars * 700 Connectors</u>
= 2.870.000.000 Connectors p.a.

Assumption 3 (plus, minus/ ground, Auxiliary contact) contacts (usual are 6 and more) per connector as average.

Basic Szenario	Realistic Szenario
2.870.000.000 x 3 contacts	2.870.000.000 x 6 contacts
=	=
8.610.000.000 contacts p.a.	17.220.000.000 contacts p.a.

Source 1: https://blogs.sw.siemens.com/ee-systems/2020/07/28/wiring-harness-development-in-todays-automotive-world/ (Dez. 2025)
2: https://de.statista.com/themen/1140/automobilproduktion/#topicOverview (Dez. 2025)

Figure: 1 Connector Volume p.a.- Source: M. Rueter

3 PFAS containing Articles and Substances in electrical Interconnections

a. Lubrication and Contact Wetting

1) Purpose for use

Since no contact surface is perfectly smooth, thinly applied contact lubricants fill in existing microscopic irregularities, not only improving contact quality and electrical performance, but also extending service life by reducing hot spots during current transfer and abrasion.

By filling the air gaps between contact surfaces, lubricants significantly increase the actual surface area, which in turn prevents local current leakage and the associated temperature rise and resulting oxide formation. Contact lubricants form a barrier to airborne contaminants and reduce frictional effects by providing fluidity of motion. Only by using contact lubricants multipole connectors can be reliably mated or unmated by hand.

If the surface contact is insufficient, the current is only transmitted through a small part of the surface, resulting in intense heating at the contact points where the surface oxidizes and increases the contact resistance. Regardless of whether they are static or dynamic, mechanical wear occurs on metal interfaces. With static contacts, abrasion occurs due to minimal movement of the contacts caused by vibration or temperature changes. When surfaces rub against each other, metal particles brake off from the tips and bore through the protecting coatings. This exposes the surface itself and the underlying metal to oxidation and wear. In addition, the detached metal particles can cause interference with current transmission and switch failure.

Industrial contacts are used at operating temperatures up to approximately120°C, due to contact resistance local temperatures at the contact points can increased even further. For reliable lubrication of the contacts at temperatures >130°C, only PFPE-based contact lubricants are currently available. Moreover, industrial connectors are frequently used in harsh ambient conditions in corrosive atmospheres, so that the contact lubricants must additionally be resistant to corrosive media, which likewise only synthetic lubricants have been able to ensure so far.

2) Function of PFAS content

The lubrication of different friction partners in electrical applications fulfils various functions. Basically, it serves to optimise friction between different material pairings. These can be plastics, metals or combinations of both. On the one hand, plugging forces are reduced, the frequency of plugging and unplugging cycles is increased, fretting corrosion is avoided or, in general, the stucking of moving elements is prevented.

Lubricants containing PFAS are used to ensure the above-mentioned properties under demanding temperature conditions (extreme cold and heat during actuation; actuations after reflow soldering process 260°C) that prevail in the applications even after several years of ageing. Another key reason for using PFAS based lubricants is the excellent material compatibility in relation to the various metals and plastics used in connectors

3) Service time over Product lifetime

Under normal condition no service or additional wetting is required

b. Fluor elastomeric sealing

1) Purpose for use

Connectors for non-office applications need in many cases high IP protection for error-free operation. For this requirement O-Rings or custom designed sealings are used to keep the electrical contacts from being contaminated with liquids, chemicals, dust and protect the connector against short circuits and therefore ensures secured electrical operation.

In case of IP protected connectors in environments with an extended temperature range and aggressive chemicals fluor elastomeric polymers like FKM, FFKM, FEPM, FEP, PFA and PTFE offer superior material properties. The fluor elastomeric sealings also provide excellent performance over the lifetime of the entire connector. The design of the sealing and therefore the entire connection is in many cases directly related to the material properties which are used for those sealings.

2) Function of PFAS content

Electronic connectors are used in various applications; therefore they must withstand different external influences. Fluor elastomeric sealing materials like FKM, FFKM, FEPM, FEP, PFA und PTFE provide excellent material properties like

- wide temperature range (-30 to +200 °C)
- resistance to different organic solvents, acids and bases
- UV and Ozon resistance
- Durability and Longevity over lifetime

3) Service time over Product lifetime

Connectors with integrated sealings do not require service over lifetime.

c. PFAS containing Membranes for Pressure Release in Connector Housings

1) Purpose for use

The following described application is a specific application of technical fibres for the use in EEE – but also on part level e.g. sensor or connector.

The membranes are typically used for sealed applications within EEE applications.

In a connector the membrane design elements are typically based on fluoropolymers (e.g., PTFE, ePTFE, etc.) and are used to prevent the penetration of humidity into the product and at the same time to allow some gaseous media to escape to the environment to avoid under- or overpressure inside the product or to enable gas exchange into defined areas of Electronic Equipment for measuring of gas concentrations.

In case of harsh temperature change between ambient and ECU the thereon related vacuum can lead to suction of wetting water on the ECU-housing. The water based liquid film inside the ECU or electronic

application may then lead over lifetime to an electric failure of the EEE-application based on electrochemical migration.
Beside this quality related function of the membranes, they are also required in e.g. motor engine ECU's as they need to measure continuously the current ambient pressure to ensure a correct functioning of the engine. As the sensor is an internal element of the ECU, a sufficient pressure equalization of ECU- and ambient-pressure must be ensured. This is particularly important to comply with the high requirements for exhaust gas control.

The over years developed state-of-the-art technical solution that yields acceptable device sizes and function is an application of a porous membrane that compensates the pressure of the ambient and inside the control unit while blocking harmful media. The only known membrane materials that overall fulfil the requirements of media robustness, sufficient air flow rate and high-temperature stability are expanded Polytetrafluoroethylenes (ePTFE) which are a subset of the PFAS-group.

We note that all membranes used in our applications are mainly based on fluoropolymers that fulfil the OECD criteria of "polymers of low concern".

For some specific applications an additional PFAS is applied to achieve certain technical properties. The amount of this additional e.g. coating is very low in an area of a few percentages.

Conclusion:
There are typically no or very few additional design elements required to achieve the required functions.

This results in a high degree of design freedom at the EEE application level, but especially also in the final application, e.g. in the vehicle.

The membrane/vent is based on PFAS and is a very efficient key element in ensuring the safe functioning of the EEE and the applications associated with it.

2) Function of PFAS content

The membranes are typically used for sealed applications.

Fluoropolymers are essential materials for ensuring the required media and high-temperature robustness for above mentioned applications, e.g. by housing ventilation in various components

The unique properties of fluoropolymers regarding the chemical resistance against media (e.g. bad fuels, oil liquids, greases, water solutions, Li-Ion battery electrolyte, DEF, exhaust gas, etc.) in combination with high temperatures in an area of 150 °C are key criteria to achieve the required performance function.

Other special requirements that the used materials must meet are:

- - Both hydrophobicity and lipophobicity for water- and oil-repellence
- - High gas permeation of thin membrane
- - Low swelling in media and humidity uptake
- - Low ion elution in case of e.g., fuel cell applications
- - High lifetime
- - media resistance e.g. as mentioned in the non-exhaustive listing below,
  - Both hydrophobicity and lipophobicity for water- and oil-repellence
  - High gas permeation of thin membrane
  - Low swelling in media and humidity uptake
  - Low ion elution in case of e.g., fuel cell applications
  - High lifetime
  - media resistance e.g. as mentioned in the non-exhaustive listing below,

3) Service time over Product lifetime

We do not have quantitative data on emissions of PFAS from the use phase because they are used as components within a wide range of end-products by different end users. However, we believe that emissions during their use phase are negligible.

In larger quantities, mainly the fluoropolymers PTFE is used in venting products. According to our information, for these fluoropolymers neither the release of relevant quantities of non-polymeric residuals nor the release of degradation products during the use phase is to be expected for the following reason:

Fluoropolymers are specifically used in venting applications because they do not react, degrade, or erode, even when exposed to aggressive chemicals or relevant application temperatures.

We therefore believe that it is very unlikely that relevant amounts of PFASs here mainly PTFE will be released into the environment from the products during the use phase.

d. PFAS containing Potting Materials

1) Purpose for use

The primary purpose of using Fluor elastomer potting materials is to provide a protective barrier around sensitive connection components, circuits, and devices. This encapsulation shields the internal components from environmental factors such as moisture, dust, chemicals, and mechanical stress in industrial environments. PFAS containing potting materials are realising an extension of life of connections and connectors in harsh environments. Further most of potential substitutes are based on containing silicon materials which are exhale silicon particles. These particles are creating problems in many different applications such as automatic painting and colour coating. Automobile production can be mentioned here, especially painting with the hart requirement of “silicon freeness” (Keyword: substances that interfere with paint wetting).

2) Function of PFAS content

Increasing the resistance against high temperature, Mineral oils; increasing aging resistance.
PFAS-containing potting materials act as a chemical barrier, preventing corrosive substances, solvents, and other chemicals from reaching and damaging the enclosed contacts, connections and electronics. The offer of good thermal stability and heat resistance, helping to dissipate heat generated by electronic components and maintain optimum operating temperatures. PFAS-containing potting materials promote strong adhesion to various substrates to be resistant against chemicals such as:
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- water based liquids
- gasoline / petrol super
- diesel fuel
- Biodiesel
- engine oil
- brake fluid
- preservatives (car wax, polishes, …)
- battery acid
- antifreeze fluid
- windscreen washer fluid
- cold cleaning agent
- exhaust gas
- ammonia related gas
- Dust
- Sand

and ensure that the potting material adheres securely to the components and the surrounding housing. PFAS-containing potting materials can provide non-stick properties, making it easier to remove components from moulds during the encapsulation process.

e. PFAS additives in plastics

1) Purpose for use

PFAS-based additives such as PTFE (polytetrafluoroethylene) and PFBS (perfluorobutane sulfonic acid) serve distinct yet complementary functions in improving flame retardancy in polymer materials used for electrical connectors, helping them meet stringent fire safety standards.

The polymers commonly used in electrical connectors are selected for their excellent mechanical strength and insulating properties. These materials are often used in components like strain reliefs and housings, which operate near electrical currents. As such, they must comply with stringent fire safety standards, including IEC 60898, IEC 60947, and IEC 60335 from the International Electrotechnical Commission (IEC), as well as the internationally recognized UL 94 standard from Underwriters Laboratories, or sector specific requirements like EN45545-2 for railway industry

PTFE is widely used as flame retardant synergist for polymers (e.g. PC, ABS, PBT, PA). Its primary role is to prevent melt-dripping during combustion, which is critical for achieving the UL 94 V-0 flammability classification. By suppressing dripping, PTFE helps prevent the spread of fire and acts as a synergist in flame retardant systems.

PFBS and its salts are used to enhance flame retardancy in polycarbonates (PC). PFBS operates via a condensed-phase mechanism, promoting the formation of a carbon-rich char layer during thermal decomposition. This char layer acts as a barrier against heat and oxygen, improving fire resistance. PFBS remains effective even at concentrations under 0.1% and essential for achieving high flame retardancy in PC-based materials

PTFE and PFBS are crucial for ensuring the flame retardant performance of polymers used in electrical connectors. Their unique properties enable compliance with international fire safety standards under demanding thermal and environmental conditions. Despite regulatory pressure, these substances currently have no viable alternatives for certain high-performance applications, underscoring their continued relevance in the connector industry.

2) Function of PFAS content

PTFE usually makes up a small amount of the material (≤0.9% of total composition) and complements the flame retarding system. The mode of action is described as a “physical effect of microfibrils formed during processing which shrink back under fire, preventing dripping release” in case of polyamides.(1) For polycarbonate and ABS, rheological effects of reduced viscosity and induction of a flow limit (“solid-like behaviour at low shear stresses below a yield point”) are discussed in literature.(2)(3) Since the main (flame retarding) component BDP functions as a plasticizer for PC/ABS, the benefits of flame retardation are negated by the decreased viscosity which promotes dripping. The addition of PTFE as synergist is necessary to compensate for this effect, allowing the material to fulfil the flammability standard according to UL94 V-0. The anti-dripping flame retardance provides a higher amount of safety and security to end-users, greatly reducing the likelihood of a thermal event and PTFE provides a critical anti-dripping property to flame retarded grade polymer resins, this prevents melt-dripping in fire event in finished goods.

PFBS, the potassium salt of PFBS, acts in polycarbonate systems primarily through a condensed-phase mechanism promoting the formation of a carbon-rich, intumescent char layer that insulates the material, limits heat and oxygen transfer, and suppresses flaming drips.
During thermal decomposition, PFBS also releases fluorinated and sulfonyl radicals that interact with degradation intermediates in the gas phase, slightly modifying combustion reactions. The salt promotes the formation of a compact, stable carbonaceous layer (char) on the surface. However, this radical gas-phase activity is minimal, due to the high C-F bond enthalpy of 488 kJ/mol (7). Together, these condensed- and gas-phase effects contribute to the materials overall flame retardancy
This protective layer serves as a barrier against heat and oxygen, reduces the transport of flammable degradation products, and thereby slows down flame propagation.(4)(5)(6)
The key role is played by the catalytic influence on polycarbonate decomposition: PPFBS releases basic species at temperatures close to the main decomposition range of PC, which accelerate intermolecular rearrangements and bond cleavage reactions. This shifts the pyrolysis pathway toward early char formation while suppressing the generation of low-molecular-weight, flammable volatiles. As a result, the surface becomes stabilized, preventing uncontrolled dripping or rapid burn through.(5)(6)
Gas-phase contributions, such as dilution by CO_2, are of minor importance; the primary effect clearly lies in controlling the decomposition process and promoting the formation of a protective carbon layer.(5)

As of 2025, there are no commercially available PFBS-free flame retardant systems in polycarbonate that meet stringent requirements such as EN 45545-2 (flammability rating R22/R23 HL3) or UL 94 V0 at thin wall sections. Thin sections heat up more quickly and are more easily ignited. PFBS in polycarbonates enables UL 94 V-0 ratings at this very thin wall thicknesses (< 1mm), which today cannot be achieved by other additives, in particular in combination with glass fibre reinforcements.
Polycarbonate manufacturers are actively working to qualify alternative flame retardants without PFBS, but these are, as of today, neither commercially available nor qualified for high-performance applications like railway and the feasibility of achieving equivalent performance remains highly uncertain.

(1) Diniz, A. T. S. et al. (2023) ‘High heat resistance can be deceiving: Dripping behaviour of polyamide 4.6 in Fire’, Macromolecular Materials and Engineering [Preprint]. doi:10.1002/mame.202300091.
(2) Matzen, M. et al. (2015) ‘Influence of flame retardants on the melt dripping behaviour of thermoplastic polymers’, Materials, 8(9), pp. 5621–5646. doi:10.3390/ma8095267.
(3) Schartel, B. (2010) ‘Phosphorus-based flame retardancy mechanisms—old hat or a starting point for future development?’, Materials, 3(10), pp. 4710–4745. doi:10.3390/ma3104710.
(4) Li, G. et al. (2016) ‘Thermal properties of polycarbonate containing potassium perfluorobutane sulfonate’, 3rd International Conference on Mechatronics and Information Technology, pp. 501-505. doi: 10.2991/icmit-16.2016.91.
(5) Huang, X. et al. (2006) ‘Mechanistic study on flame retardance of polycarbonate with a small amount of potassium perfluorobutane sulfonate by TGA–FTIR/XPS’, Polymer Degradation and Stability, 91(4), pp. 606–613. doi: https://doi.org/10.1016/j.polymdegradstab.2005.02.028.
(6) Nodera, A. et al. (2004) ‘Thermal Decomposition Behaviour and Flame Retardancy of Polycarbonate Containing Organic Metal Salts: Effect of Salt Composition’, Journal of Applied Polymer Science, 94, pp. 2131–2139. doi: 10.1002/app.21091.
(7) Alfa Chemistry Fluoropolymers; https://fluoropolymers.alfa-chemistry.com/resources/carbon-fluorine-bond.html (24th of Nov.2025)

3) Service time over Product lifetime

Articles don’t require service and remain in product over lifetime.

f. Insulation in coaxial connectors for high frequency applications

1) Purpose for use

The insulation in coaxial connectors fulfils several essential functions:
Electrical isolation: It reliably isolates the inner conductor from the outer conductor to prevent short circuits, ensure stable signal transmission, and maintain a defined impedance (e.g., 50 ohms).
Mechanical centring: The insulation precisely fixes the inner conductor in the centre of the connector. This is essential for consistent electrical properties, low signal attenuation, and trouble-free operation.
Impedance control: The dielectric constant of the insulation material directly influences the impedance of the connector (typically 50 or 75 ohms) and is crucial for low-loss signal transmission at high frequencies and for matching to the overall RF system. The dielectric constant value also determines how small a connector can be and whether standardized specifications for the connector interface can be met.
High frequency properties (minimizing RF losses and reflections): High quality insulating materials with low dielectric loss (e.g., PTFE) reduce attenuation losses and reflections in the high frequency range. Signal transmission is improved. (e.g. see IEC61169-52 for specifications); (e.g. see ASTM D2520 or ASTM D3380 for testing)
Thermal and mechanical stability: In challenging applications, the insulation must retain its shape and function even under temperature changes, vibrations, and mechanical stress.
Environmental protection: In some applications, the insulation also protects against moisture, dust, or temperature fluctuations.

2) Function of the PFAS content:

RF connectors are used in a wide variety of applications and processes and must therefore withstand various external influences and meet size specifications from relevant standards. PTFE as an insulation material offers the necessary material properties, such as:
• Wide temperature range (-200 to +260 °C)for use in harsh environments with very high and low ambient temperatures and for use in high-temperature manufacturing processes such as soldering
• Resistance to a wide range of chemicals, solvents, and acids
• UV and ozone resistance
• Weather resistance resistance against temperature, aging, or humidity): a slight change in the dielectric constant (εr) e.g., due to temperature, aging, or humidity causes a frequency shift. PTFE has extremely low moisture absorption - practically 0%. This makes PTFE particularly stable in this respect, resulting in minimal frequency shifts.
• Low Dielectric loss (dependent on loss factor tan δ): Due to its extremely low tan δ, PTFE contributes practically nothing to the overall damping
• Durability and resistance throughout the entire service life
• Low permittivity (< 2.4)

3) Service time over Product lifetime

Articles don't require service and remain in product over lifetime.

4 Qualification Timeline for New Product -(alternatives)

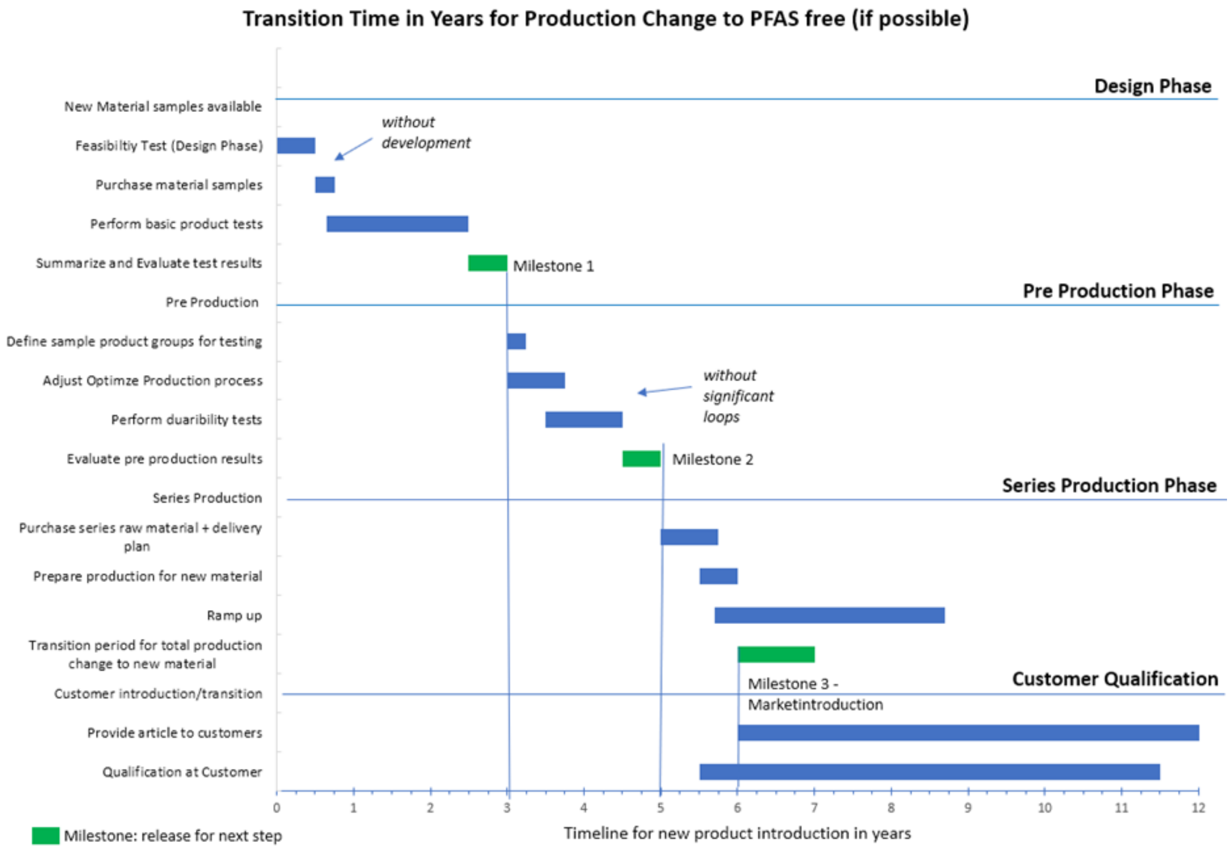

Figure: 2: Timeline for New Product Introduction – Source: A. Schier

Connector Development Timeline and Qualification Process

The qualification phase can only begin once materials have been identified that meet the fundamental technical and regulatory requirements. Based on these materials, sample connector designs are developed and tested to ensure they fulfil the intended functions in typical application scenarios.

Following successful initial testing, the project moves from Design Phase 1 into Design Phase 2, which takes place under pre-series conditions. This phase focuses on evaluating and optimizing the manufacturing process. Once this is complete, the process transitions into Design Phase 3, where production is carried out under series conditions. At this stage, tools and machinery must be procured and commissioned to finalize the Production Part Approval Process (PPAP) and ensure a stable, repeatable manufacturing process.

Assuming that prequalification with test samples can be completed within one year, the transition to full series production typically requires an additional three to four years. After market launch under series conditions, the new products must undergo customer testing and approval. Depending on the application, this can include formal approvals for use in regulated environments, such as transportation or radiation protection, where certification processes may take several additional years.

5 Concerns Regarding the Proposed PFAS Restriction

Influence due to new development and upstream, unavailability and performance losses

Testing and product documentation for alternative materials require significant effort and resources (see also Qualification Timeline).
At this stage, it is not possible to provide a reliable cost estimate. However, it is important to note that evaluations of available alternative materials have shown that they often fail to meet the required performance characteristics. and lack the range of properties required for electronic and semiconductor applications, such as high chemical and thermal resistance.

The proposed restriction will result in increased costs and reduced productivity, both in terms of product performance and usability. This would place an additional burden on customers, potentially limiting their choices and reducing the incentives for technological advancement. Furthermore, products manufactured with less durable and reliable alternatives would likely require higher maintenance and replacement frequency, ultimately resulting in increased waste.

Assuming that suitable alternatives are already available, will undoubtedly lead to sudden supply disruptions. The COVID 19 pandemic has already demonstrated how vulnerable global supply chains can be, with widespread shortages across multiple sectors and significant societal impacts. Supply disruptions have threatened e.g., the semiconductor industries, not only in the automotive sector but also in the consumer electronics. It shows very clearly, that the unavailability of a single component or material can lead to complete thereon based production stops up to the final product e.g., automotive.

The proposed restriction has the potential to trigger similar crisis in the supply chain, but on a broader scale, impacting not only the semiconductor but extend to a very broad ranges of supplies like mechanic parts, electronic parts, chemicals. The risk of widespread shortages due to broad impact of this restriction is therefore significantly higher.

The risk for shortages based on this PFAS-restriction is therefore very much higher.

6 PFAS Waste treatment

The typical process of end-of-life treatment depends on the specific application sector. In the automotive industry, for example, the first step is dismantling of certain components of interest are required as part of compliance with specific regulations such as the End-of-Life Vehicles Directive -ELV (2000/53/EC). However, due to their small size and mounting location, electrical and electronic equipment (EEE) often remains in the vehicle.

Electrical connectors are typically part of electrical goods in scope of the WEEE directive (2012/19/EC) or other regulated markets. Hence the transition from the use phase to waste is well defined, making the uncontrolled disposal unlikely.

Most of the technically used PFAS are long time stable and very resistant to chemicals. Waste treatment technologies for PFAS are mostly investigated and technically evaluated on energy-assisted technologies. In case of polymeric PFAS, incineration technologies were investigated with PTFE waste.

Under test conditions in a waste incineration chamber, in accordance with the 17th BImSchV (German Federal Emission Control Ordinance), it was demonstrated that PTFE can be almost fully transformed into fluoride (F^-) (as hydrofluoric acid (HF)). Samples of the flue gas were analysed for the presence of 31 PFAS and found to be without significant measurable PFAS content. (1)

At temperatures above 750°C PTFE decomposed to C2F4 and C3F6 in a pyrolysis process. During further combustion CF4 is generated. At combustion temperatures above 1000°C, the CF4 formation is significantly reduced. (2) Based on this result a municipal incineration system operating under §8 of the 17.th BImSchV (3) was decided? sufficient to not detect any PFAS in the flue gas with exception of greenhouse gases like CF4 or C2F6 but with low evidence due to weak database. Technologies for CF4 decompositions are in operation and development with focus on semiconductor processes. Hazardous waste incineration systems typically operates at about 200°C and higher combustion temperature.

A test facility for incineration of PFAS production waste was setup in Cooperation with the German Federal Environmental Foundation ("Deutsche Bundesstiftung Umwelt" DBU) and the company Dyneon. This facility demonstrated more than 90% decomposition of PFAS into its monomers. (4) Other test facilities investigated the incineration of PFOA-treated fibres and observed decomposition at 1000°C without chromatographically detectable PFAS in the flue gas. (5) Additionally, in a literature study PFOA and PFOS decomposition was successfully investigated at 350°C in supercritical water. (6)

The incineration of Perfluoropolyether (PFPE) is less studied but it was observed, that during development of PFPE fluids they become unstable at temperature above 290°C (7) Other incineration systems for PFPE operate at 330°C with metallic iron reactants like aluminium powder for binding decomposed PFPE. (8) For treatment of radioactive PFPE lubricants an incineration system with MnO2-catalyst and N12CO3 immobilizer was successfully tested (9)

Further investigations into the incineration of PFAS were carried out in the emission analyses (10) and led to the conclusion that no PFAS emissions could be measured in the flue gas, as the concentrations are below the analytical detection limits. The measurements have proven a PFAS destruction greater than 99,99%.

Conclusion

The end-of-life treatment of PFAS containing materials, particularly in highly regulated sectors such as automotive and electronics, is already well structured and controlled**.** High temperature incineration technologies, when operated in accordance with stringent environmental standards, have demonstrated high efficacy in decomposing PFAS substances, including polymeric forms like PTFE and PFPE.

To support safe and sustainable PFAS waste management in the future, regulatory efforts should prioritize ensuring reliable compliance with established disposal standards, while also fostering continued research into innovative treatment technologies.

Such targeted measures, combined with robust controls on the manufacture and use of PFAS containing substances and materials, offer a more balanced and effective regulatory approach than a blanket ban on technically valuable substances, that serve critical functions in industrial applications.

(1) Krasimir Aleksandrow, et. al; "Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas"; Elsevier Chemosphere 226, p898-906; 2019
(2) Sandra Huber, et. Al.; "Emissions from incineration of fluoropolymer materials"; Researchgate OR 12/2009
(3) 17. BImSchV
(4) Press Release "Pilotprojekt: Recycling von Fluorpolymeren"; Universität Bayreuth; Lehrstuhl für Werkstoffverarbeitung
(5) Takahoro, Yamadam et. al.; "Thermal degradation of fluorotelomer treated articles and related materials" Elsevier Chemosphere Vol 61, Issue 7 p974-984; 2005

(6) Sanny Verma, et. Al.; “Recent advances on PFAS degradation via thermal and nonthermal methods” Chemical Engineering Journal Advances; Elsevier Marc. 2023
(7) William R. Jones, et. Al.; “Thermal Oxidative Degradation Reactions of Linear Perfluoroalkyl Ethers”; II Symposium on Fluorpolymers; 183rd National Meeting of the American Chemical Society; 1982;
(8) Mimi Y. Keating, et. Al.; “Decomposition of perfluoropolyether lubricants” Journal of Thermal Analysis and Calorimetry 106; p213-220; 2011
(9) XinHang Du, et. Al.; “An efficient approach for the treatment of radioactive waste perfluoropolyether lubricants via a synergistic effect of thermal catalysis and immobilization”; Journal of Environmental Sciences, Vol 136, p512-522; 2024
(10) Gehrmann, Hans-Joachim, et. Al.; “Mineralization of fluoropolymers from combustion in a pilot plant under representative european municipal and hazardous waste combustor conditions”; ELSEVIER Chemosphere 365 (2024) 143403

7 Derogation request

We welcome the proposed derogation in the background document under point 6j, which allows the use of anti-dripping agents in plastics for electronic components for a period of 13.5 years after entry into force. However, there is a need for extension of this exemption to include non-polymeric PFAS used in the electronics sector.

Although alternatives to PFBS are already under development, their technical suitability has not yet been demonstrated in practice. The necessary testing, qualification, and certification processes can take several years. If the current transition period remains unchanged, the relevant substances would be banned in 18 months after the regulation enters into force. This timeframe is extremely limited and poses a significant risk to product development, qualification, and market readiness.

To address this risk, we propose aligning the wording of exemptions 5z and 6j. Both exemptions refer to the same application but are phrased differently. Exemption 5z is formulated more broadly and covers additional additives that are essential for ensuring product functionality. Harmonizing these exemptions would help close regulatory gaps and provide the flexibility needed to maintain innovation, supply chain stability, and compliance across the sector.

In addition, it must be possible to apply for a further derogation in case no suitable alternative is available on the market. For example, the exemption methodology should be according to the current RoHS Directive.

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