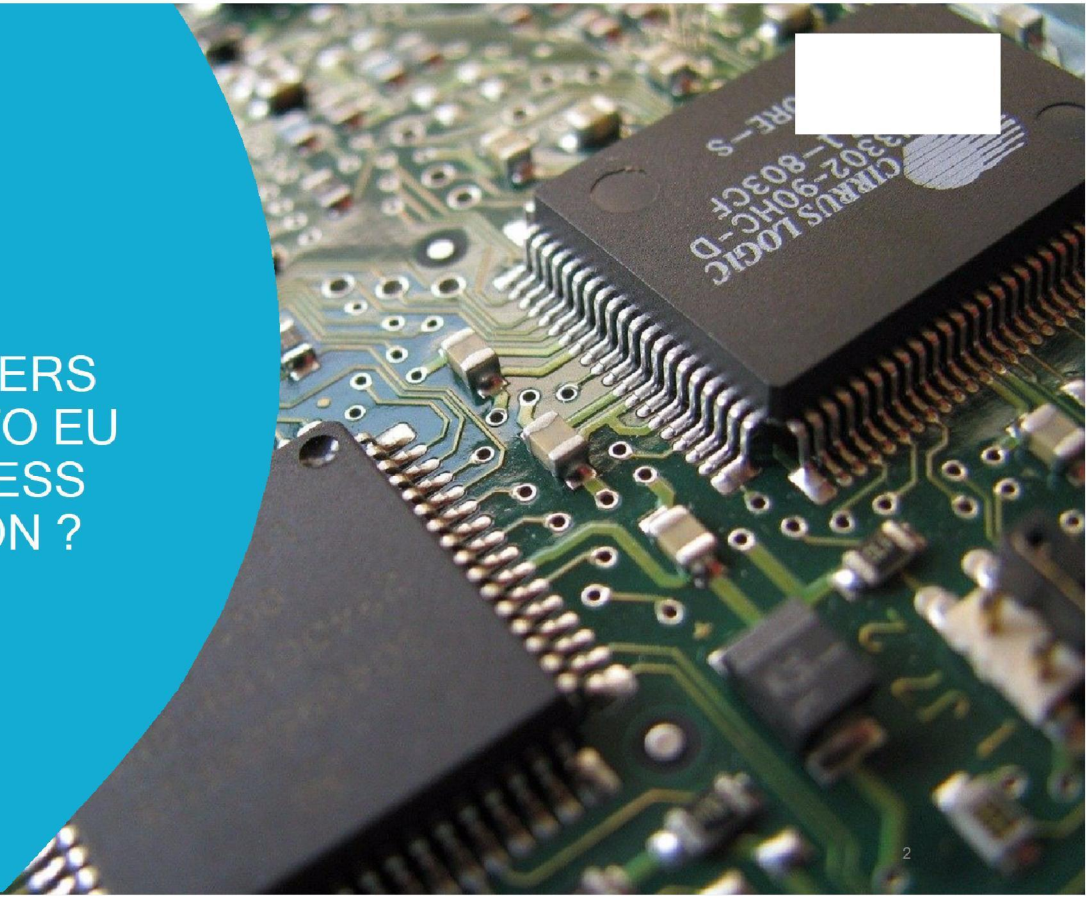
FPG EXCHANGE WITH RIJKSINSTITUUT VOOR VOLKSGEZONDHEID EN MILIEU

30 MARCH 2022

WHY FLUOROPOLYMERS ARE CRITICAL TO EU COMPETITIVENESS AND INNOVATION ?



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PLASTICS EUROPE
Enabling a sustainable future
Fluoropolymers Product Group

ONE-OF-A-KIND POLYMERS

Fluoropolymers are unique chemical substances used across numerous technologies, industrial processes and everyday applications from the aviation industry to transportation, medical devices and energy production and technical apparel.

With a unique set of properties, they are durable, chemically inert and mechanically strong. Fluorpolymers help to keep us safe and enable innovation.

WHY DO WE USE FLUOROPOLYMERS?

- Ensure , reliability and performance across a variety of sectors
- Low-risk polymer for human health & environment
- Help drive EU industry competitiveness and innovation
- Critical to numerous technologies enabling the Green Deal, reducing waste and emissions
- Few, if any, viable alternatives

Uses of fluoropolymers

- Promoting sustainable and smart mobility through electric vehicles.
- Extending the lifespan of medical equipment and devices, reducing the need for replacements, risk of failure and cross infections.
- Enabling a data driven economy though the manufacturing of microprocessors and semi-conductors.
- Facilitating the Renovation Wave and the construction of energy efficient buildings.
- Driving innovation and helping decarbonise the aviation industry.
- Assisting the chemicals industry in preventing corrosion in harsh environments.
- Ensuring food and pharmaceuticals remain fresh and uncontaminated.
- Protecting workers in professional protective and high-performance clothing.

European FP market, by end users
% in tons, 2020

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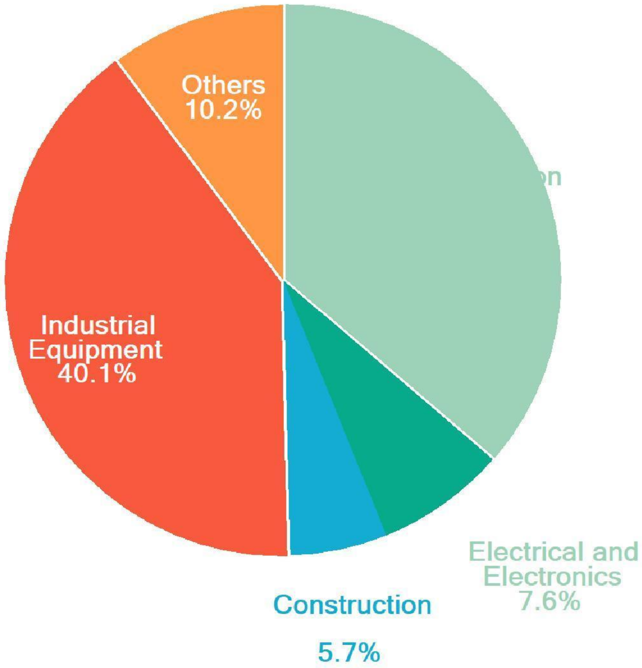

Source Allied Market Research

Repartition by key end-users

Transport equipment

Electrical and electronics

Industrial equipment

Sales to downstream sectors

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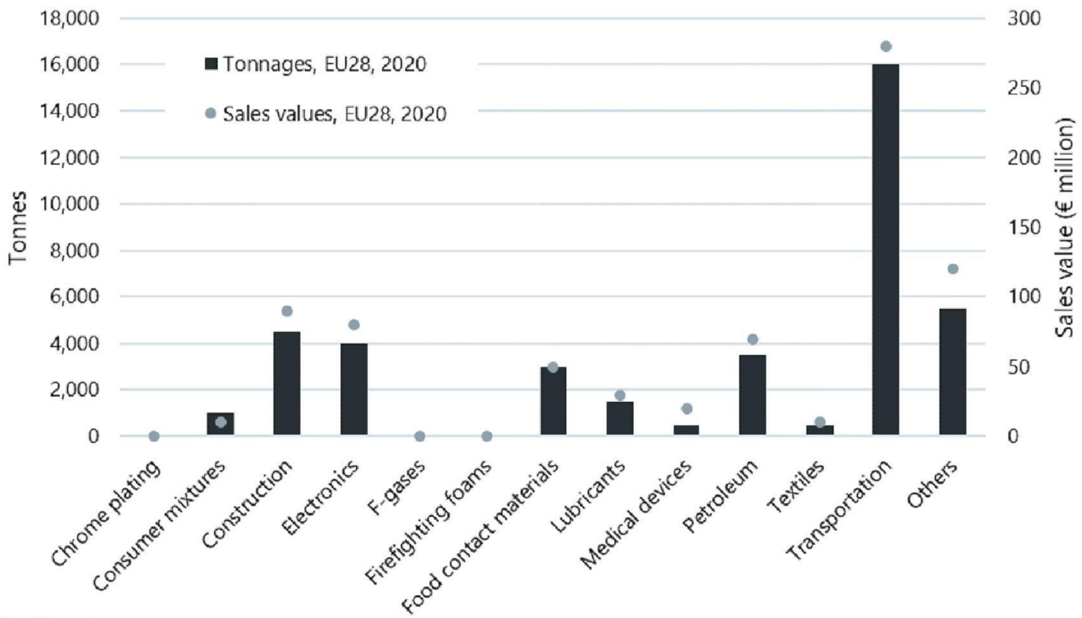

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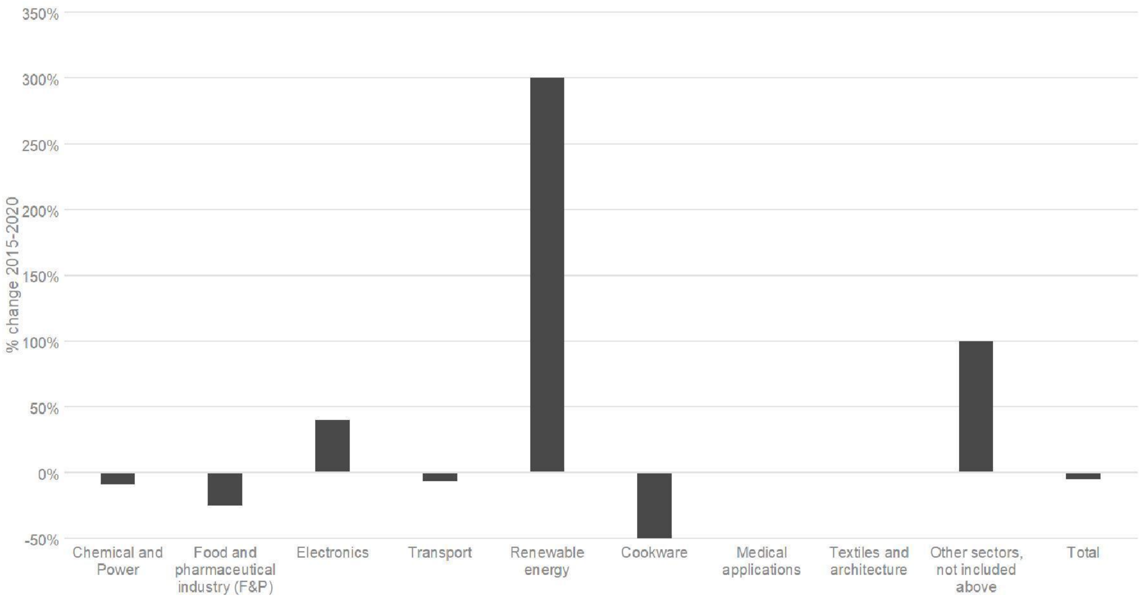
Sales to downstream sectors

Sales value, % change 2015-2020



Market value

Sales of fluoropolymers onto the EEA market generate revenue of approx. €750 million per year and sales onto the EU28 market generate €740 million per year.

Just over €1 billion worth of fluoropolymers are produced in the EU28/EEA

- The value of exports (€550 million) is more than twice the sales value of imports (€270 million).

Quantities (€m)	EEA/EU28 in 2020	% change in EU28 2015-2020
Sales value of product produced in the EU28 / EEA	1,030	+23%
Sales value of imports into the EU28 / EEA	270	-13%
Sales value of exports from the EU28 / EEA	550	+45%
Total value sold in the whole EU28 / EEA	750	-5%

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Plastics Europe – Enabling a sustainable future – Fluoropolymers Product Group

Where are Fluoropolymers used and why?

What happens if FLPs are banned in the EU?

Introduction to the use of Fluoropolymers

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Given the market prices of Fluoropolymers (FLP), users in general opt for FLPs only if nothing else (cheaper) works. As such it has become a necessity rather than a choice

FLPs exhibit extraordinary properties, each of which could be found in alternative materials separately, but very often the combination of properties is governing the use of FLPs.

Replacing FLPs by other materials has consequences. The trade-offs, as we will discuss, are in areas of fire safety, weight savings and performance.

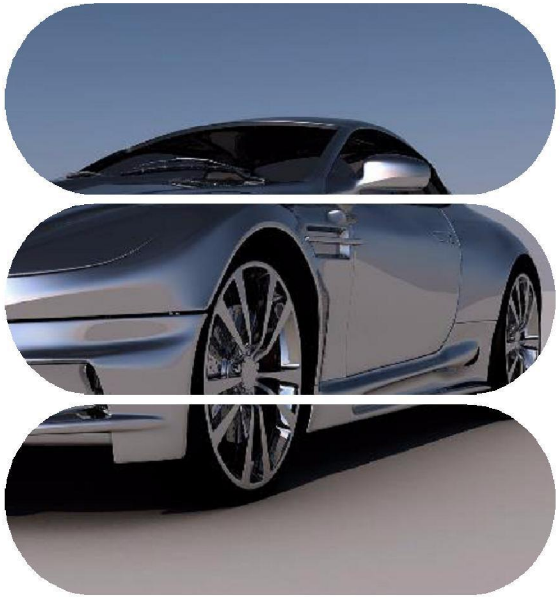
Automotive sector

Key benefits of fluoropolymers

- Under the hood temperatures of cars are high due to both noise reduction as well as ever-increasing fuel economy (turbochargers, direct injection etc). Also, aggressive synthetic oils are used in brake and other hydraulic systems. FLP's are required for the combination of their high continuous service temperatures as well as resistance to aggressive chemicals (oils, Adblue, fuels)
- Key benefits include:
  - Better fuel economy from weight saving
  - Increased lifetime of components
  - Improved reliability and lower maintenance costs.
  - Permits use of alternative fuels

Issues with alternatives

- Alternative materials in most cases increase the weight of the car and have an adverse effect on fuel economy. As such this will increase the vehicles overall carbon footprint
- Lower quality material replacements will result in higher maintenance cost and lower car reliability.



Examples of fluoropolymers in automotive

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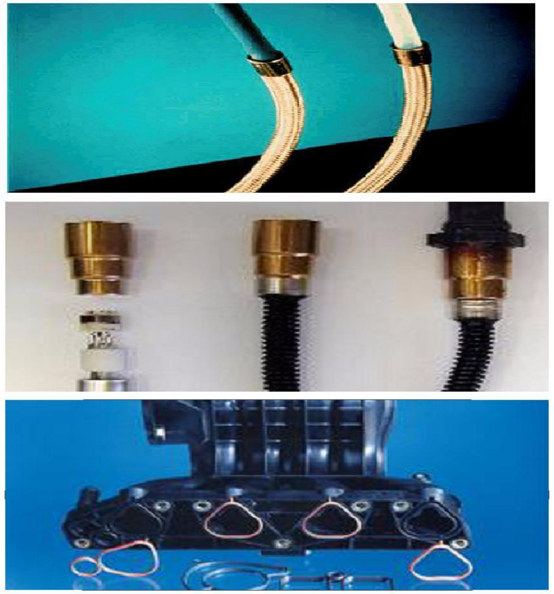
Types of fluoropolymers and applications

PTFE PFA/MFA FEP FKM THV	Fuel lines and hoses Fuel management systems Seals & gaskets Oil pan O rings ABS brake lines Lambda sensor grommet and wiring Turbo charger hoses



Examples of fluoropolymers in automotive

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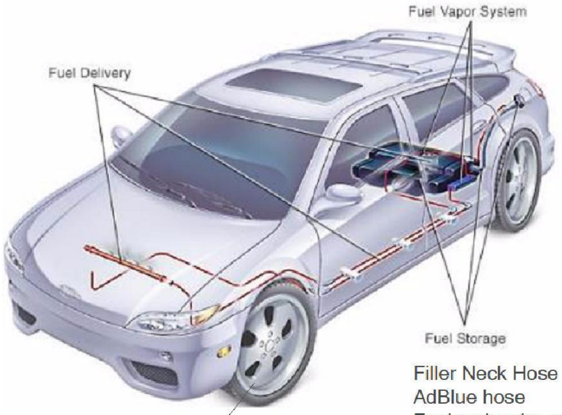
Direct Fuel injection seals
Turbo charger hose
Fuel filter seals
Fuel rail seal

Fuel vapour line
Exhaust gas return line
Fuel return line

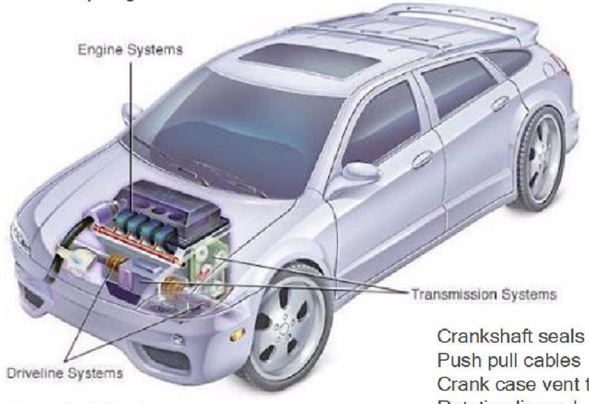


Filler Neck Hose
AdBlue hose
Fuel tank valve seal
Fuel cap seal

Break pad wear
indicator wire

Lambda sensor
- Wire
- Grommet
- Sleeve

Oil pan gaskets



Crankshaft seals
Push pull cables
Crank case vent tube
Rotating lip seal

Cam shaft Seals
Cylinder head gasket
Valve stem seals
Cylinder lining o rings

Aerospace industry

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Key benefits of fluoropolymers

- Fluoropolymers in aircrafts are used to ensure:
  - Safety - in particular fire safety
  - Weight savings - often in combination with safety
  - Hygiene - Easy clean surfaces

Issues with alternatives

- Alternative materials in most cases increase the weight of the aeroplane and have an adverse effect on fuel economy, by increasing the carbon footprint.
- Most importantly are the low smoke and fire resistance properties of Fluoropolymers in critical systems as well as in aircraft interiors - which will give extra seconds to vacate an aeroplane that saves lives

Examples of fluoropolymers in aerospace

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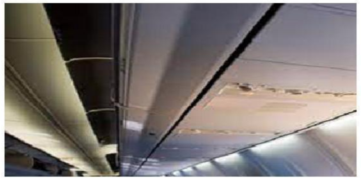
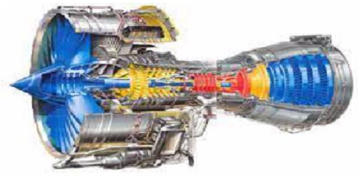


Types of fluoropolymers and applications

PTFE
PFA/MFA
ETFE
ECTFE
FEP
PVF

Fly by wire systems
Wi-Fi wiring
In-flight entertainment wiring
Fuel hoses
Interior film
Jet engine parts
Overhead bins
Liq oxygen seals



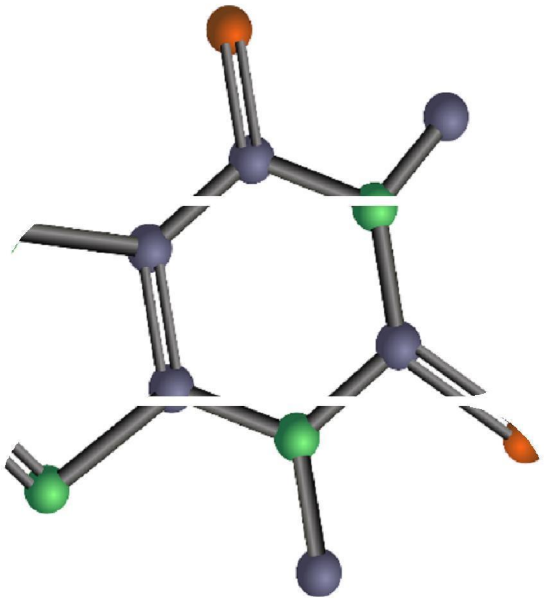
Chemical Process Industry

Key benefits of fluoropolymers

- In general, fluoropolymers in chemical manufacturing equipment are used to protect steel housing against a harsh chemical environment. They prolong the life of equipment, including pipes, fittings etc., prevent chemicals from spilling into the environment and keep workers safe.
- The key properties of FLPs are their ability to function under continuous service temperature (up to 260C for PTFE) and resistance to harsh chemicals.

Issues with alternatives

- In harsh environments, materials that do not withstand these environments as well are sometimes used. This results in more frequent shutdowns of complicated processes - which is inherently unsafe - and may cause unwanted spills and accidents.
- An alternative, in some cases, is the use of exotic alloys which significantly drives costs up.



Examples of fluoropolymers in the Chemical Process Industry

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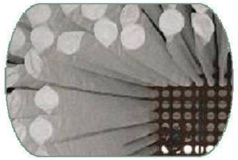
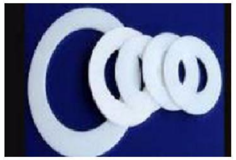




Types of fluoropolymers and applications

Types	Applications
PTFE PFA/MFA ETFE ECTFE FEP FKM PVDF	Gaskets Vessel liners Pump lining Valve and pipelining Coating Expansion joints and bellows Filters in flue gas systems Electrolyser in Chlor-Alkali Industry Heat exchangers in power plant de-sulferisation units

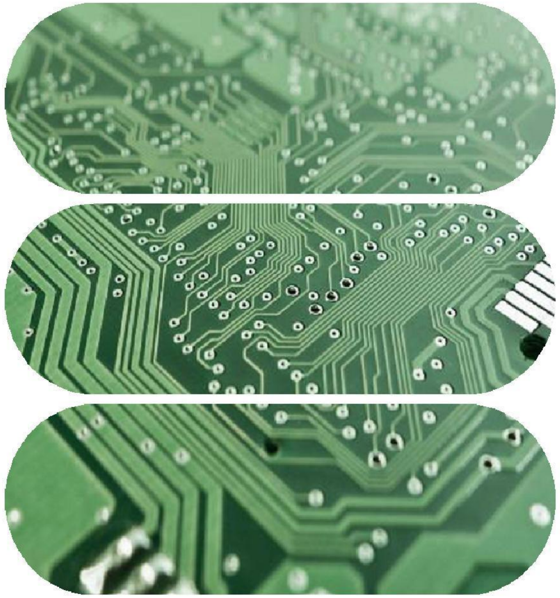
Electronics industry

Key benefits of fluoropolymers

- Excellent dielectric properties in combination with other properties, such as resistance to high soldering temperatures and flammability/low smoke are the reasons FLPs are used in a wide area of applications.

Issues with alternatives

- Alternatives impact performance and fire safety.
- Other materials lack excellent electrical and thermal insulating properties, which are crucial for miniaturisation in electrification and digitalization. Ordinary wires aren’t equipped to handle the high-power consumption and high frequencies of 5G radios and cells, USB-C cables and plenum cables and are flammable.



Examples of fluoropolymers in Electronics

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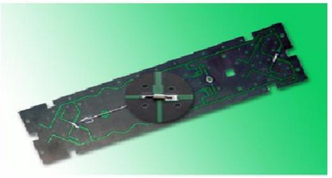
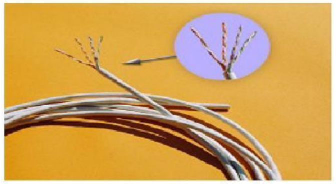



Types of fluoropolymers and applications

PTFE
FEP
PFA
ETFE
PVDF

Cabling:
- Plenum
- USB-C
- MT riser cables manufacturing

PC casings
HF wiring boards
IC cushioning
Mobile telephone antennas



Semiconductors industry

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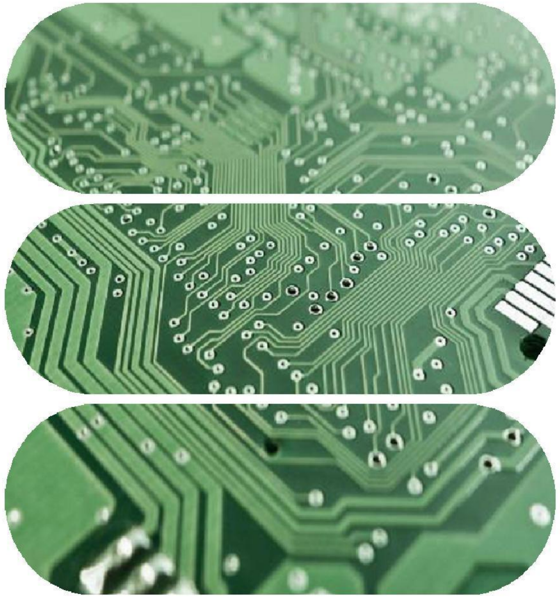
Key benefits of fluoropolymers

- High purity FLPs in semiconductor manufacturing is needed to keep aggressive fluids used in manufacturing ultra pure. It allows larger wafers and, therefore, ever-improving and affordable microchips and LEDs due to higher production yields in semiconductor manufacturing.

Issues with alternatives

- There are no alternatives if manufacturers want to get to current wafer size. A larger wafer diameter enables producing more semiconductor devices from a single wafer, enhancing productivity and efficiency. If foundries would still produce 1 inch wafer today, there is no chance they'd be able to support the volume of smart-phones, tablets and PCs.



Examples of fluoropolymers in Semiconductors

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Types of fluoropolymers and applications

PTFE
PFA
PVDF

Semi-Conductor manufacturing
Liquid handling systems
Wafer carriers

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Medical/Pharma Sector

Key benefits of fluoropolymers

- FLPs are used in tools, body implants, and pharma packaging
- Key benefits include:
  - Patient comfort and safety
  - Reduced risk of cross-infections and thus medical complications
  - Higher consistency of dosages, increasing effectiveness and safety of drugs
  - Biocompatibility (USP Class VI)
  - Tissue attachment and cell adhesion without an adverse reaction, reducing the risk of complications.

Issues with alternatives

- Alternatives may impact health risks from cross contamination and over- or under-dosage of pharmaceuticals
- Biocompatibility is less good, resulting in implant rejection

Examples of Fluoropolymers in Medical/Pharma

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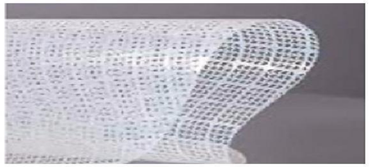
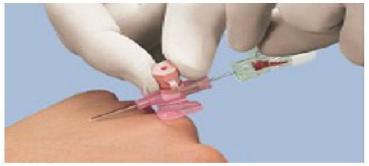
Types of fluoropolymers and applications





PTFE
PCTFE

- Catheters
- Implants (Stints, arteries, hernia mesh, etc.)
- Medical garments
- Packaging Films
- Equipment and tool lining
- Metered dose inhalers
- Caps for Medical Injection doses

Construction Industry

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Key benefits of fluoropolymers

- FLPs have excellent weatherability properties and enhance fire resistance.
- Roofing systems and exterior coatings that use FLPs do not stain, avoid algae growth and have a very long life.
- Use of FLPs reduces maintenance cost while maintaining aesthetics throughout the lifetime of the building.
- PTFE tape is resistant to both petrol and oil due to its chemical inertness. It is used in automotive applications to seal and lubricate fuel line joints.
- Plumber's lubricating and sealing tape is designed to cope well under moderately high pressure and heat demands.

Issues with alternatives

- Conventional coatings would require frequent re-application, while PVDF/PTFE life in the application is greater than 30 years.
- Prior to PTFE, hemp was used. Hemp has lower resistance to aggressive fuels and dries out in natural gas service, causing leakage.

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Examples of Fluoropolymers in Construction

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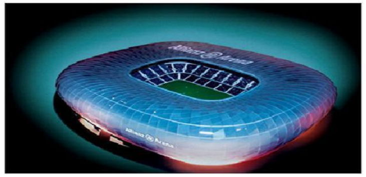
Types of fluoropolymers and applications

PTFE ETFE FEP PVF PVDF	Coated Fabric for Buildings/Roofs Façade and Infrastructure protection Green houses Gas tapes



Energy Segment

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Key benefits of fluoropolymers

- FLPs are used in the fossil energy segment due to their resistance to high temperatures and harsh chemicals
- FLPs are used in the renewable energy segment for:
  - Photovoltaic cells back and front sheets extanding service life
  - Lithium batteries binder materials, extending life and fire safety
  - Fuel cells, resistance to harsh chemicals

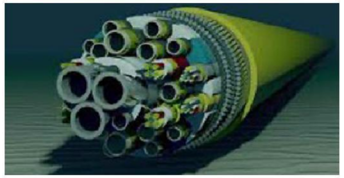
Issues with alternatives

- In the fossil energy segment, materials that withstand these enviroments less well are sometimes used. This results in more frequent shutdowns of complicated processes, which is inherently unsafe, and may cause unwanted spills and accidents.
- In the renewable energy segment, alternative materials will influence service life and safety. This increases costs and delays the energy transition

Examples of Fluoropolymers in Energy

Types of fluoropolymers and applications

PTFE PFA PVDF ETFE	Photovoltaic cells Li-ion batteries Fuel cells Downhole piping Umbilicals Heat exchangers



Food Food Contact

Key benefits of fluoropolymers

- FLPs are primarily used for their low friction, non-corrosive, non-stick and easy clean properties at elevated temperatures,

Issues with alternatives

- Other materials can be used, but may result in higher:
  - cleaning costs
  - waste
  - use of oils

Examples of Fluoropolymers in Food Contact Applications

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Types of fluoropolymers and applications

PTFE PFA FEP FKM	Non-stick cookware Baking liners Industrial baking belts Oven coatings Food packaging films Belt Conveyors Industrial bakeware Laser Marked and Printed Tubes for Identification

Examples of Fluoropolymers in Consumer Applications

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Types of fluoropolymers and applications

PTFE PFA FEP FKM	Non-stick cookware Baking liners Appliances (Motor-) bike break lines Watch bands Smart phones




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FPG RMOA AND CURRENT ACTIVITIES ON LIFE CYCLE OF OUR PRODUCTS

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RMOA key takeaways

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Association of Plastics Manufacturers
Fluoropolymers Product Group

1 EU GREEN DEAL

A full PFAS REACH restriction would put at risk key applications that are necessary to ensure competitiveness of the EU industry, as well as the very ambitious goals set forward by the European Green Deal.

PlasticsEurope
Association of Plastics Manufacturers
Fluoropolymers Product Group

FPs, along with their relevant monomers, should be derogated from the PFAS REACH restriction. The use of polymerization aids should also be allowed by regulators to enable continued EU manufacture of FPs.

2 PFAS REACH RESTRICTION

PlasticsEurope
Association of Plastics Manufacturers
Fluoropolymers Product Group

3 INDUSTRY COMMITMENT

The industry should commit to efficiently address the concerns related to the manufacture and purity of FP products and pursue R&D programs for the advancement of technologies allowing for the replacement of PFAS-based polymerization aids and their implementation when proven technically feasible, environmentally sound and viable.

PlasticsEurope
Association of Plastics Manufacturers
Fluoropolymers Product Group

EU legislation dealing with industrial emissions and waste should be reviewed and updated to ensure that adequate technical controls are put in place to minimise any risk

4 EU LEGISLATION

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Association of Plastics Manufacturers
Fluoropolymers Product Group

5 COMPETITIVENESS

It is expected that any regulatory action that may lead to limiting the market access for fluoropolymers could result in the complete relocation of this industry outside the EU.

fluoropolymers.plasticseurope.org/

Development of data and evidence on fluoropolymers

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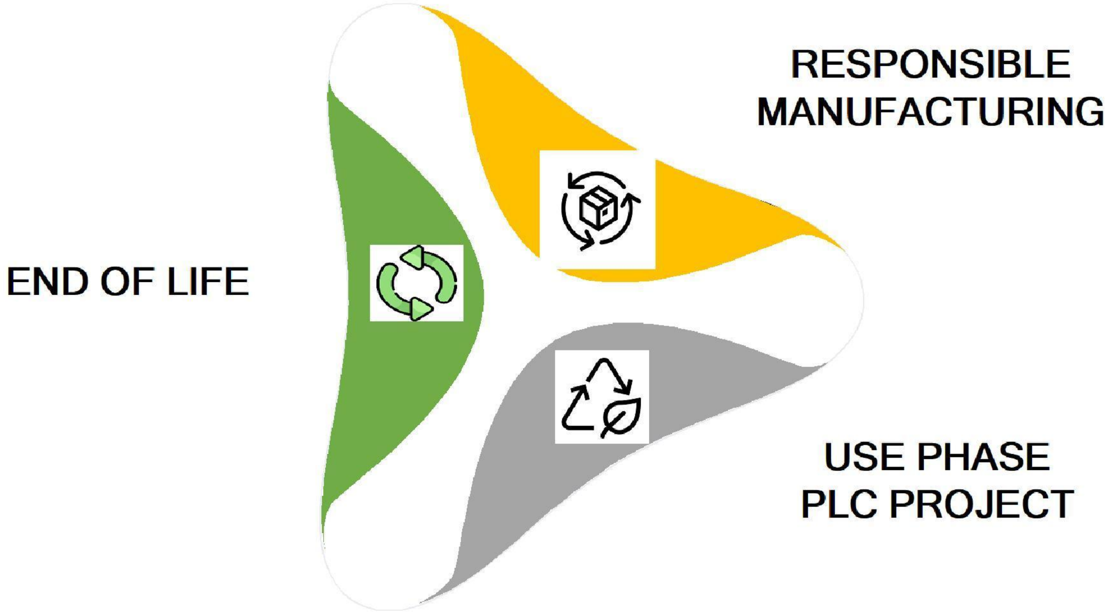

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THE FLUOROPOLYMER PRODUCTS GROUP COMMITS TO RESPONSIBLE MANUFACTURING PRINCIPLES

The fluoropolymer industry, represented by the **PlasticsEurope Fluoropolymer Products Group**, is committed to develop and implement innovative solutions to minimize the environmental footprint associated to fluoropolymer production and to reduce their potential emissions, based on the Best Available Techniques (BATs).

The fluoropolymer industry has adopted and will continue to develop new technologies and to invest in R&D to reach this goal. Therefore, the Fluoropolymer Products Group member companies commit voluntarily to the following **responsible manufacturing principles.**

FPG'S PRINCIPLES

1 BEST AVAILABLE TECHNIQUES

Continue to maintain, improve and/or develop Best Available Techniques in the manufacturing processes and management of environmental emissions related to fluoropolymers.

2 CONTAINMENT, CAPTURE & RECYCLE TECHNOLOGIES

Continuously improve and develop containment, capture, and recycle technologies to minimize emissions into the environment from PFAS substances intentionally and non-intentionally present in fluoropolymers including fluorinated raw materials, polymerization aids, monomers, intermediates, and process chemicals as well as by-products.

3 SAFE SUBSTITUTION OF PFAS-BASED POLYMERIZATION AIDS

Intensify our efforts to investigate and develop R&D programs for the advancement of technologies for the replacement of PFAS-based polymerization aids during fluoropolymer production. Where proven technically feasible, environmentally sound, and viable at an industrial and commercial scale, FPG commits to replace the use of PFAS as polymerization aids.

4 ENHANCED RECYCLABILITY AND REUSABILITY

Continue to proactively work with its downstream users to increase recyclability and reuse of its products and develop R&D programs in line with the objectives of a circular economy.

5 ENSURE WORKERS MINIMAL EXPOSURE TO CHEMICALS

Continue to minimize the exposure levels for workers to chemicals used in the fluoropolymers manufacturing process.

6 MONITOR COMMITMENTS THROUGH THIRD-PARTY ASSESSMENT SYSTEMS

Introduce or expand already existing third-party assessment programs to help verify progress in members' commitments.

7 OPEN AND TRANSPARENT DIALOGUE WITH KEY STAKEHOLDERS

Continue to engage in an open and transparent dialogue with policymakers, employees, NGOs and other key stakeholders.

FPG COMMITMENTS

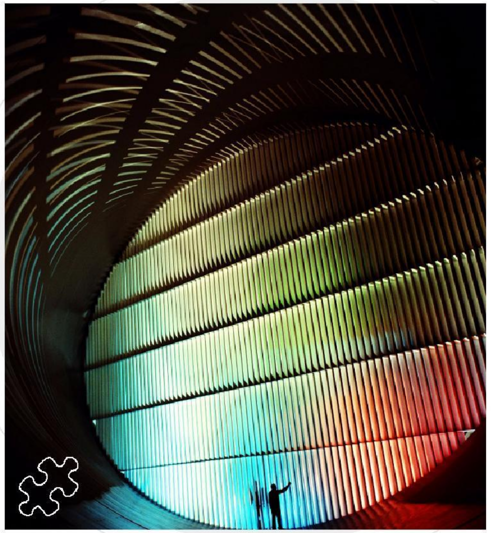
Each member company takes actions to implement these responsible manufacturing principles. In addition, the Fluoropolymer Products Group members aim to demonstrate progress on these actions by reporting on their achievements. As a first step, the Fluoropolymer Products Group is currently working on a review of wastewater related monitoring activities. The objective is the identification of best practices and possibly recommendations for procedural changes.

FPG members have voluntarily committed to responsible manufacturing principles.

FPG member companies are working on both individual and joint projects at the trade association level with third party experts to continue to implement FPG responsible manufacturing principles.

With the support of the consultancy firm Ramboll, FPG is working on a project of defining a set of implementable and measurable activities to minimize our environmental footprint with respect to the manufacturing of fluoropolymers.

A “responsible manufacturing label” could be assigned to the companies that fulfill a certain number of selected activities. The label will indicate that the individual company goes beyond the related minimum legal requirements.



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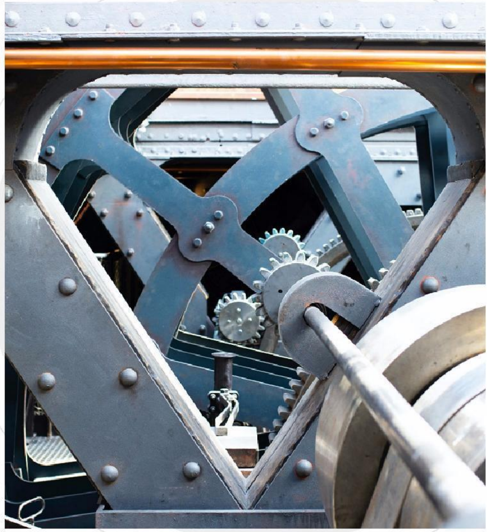
Recent work by the industry on PLC shows that the main commercial fluoropolymers meet the criteria to be considered polymers of low concern.

The above information is an EMBARGOED MANUSCRIPT submitted for publication. Therefore, we ask you NOT TO CITE OR QUOTE, and this information is for YOUR USE ONLY.

In 2018, the Henry et al. paper assessed four fluoropolymers (PTFE, FEP, PFA and ETFE) towards PLC criteria. Over the past two years, the industry has assessed 14 additional commercially available fluoropolymers for performance properties and functionalities. The data of this study show that they satisfy the accepted polymer hazard assessment criteria to be considered polymers of low concern (PLC).

The current study in combination with Henry et al. 2018, represent approximately 96% of the global fluoropolymers sold globally in 2021.

The article is currently under peer-review and is anticipated be published before the Summer.



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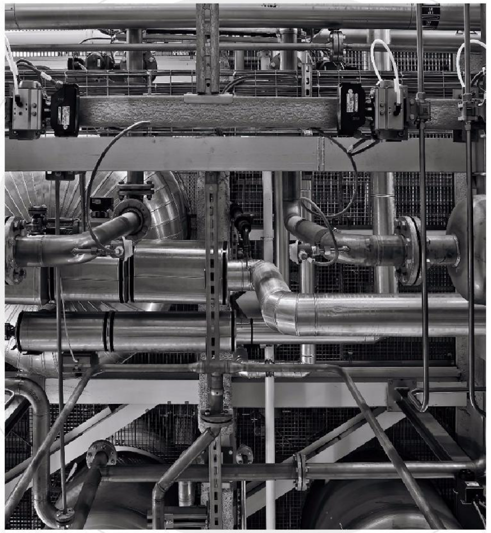
Concerns related to the disposal of PFAS, are not typically related to fluoropolymers as there is evidence that fluoropolymers such as PTFE
do not degrade in the environment or release substances of toxicological or environmental concern.

INCINERATION

Various studies strongly suggest that PTFE, the most stable fluorine-containing polymer, undergoes complete thermal decomposition at a temperature of about 800°C. Therefore, it is assumed that all other fluorine-containing polymers also thermally decompose completely at a temperature of 800°C.

Performance Fluoropolymers Partnership under American Chemistry Council is conducting a scientific study on incineration of FPs. Study project aims to identify optimum combustion conditions of FPs to achieve 'controlled emissions state' and ensure fluoropolymers get completely mineralized.

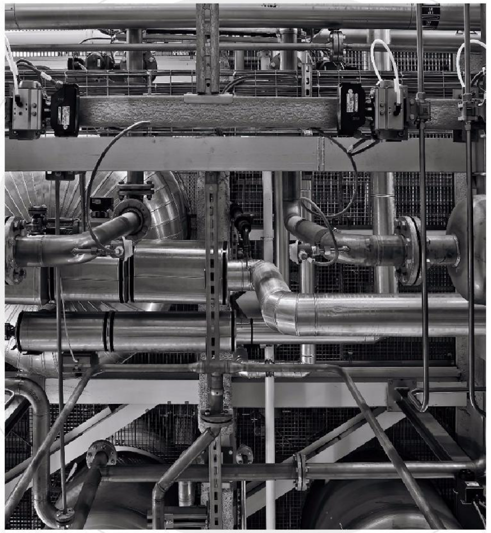


Landfill

FPs are inherently safe, non-mobile, non-bio accumulative and non- toxic. FP waste is chemically inert and, therefore, FPs disposed in landfills do not pose any threat to human health and environment.

Recovery & recycling

- ✓ Solid FP waste is grounded and fed back into the manufacturing cycle of FP products, wherever possible.
- ✓ One FP manufacturer is operating an Upcycling facility to convert PTFE waste into its monomer.



ANNEX

PLASTICS EUROPE
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S.No.	Industry/Application area	Uses	Fluoropolymers used	Emissions	Use segment	Key Benefits - Why are FLP's used in this application?	Issues of alternatives - what are the trade-offs?	Impact on Sustainability	End-of-life options
				During life	Industrial Professional Consumer		Cost and time of requalification. Impact of performance		
1	**Chemical Process Industry**	Gaskets, seals, packing Vessel liners pumps Valve and pipe lining Chemical transfer hose tubing coating expansion joints and bellows heat exchangers, Chlorine-Alkaline Electrolysis Cells (UHDE) inlet and outlet tubes, gaskets Filter bags	PTFE PFA/MFA ETFE ECTFE FEP FKM	0 during intended use	Industrial	In general Fluoropolymers in chemical manufacturing equipment is used to protect steel housing against a harsh chemical environment. As such it prolongs life of equipment, including pipes, fittings etc., prevents spilling of chemicals into the environment and keeps workers safe. Key properties used in general is the continuous service temperature (up to 260C for PTFE) and resistance to harsh chemicals.	IIn the absence of Fluorpolymer use in harsh enviroments, materials that withstand these enviroments less well can be used. It will result in more frequent shutdowns of complicated processes - which is inherently unsafe - and may cause unwanted spills and accidents. An alternative, in some cases, is the use of high end alloys which significantly drives cost up, and in extreme cases even exotic alloys won't have the required corrosion resistance Chemical industry is highly efficient and added capital cost will probably cause the industry to operate outside EU borders in time.	Risk of spills and othe runwanted emsissions from Chemical manufacturing sites	In general equipment in the chemical industry stays in use over the life of the plants (>30yrs). When plants are decommissioned, metals are recycled by scrap dealers. With proper regulation in place, FLP's could be seperated as well for incineration, chemical/mechanical recycling
2	**Powerplants**	Desulpherization of powerplant flue gas, heat recovery to improve overall efficiency Generator cooling hose PTFE nozzles high voltage circuit-breakers	PTFE PFA FEP	0 during intended use	Industrial	Long life of heat exchanger tubing - as in the case of chemical plants, frequent shut downs are unsafe and costly. For coolant hoses in generator stator winding cooling PTFE offers , no ageing. excellent electrical resistance, no risk of arcing	Any other material is either very expensive or does not last as long as FLP heat exchangers - thus requiring frequent unwanted power plant stops.	Higher emissions of SO2 to the atmosphere	These HEX (70-100t/piece) are easily taken apart and the FLP could be offered to any of the EOL options

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3	**Automotive (with ICE)**	Fuel lines Hoses Fuel management systems Seals & gaskets Oil pan O rings ABS brake lines Lambda sensor components Break pad wear indicator Wire conduits Push-pull cable liner	PTFE FEP PFA THV ETFE FKM	0 during intended use	Industrial when producing the components, Professional when installing, Consumer in use	Under the hood temperatures of cars are high due to noise reduction as well as ever increasing fuel economy (turbo chargers, direct injection etc). Also aggressive synthetic oils are used in break- and other hydraulic systems. FLP's are required for the combination of its high continuous service temperatures as well as resistance to aggressive chemicals (oils, Adblue, fuels) Key benefits include Better fuel economy from weight saving Increased lifetime of components Improved reliability and lower maintenance costs. Permits use of alternative fuels About 300 – 500 grams of FLP is used per car	Alternative materials in most cases increase the weight of the car and averse effect on fuel economy. As such will increase carbon footprint Lower quality material replacements will result in higher maintenance cost and lower car reliability. Component developemnt and re-qualification are costly and in general take years.	Higher carbon footprint	In general the components used in cars are small and integrated in complicated equipment. Seperation is not easy, and probably costly.
4	**Automotive (with Fuel cell and or battery)**	Fuel cells as a power source	IX membranes FKM	0 during intended use	Industrial professional	Fuel sells for use in cars use a FLP membrane as well as FLP seperation gaskets, as the environment is acidic. The key benefit is longer life and safety in an hydrogen environment.	Lower electrical performance which means larger fuel cells for same power output. FC's are competing with the ICE that cost on average around $2500. High efficiency is needed; not clear if that can be reached with alternative materials	Impact on life (Circularity)	Membranes are made of PSPVE film on a grid of PTFE - incineration is probably the only option
		Battery as power source	PTFE PVDF	0 during intended use	Industrial professional	Lithium batteries need binder material for the eletrolyte (which is semi liquid). FLP's have proven to be extending batterie lifetime. Also FLP's are used as a seperator increasing the safety of (car-) batteries	Industry accepts a lower margin of fire safety - which will not happen.	Impact on life (Circularity)	Li-ion batteries will be recycled in the future. Seperating the binder material from the kathode material will be difficult - but not undoable.

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5	**Aerospace**	Fuel Hoses	PTFE	0 during intended use	Industrial	Overbraided, conductive PTFE hoses are used for aircraft fuel transport to the jet engines. A combination of resistance to heat and to aggressive Jet fluel is the reason FLP's are used.	Aircraft industry is very conservative industry. Proven safe solutions are hard to replace on current aircraft designs. Other materials, such as metals, are less safe, heavier, and do not allow for modern design constructions that vibrate extensively.	GHG emissions (light weight)	Fuel hoses are relatively easy to take apart and FLP's can be seperated.
		Jet engines	PTFE FKM	0 during intended use	Industrial	Components as seals, hoses and wiring need to withstand extreme temperatures and aggressive fuels and greases. Weight reduction, Reduction in emissions, increased fuel economy and Safe aircraft operation	Other materials would increase weight and or reduce safe operation. Requalification time is lengthy	GHG emissions (light weight)	In general the components used in jet engines are small and integrated in complicated equipment. Seperation is not easy, and probably costly.
		In-flight connectivity	PTFE	0 during intended use	Industrial professional	Recent developments enable improved communication and internet access in aircrafts with excellent telecommunications and positioning signals without increasing the size/weight of hardware required. This is achieved with cable-based antennas constructed with engineered fluoropolymers and light coaxial cables.	Other materials to be used in coax cables would decrease fire safety and impact performance.	GHG emissions (light weight)	In General wire and cable end-of-life operations exist - mainly to extract copper for re-use. FLP's could with some effort be seperated as well.
		Aircraft interior Films	PVF	0 during intended use	Industrial professional	Aircraft interiors (siding) can be coated with a FLP film. This specific choice combines three FLP benefits: Fire Safety , easyclean and non fouling and long life. The FLP has a fire retardency effect on the underlying composite structure	There are no films that exhibit the same combination of benefits. Note that once installed the interiors last the liftime of an aoroplane.	Circularity (Longer life)	It is relatively difficult to separate the films from the underlying composit structure and incineration is probably the best end of life option
		Overhead bagage bins	PTFE	0 during intended use	Industrial professional	ABS used for overhead bins contains PTFE for so called anti drip effect - enhanced fire safety	Safety: Industry has to accept a lower UL fire class.	GHG emissions (light weight)	Impossible to separate PTFE from the ABS matrix. Incineration is the only option. Mechanicat recycles has an impact on the anti-drip effect.
		Sealants	PTFE	0 during intended use	Industrial professional	Sealants based on FLP are used extensively in aircraft: - To seal components against moisture or fluids - To provide leak proof against water, fuel and air -To improve aerodynamics (minimize noise and air resistance To improve fretting protection (avoiding abrasion between surfacses due to moveable structure (wing flaps)	Alternatives to the PFAS might be possible, but would require a completely new development of the sealant, which might take years and would be not in line with the authorisation requested.	GHG emissions (light weight)	
		In-flight entertainmentt cabling	PTFE		Industrial professional	Typical modern aircraft have 150 – 250 km's of wiring installed. (Airbus 380 has >500 km). Excellent dielectric properties allow for very thin cables, while the main reason to use FLPs in cable systems is fire safety.	Opting for conventional insulation systems would increase the weight of the cable system significantly and would thus increase the fuel use. The trade-off here is on safety and GHG emissions.	GHG emissions (light weight)	In General wire and cable end-of-life operations exist - mainly to extract copper for re-use. FLP's could with some effort be seperated as well.
	Aerospace (cont'd)	High Performance Aerospace Wires	PTFE	0 during intended use	Industrial professional	The move in aerospace industry to "fly-by-wire" whereby conventional manual flight controls are replaced by an electronic system which has as primary benefit weight reduction. PTFE as insulation provides excellent electrical resistance combined with fire resistance and low smoke	Opting for conventional insulation systems would increase the weight of the cable system significantly and would thus increase the fuel use. The trade-off here is on safety and GHG emissions.	GHG emissions (light weight)	In General wire and cable end-of-life operations exist - mainly to extract copper for re-use. FLP's could with some effort be seperated as well.

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				During life	Industrial Professional Consumer		Cost and time of requalification. Impact of performance		
	Medical	Catheter	PTFE	0 during intended use	Industrial professional	Patient comfort and safety Reduced risk of cross-infections and thus medical complications. Higher consistency of dosages, increasing effectiveness and safety of drugs. Less frequent clogging and thus less frequent re-application/replacement for the patient (e.g. catheters, tubes). Biocompatible (USP Class VI)	Alternatives impact comfort and patient safety (infections) negatively		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Needle coatings	PCTFE	0 during intended use	Industrial professional	Safety in deep needle operations including certain drug injections and biopsies	Alternative materials create room for cross-contamination and material failure		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Implants: Cardiovascular grafts, arteries, hernia mesh, stents, ligaments	PTFE	0 during intended use	Industrial professional	Inert, compatible with body, no repulsion, life time Reduced risk of cross-infections and thus medical complications. Increased lifetime of implants reducing risk of failure and risk of replacement. Allows tissue attachment and cell adhesion without an adverse reaction, reducing risk of complications.	For now PTFE seems to be the only proven material that works well in this application.		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Medical garments		0 during intended use	Industrial professional	Disease transmission prevention - as a result of non stick properties.	Other materials, like PE, can be used, but do not have the ultimate performance.		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Packaging films for medical products		0 during intended use	Industrial professional	Easy to sterilise before use.	Other materials, like PE, can be used, but cannot be cleaned as thoroughly as FLP's		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Sterile, corrosion resistant equipment linings and coatings such as diafrahgm pumps		0 during intended use	Industrial professional	Easy sterilization and thus reduced risk of cross-infections	Other materials, like PE, can be used, but cannot be cleaned as thoroughly as FLP's and therefore cannot easily be re-used.	Circularity (Longer life)	Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
	Pharmaceutical	Lined fluid systems	PTFE PFA FEP	0 during intended use	Industrial professional	For Easy clean and sterilization - FLP's are used for similar reasons as the chemical Industry do.	Other materials can be used, such as glass. Life of the equipment becomes an issue.	Circularity (Longer life)	Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Metered dose inhalers coatings		0 during intended use	Industrial professional	Higher consistency of dosages, increasing effectiveness and safety of drugs.	Alternatives may impact health risks from cross contamination and over- or under-dosage of pharmaceuticals		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible
		Medical packaging (caps for injection doses)	FEP PFA ETFE	0 during intended use	Industrial professional	Higher consistency of dosages, increasing effectiveness and safety of drugs.	Alternatives tend to either contaminate the medicine or lack the non stick properties.		Medical waste is already collected separately and incinerated. Separation of FLP's is not feasible

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	Electrical/Electronics	Wire and cable insulation (plenum cabling (Cat 5-7), UBS-C, mobile telephony riser cables)	FEP	0 during intended use	Industrial professional	Excellent dielectric properties in combination with other properties are the reasons FLP's are used in a wide area of applications. Specifically Plenum cables are installed in a/c ducs (in US and airports and buildings worldwide) and have to be insulated by FLP's for fire safety (on top of the am reasons)	Cable of which the jackets can burn, need to be installed in metal conduits where possible, increasing the cost significantly		In General wire and cable end-of-life operations exist - mainly to extract copper for re-use. FLP's could with some effort be seperated as well.
		Hard disk drives	PTFE	0 during intended use	Industrial	FLP components in hard drives extend life of the parts that need high dielectric strength.	Alternatives decreases lifespan of the components in which they are used by up to three times due to the lack of extreme temperature resistance	Circularity (Longer life)	Electronic waste is increasingly collected separately , but separating out the FLP parts is difficult.
		Wireless devices	PFA PFTE	0 during intended use	Industrial	FLP's are used in the antenna (coax), circuit boards and Li-ion batteries	Other materials have reduced purity during fabrication, may lead to cross-talk when operating at high frequencies The alternatives to lithium-ion batteries are lead acid batteries, which do not contain fluoropolymers. They offer reduced performance notably in terms of energy efficiency and are heavier resulting in reduced functionality and increased energy consumption compared to lithium-ion batteries		Electronic waste is increasingly collected separately , but separating out the FLP parts is difficult.
		connectors		0 during intended use	Industrial	In the effort of extreme miniaturization, small parts with high dielectric strength are needed. FLP's have a proven track record.	Equipment will need to become bulkier in order to get the same dielectric performance - in some cases where high heat resistance is also needed, replacement will be an issue	Circularity (Longer life)	Electronic waste is increasingly collected separately , but separating out the FLP parts is difficult.
		HF printed wiring boards	PTFE PFA	0 during intended use	Industrial	Excellent dielectric properties at microwave frequencies, while PTFE films do not melt during soldering process.	HF boards cannot be made		Electronic waste is increasingly collected separately , but separating out the FLP parts is difficult.
		Wearable devices	FKM	0 during intended use	Industrial Professional Consumer	FLP's are used in smart watch straps. The value in this application is longevity and skin compatibility	Alternative materials do not show combination of properties such as water/dust/dirt repellency, chemical inertness and does not casue skin sensitivity and irritation.	Circularity (Longer life)	Watch bands can easily be collected. Recycling is partly possible, but cured rubbers cannot be uncured.

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5	**Semiconductor and other electronic manufacturing**	Plasma machinery	PFA	0 during intended use	Industrial	Specifically in semiconductor manufacturing FLP's are used in fluid handling part of the process where ultra pure types are used with very low leachable content that can withstand the harsh chemicals used in the etching process	There are no alternatives if manufacturers want to get to current wafer size. A larger wafer diameter enables producing more semiconductor devices from a single wafer, enhancing productivity and efficiency. If foundries would still produce 1 inch wafer today, there is no chance they'd be able to support the volume of smart-phones, tablets and PCs.		FLP's from disbanded fabs are collected, cleaned and re-used
		Wafer carriers	PTFE PFA HP	0 during intended use	Industrial	Resistance to harsh chemicals Purity - no contamination of wafers, or ultrahigh-purity process fluids	There are no alternatives for this specific use while keeping the overall yield of IC's per wafer high		FLP's from disbanded fabs are collected, cleaned and re-used
		Fluid handling systems	PFA	0 during intended use	Industrial	High purity PFA is needed to keep fluids used in manufacturing ultra pure. It allows larger wafers and therefore ever improving and affordable microchips and LEDs due to higher production yields in semiconductor manufacturing. Manufacturing cost savings (component lifetime increase, lower maintenance cost, lower material consumption). Reduced environmental risk (leak prevention, lower exposure of workforce to chemicals).	There are no alternatives if manufacturers want to get to current wafer size. A larger wafer diameter enables producing more semiconductor devices from a single wafer, enhancing productivity and efficiency. If foundries would still produce 1 inch wafer today, there is no chance they'd be able to support the volume of smart-phones, tablets and PCs.		FLP's from disbanded fabs are collected, cleaned and re-used
		Fab Infrastructure		0 during intended use	Industrial	Fluoropolymer articles in water purification, chemical delivery and waste management systems (tank and duct linings, pipes,etc	See above		FLP's from disbanded fabs are collected, cleaned and re-used

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6	**Renewable energy**	Photovoltaic solar cells	PVDF ETFE	0 during intended use	Industrial professional	Photovoltaic cell life is amongst others influenced by moisture. Performance is reduced significantly when moisure enters the cell. Most cells need a life guarantee of 20 - 30 years in order to to have investment payback vs conventional energy systems. FLP front and backsheets provide that moisture barrier and life time guarantee as well as improved fire safety	Alternatives reduce life and reliability of photovoltaic cells.	Circularity (Longer life)	Larger films protecting the cells are easily removable and could be mechanically recycled
		lithium batteries	THV ECTFE PTFE PVDF	0 during intended use	Industrial Professional	Lithium batteries need binder material for the eletrolyte (which is semi liquid). FLP's have proven to be extending batterie lifetime. Also FLP's are used as a seperator increasing the safety of (car-) batteries	Alternative materials increase the risk of fire and will reduce battery life and charge speeds	Circularity (Longer life) and GHG emissions	Batteries will need to be recycled if only for rare metal content. Binder material will probably be incinerated.
		Hydrogen electrolysers		0 during intended use	Industrial	The production of hydrogen using the electrolyser route requires a FLP membrane, whereas most of the fluid handling syetems are also FLP. This to withstenad a harsh environment and thus extending life.	FLP membranes are part of an very efficient PEM - alternative materials exist, but are less efficient and less resistant to harsh environments	Circularity (Longer life) and GHG emissions	Membranes can be easily collected separately , but need to be incinerated
		coatings for windmill blades	PVDF	0 during intended use	Industrial professional	Once constructed it is very costly to take it down and disassemble for maintenance. FLP coatings make sure blade life is extended	Alternative materials can certainly be used, trade-off is higher maintenance cost and potentially safety concerns	Circularity (Longer life)	It is impossible to separate the coating from the blades and incineration is the route of choice

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7	**Construction/Architechture**	Coated fabrics for buildings/roofs	PTFE	0 during intended use	Industrial professional	FLP's are used in construction because of its excellent weatherability properties and enhanced Fire Performance. Roofing systems as well as exterior coatings do not stain, avoid algae growth and have a very long life. As such maintenance cost is very low while the esthetics remain good through the lifetime of the building. Extending life is an important parameter in the efforts to move towards a Circular economy	Alternative materials can certainly be used, trade-off is higher maintenance cost and potentially safety concerns	Circularity (Longer life)	PTFE coated fabrics are difficult to separate.
		façade and infrastructure protection	PVDF PVF	0 during intended use	Industrial professional	FLP's are used in construction because of its excellent weatherability properties. Roofing systems as well as exterior coatings do not stain, avoid algae growth and have a very long life. As such maintenance cost is very low while the estetics remain good through the lifetime of the building. Extending life is an important parameter in the efforts to move towards a Circular economy	Conventional coatings need frequent re-appliance and start to look dirty after some time.	Long vs short life in the circularity definition	PVDF/PVF coatings in metal are difficult to separate
		Gas tapes	PTFE	0 during intended use	Industrial Professional Consumer	Due to its chemical inertness, PTFE tape is resistant to both petrol and oil. Therefore, it is often used in automotive applications to seal and lubricate fuel line joints. Plumber's lubricating and sealing tape is designed to cope well under moderately high pressure and heat demands.	Prior to PTFE, Hemp was used. Hemp has lower resistance to aggressive fuels and dries out in natural gas service causing leakage.	Increased leakage of GHG gases (methane)	It is relatively easy to separate the tape from the threads and treat seperately. Incineration/upcycling is probably the best option

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	Food	Bakeware/Cookware	PTFE FEP PFA	0 during intended use		In this food segment FLP's are used mainly for their non-stick and easy clean properties – at elevated temperatures. FLP's also allow for cooking with little or no oil.	Certainly possible to cook/bake without FLP lined cook and bake ware. It requires more oil to prevent attachment to the cooking surface (Health) while cleaning requires more time.	Higher use of water for cleaning	It is difficult to separate coatings from cook and bake ware. Incineration during the iron/aluminium recycling process is easiest
		Ind Bakeries - belts	PTFE	0 during intended use		In this food segment FLP's are used mainly for their non-stick and easy clean properties – at elevated temperatures	Transport belts not coated with FLP; are less easy to clean (hygiene) and bread and bakery tends to stick to the belt.	Circularity (Longer life)	It is difficult to separate coatings, often, woven glass cloth. Incineration during the glass recycling process is easiest
		Oven and duct coating		0 during intended use		In this food segment FLP's are used mainly for their non-stick and easy clean properties – at elevated temperatures	Uncoated ducts and ovens need daily time consuming cleaning	Higher use of water for cleaning	It is difficult to separate coatings from substrates
	Consumer	Wearables	FKM	0 during intended use		See under Electronics			
		Cell phones	PTFE FEP	0 during intended use		See under Electronics			
		Apliances	PTFE	0 during intended use		In this segment FLP's are used in hi temp area's which in some cases are subject to strong surfactants	Alternatives reduce life of the appliance	Circularity (Longer life)	Appliances are often collected separately. Taking out the small FLP parts will be labour intensive
		Bicycles/motorcycles	PTFE	0 during intended use		See under automotive			
		Cosmetics	PTFE	0 during intended use		According to the web-based International Cosmetic Ingredient Dictionary and Handbook (wINCI; Dictionary), these fluoropolymers are reported to have the following functions in cosmetics: bulking agents, slip modifiers, film formers, viscosity increasing agents, dispersing agents, skin conditioning agents, skin protectants, and hair conditioning agents.1 Most of the ingredients have the film former function in common			
		Cars	Various	0 during intended use		See under automotive			

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