



September 17, 2026

Hon. James Kenney, Secretary
New Mexico Environment Department
Harold Runnels Building
1190 St. Francis Drive, Suite N4050
Santa Fe, New Mexico 87505

Re: House Joint Memorial 3 -- Fluoropolymer Exemption

Dear Secretary Kenney:

AGC Chemicals Americas (“AGCCA”) and its parent company, AGC America, Inc., (jointly referred to as “AGC”) appreciate this opportunity to provide information to support the efforts of the New Mexico Environment Department (NMED) in implementing House Joint Memorial 3, which directs NMED to report on the environmental, health and economic impacts of the statutory exemptions set forth in the PFAS Protection Act (“PPA”); NMSA §§ 74-15-1 to 74-15-7 and to recommend to the legislature whether to continue, modify or remove those exemptions. Our comments focus primarily on the exemption for products containing fluoropolymers in PPA Section 3(A)(16), NMSA § 74-15-3(A)(16). As discussed in these comments, the evidence demonstrates that fluoropolymers and products containing fluoropolymers are safe, in addition to being critical to the economy of New Mexico, and that continuing the fluoropolymer exemption in the PPA is clearly justified.

AGCCA manufactures and supplies a range of specialized industrial chemicals and materials, including resins, coatings, films and membranes, that are incorporated into a wide range of products essential to the daily lives of New Mexico residents and businesses. Many of these materials are comprised of fluoropolymers. AGC’s other North America businesses including automotive glass, life sciences, electronic materials for semi-conductor applications, and coating equipment, all use essential fluoropolymers in their manufacturing operations or incorporate them into the products we sell to customers, including customers in New Mexico, or customers who incorporate them into their products that are then sold in New Mexico.

Although fluoropolymers fall within the extremely broad definition of “PFAS” used in the PPA, they are very much **unlike** the PFAS chemicals that have been found in drinking water, groundwater and blood samples, such as PFOA and PFOS. For example, unlike those PFAS

chemicals of concern, fluoropolymers are not soluble in water, so they cannot enter drinking water or groundwater. Furthermore, fluoropolymers do not degrade into smaller, water-soluble molecules. Also, fluoropolymers are not bioavailable nor do they degrade to smaller, bioavailable molecules, so they do not present toxicity concerns associated with PFAS chemicals of concern. Indeed, as discussed further below, peer-reviewed studies demonstrate that, because of these and other characteristics, fluoropolymers satisfy internationally-recognized criteria for being “Polymers of Low Concern” (PLC) -- i.e., polymers deemed to have insignificant environmental and human health impacts. (Henry et al. 2018; Korzeniowski et al. 2022). Furthermore, the safety of fluoropolymers is corroborated by a substantial body of experimental and clinical data, which we elaborate on in subsequent sections.

Fluoropolymers also possess a unique **combination** of properties that make them critical to the performance of a wide range of products and technologies, such as semiconductors, fuel cells, wind turbines, printed circuit boards, coated wires, batteries, solar photovoltaics, avionics, aircraft components, motor vehicle engines, manufacturing equipment, medical devices, scientific instruments, and laboratory and diagnostic equipment, among others. This unique, and irreplaceable, combination of properties includes the following:

- **Heat resistance:** fluoropolymers are able to maintain their physical properties at very high temperatures. This makes them particularly suitable for use in aerospace and electronic components.
- **Chemical resistance:** fluoropolymers are highly resistant to chemicals, acids, fuels, and solvents. This makes them a material of choice for use in chemical processing equipment, aerospace, automotive and pharmaceuticals.
- **Mechanical resilience:** mechanical properties include high tensile strength, flexibility, and impact resistance. This is particularly important in applications such as seals and gaskets as well as architectural films and coatings.
- **Electrical properties:** fluoropolymers have low dielectric constant, high insulation durability, and are used as sheathing materials for wire and cable due to their excellent electrical properties.
- **Inertness:** fluoropolymers are inert, non-reactive and stable (they do not degrade or decompose over time) (Henry et al. 2018). These properties make them critical to a wide range of industrial and commercial applications in situations where equipment is likely to be exposed to chemicals.
- **Cryogenic properties:** fluoropolymers present excellent cryogenic properties, which makes them particularly suitable for use in high-tech applications such as aerospace, electronics, defense applications, and chemical industries.
- **Separation / barrier properties:** fluoropolymers have excellent moisture barrier and superior gas separation properties. Fluoropolymer membranes are essential to the production of clean hydrogen.

- **Dielectric properties:** dielectric properties cover low dielectric constant (Dk) and dissipation factor (Df) and are unaffected by fluctuations in temperature and humidity. This makes fluoropolymers a critical material for use in electronics and telecommunication applications.
- **Weather resistance:** fluoropolymers are able to maintain their physical properties even when exposed to harsh weather conditions, e.g., environmental degradation, including exposure to ozone, ultraviolet radiation and extreme temperatures (Korzeniowski et al. 2022; PFP 2023). This makes them an essential material for architectural coating and films.
- **Durability:** fluoropolymers can withstand harsh conditions while maintaining their physical properties (Henry et al 2018). This makes them particularly important for use in seals, gaskets, and wires and cables insulation.
- **Anti-adhesion properties:** fluoropolymers prevent sticking, making them a material of choice for applications for which friction and adhesion are concerns.

As we discuss in more detail below, this unique combination of properties underlies the irreplaceability of fluoropolymers in a wide range of applications, including those noted above. Alternative materials may be able to achieve comparable performance to fluoropolymers for one or a few specific parameters or properties, but overall, due to deficiencies in other properties, they have lower performance and other disadvantages as compared to fluoropolymers. Thus, while alternatives might be considered to be comparable in one or two dimensions of performance, they often fail to offer the combination of properties that fluoropolymers deliver.

Specific to New Mexico, fluoropolymers are utilized in a wide range of applications that are critically important to New Mexico's residents and businesses. As we discuss in more detail below, because of their specific performance characteristics, fluoropolymers typically function to enhance the safety, durability and reliability of the applications and processes in which they are used. Because of this, and because of the unavailability of suitable replacements for fluoropolymers in most applications, if fluoropolymers were to become unavailable in New Mexico, the resulting economic dislocation would likely be widespread and severe. In addition, threats to health and safety would likely increase. For all these reasons, and based on the safety of fluoropolymers to human health and the environment, it is essential that the exemption for fluoropolymers in the PPA remain intact and unchanged.

Background

Fluoropolymers are a class of polymers in which carbon atoms in the polymer backbone are bonded to fluorine atoms. Specifically, the chemical composition of fluoropolymers consists of long, high molecular weight chains of carbon atoms bonded together in repeating units (Buck et al. 2011). These carbon atoms form the spine of the polymer chain, along which fluorine and other atoms are bonded (Ebnesajjad 2021). The large size and lack of water-solubilizing

functional groups in fluoropolymers result in materials that are considered immobile in the environment, are resistant to chemical degradation, and are stable under typical biological, and environmental conditions (Henry et al. 2018). Fluoropolymers are characterized by their ability to withstand both acids and bases, high temperatures, ultraviolet light, and strong mechanical degradation (Henry et al. 2018)

The most commercially relevant fluoropolymers are polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), perfluoroalkoxy alkane (PFA), and fluoroelastomers (FKMs). PTFE represents greater than 50% of the commercial uses of fluoropolymers (Teng, 2012; Ebnesajjad, 2021). PTFE is commercially available in bulk solid, aqueous dispersion, and micro powder forms and is widely used in chemical processing equipment, non-stick coatings, seals, gaskets, bearings, wire and cable insulation, and medical devices due to its exceptional chemical resistance, low coefficient of friction, thermal stability, and electrical insulating properties (Teng, 2012; Ebnesajjad, 2021). PVDF is a partially fluorinated fluoropolymer that is commercially available as pellets, powders, films, fibers, and coatings (Ebnesajjad, 2021; McKeen & Ebnesajjad, 2023). Compared with PTFE and PFA, PVDF offers a combination of chemical resistance, mechanical strength, abrasion resistance, and ease of melt processing (Korzeniowski et al. 2022). These attributes have led to widespread use in lithium-ion battery binders and separators, semiconductor manufacturing equipment, water treatment membranes, wire and cable jacketing, architectural coatings, and piping systems for corrosive fluids (Liu et al., 2011; Barbosa et al., 2018; McKeen & Ebnesajjad, 2023). Demand for PVDF has increased substantially in recent years due to its critical role in electric vehicle battery production and renewable energy technologies.

PFA is a fully fluorinated melt-processable fluoropolymer that combines the chemical inertness and high-temperature performance of PTFE with the ability to be extruded and injection molded into complex shapes (Teng, 2012; Ebnesajjad, 2021; McKeen & Ebnesajjad, 2023). PFA is extensively used in semiconductor manufacturing, high-purity fluid handling systems, pharmaceutical processing equipment, chemical transport tubing, valves, pumps, and fittings where contamination control, corrosion resistance, and thermal stability are critical requirements (Teng, 2012; Jacobs & Kosson, 2024). FKMs are fluoroelastomer copolymers designed to provide elastomeric performance while maintaining resistance to fuels, oils, solvents, and aggressive chemicals (Logothetis, 1989; Ameduri, 2023). Commercially, FKMs are used primarily in seals, O-rings, gaskets, diaphragms, hose linings, and other sealing applications in the automotive, aerospace, energy, and chemical processing industries (Korzeniowski et al. 2022; Jacobs & Kosson, 2024; Periyasamy et al. 2024). Their combination of chemical resistance, low permeability, and durability under elevated temperatures makes them the preferred elastomer for demanding fluid-handling and engine-system applications. All four materials are characterized by exceptional chemical resistance, very low water solubility, hydrophobicity, and high thermal stability compared with conventional hydrocarbon polymers. In short, no other materials can provide the same combination of performance, reliability and safety characteristics as fluoropolymers, which is why manufacturers rely on fluoropolymers to ensure their products perform reliably, are durable, and keep people safe.

The remainder of these comments is divided into three sections. Section 1 addresses the safety of fluoropolymers. In this section we present the extensive evidence supporting the conclusion that fluoropolymers do not present significant concerns for human health or the environment. Section 2 addresses the primary concerns that have been raised with respect to fluoropolymers, which can be characterized as “life cycle” concerns. Section 3 addresses the economic importance of fluoropolymers, and the adverse economic consequences that would result if products made with fluoropolymers were no longer exempt from the PPA.

1. Fluoropolymers are Safe for Human Health and the Environment

Available studies demonstrate that fluoropolymers are characterized by very high molecular weight, low solubility, chemical inertness and limited ability to cross biological membranes, properties that reduce the potential for bioavailability and systemic exposure (Henry et al. 2018; Lee et al. 2022). In addition, a robust body of experimental and clinical data confirms that fluoropolymers do not present significant health concerns.

A. Fluoropolymers are Polymers of Low Concern

The polymers of low concern (PLC) criteria were developed to identify polymers that do not present concern for human health or the environment (Henry et al. 2018, OECD 2023). The PLC criteria were developed to be consistent with regulatory frameworks that evaluate physical-chemical properties of polymers to determine polymer bioavailability and point to potential hazard. Polymer experts within the OECD developed a set of consensus criteria, which facilitate the regulation of certain polymers that pose minimal risk to human health and the environment (OECD 2023). The PLC framework focuses on polymers that have high molecular weight, low content of low-molecular-weight species, low reactivity, low ionic/cationic character, low bioavailability, low environmental and toxicological concern, and stability under conditions of use. Although the criteria were never formally adopted at the OECD level, in a 2009 analysis of available data, OECD concluded that polymers meeting the PLC criteria are likely to have insignificant human health and environmental impacts (OECD 2023).

Three independent, peer reviewed studies have evaluated whether fluoropolymers meet the PLC criteria established by the OECD polymer experts, with the goal of understanding whether fluoropolymers should be assessed separately from small molecule PFAS (Henry et al. 2018; Korzeniowski et al. 2022; Javed et al. 2025). The studies reviewed physicochemical data, as well as available toxicology datasets and clinical human data from implant studies.

Henry et al. applied the PLC criteria to PTFE as an example fluoropolymer and concluded that fluoropolymers like PTFE satisfy the regulatory assessment criteria to be considered PLCs (2018). The study noted that fluoropolymers meet core PLC determinants including high molecular weight (>100,000 Da), insolubility in water and lipids, non-bioavailability (cannot cross cell membranes), low residual content, and low potential for leaching. Additionally, study authors

noted that the available toxicological data provide no evidence of systemic toxicity, chronic toxicity, reproductive or developmental toxicity, genotoxicity or carcinogenicity.

Korzeniowski et al. expanded the evaluation from the Henry et al. study to 14 fluoropolymers, including fluoroplastics and fluoroelastomers, incorporated additional industry datasets from seven global fluoropolymer manufacturers, and provided a systematic mapping to the PLC criteria. The study concluded that fluoropolymers are non-bioavailable, non-bioaccumulative, and nontoxic under intended conditions of use due to their high molecular weight, insolubility, and chemical stability. The authors stated that the fluoropolymers considered in their evaluation represent approximately 96% of global commercial fluoropolymer production. Additionally, the authors reinforced the point that physicochemical properties of materials like fluoropolymers determine their hazard potential, and the high molecular weight and insolubility of fluoropolymers leads to their lack of biological access, and thus lack of toxicity. Javed et al. reached similar conclusions with respect to perfluoropolyethers satisfying PLC criteria.

B. A Robust Body of Data Supports the Conclusion that Fluoropolymers are Safe

A number of toxicology studies have been conducted using different fluoropolymer materials that show no evidence of systemic toxicity or genotoxicity, and no consistent signals for sensitization or irritation under normal use.

The US Food and Drug Administration (FDA) has extensively reviewed the safety of fluoropolymers for human health. In August 2025 FDA published an article describing the history of use of PTFE in medical devices and affirming that there is no reason to restrict the use of PTFE in devices (FDA 2025a). FDA emphasizes that fluoropolymers like PTFE are different than PFAS used in other contexts and that have been reported to be associated with health concerns (small molecule PFAS like PFOA, PFOS) and that **fluoropolymers have been safely used in medical devices for decades**. FDA cites their previous PTFE safety assessment conducted in 2021 (ECRI 2021), which involved a review of over 1,750 scientific articles and patient safety information, and concluded that there was no evidence of patient health issues associated with PTFE. FDA notes that fluoropolymers used in medical devices have a **long history of safe use, starting in the 1950s**.¹

Separately, an expert panel relied upon by FDA reviewed available acute, short term, and chronic toxicity studies, as well as carcinogenicity and other endpoints, for PTFE and

¹ We note, for the sake of completeness, that there are a number of studies, primarily case reports and case series, that cite transient adverse effects such as “fluoropolymer flu” caused by inhalation of thermal degradation products of fluoropolymers like PTFE, primarily in occupational settings such as industrial processing, as well as overheated cookware. However, exposure potential is dependent on temperature, with minimal emissions occurring at 500°F and potential breakdown of the material leading to thermal degradation products (i.e. pyrolysis) at temperatures over 750°F (Correia and Horowitz 2023). This is a unique and limited exposure scenario, not representative of the general public’s exposure conditions and is not clearly related to fluoropolymer toxicity itself.

Hexafluoropropylene/ Tetrafluoroethylene Copolymer (CIR Expert Panel et al. 2018). The panel described available toxicological studies on PTFE materials, as follows:

- Acute oral toxicity studies of two anti-cohesive coating materials containing PTFE demonstrated low acute toxicity, with no mortality at doses up to 12.5 g/kg and 2.5 g/kg in mice and up to 6.25 g/kg and 1.25 g/kg in rats, respectively.
- An acute dermal study in which PTFE powder (0.5 g) was applied to intact and abraded rabbit skin for 24 h reported no deaths, clinical signs, or behavioral alterations.
- A short-term inhalation study in rats involving exposure to a 20% dispersion of a low molecular weight PTFE resin for 9 days reported no evidence of pathology attributed to the exposure.
- In a subchronic oral toxicity study, three types of PTFE resins were fed to rats for 90 days; no adverse effects on growth or behavior, or microscopic evidence of tissue changes, were observed.
- A developmental toxicity study exposed rats orally to two anti-cohesive coating materials containing PTFE (60% PTFE or 68% to 73% PTFE) daily from gestation days 7–16, and reported no adverse findings.
- In vitro and in vivo genotoxicity studies were negative for anti-cohesive coating materials containing PTFE (60% PTFE or 68% to 73% PTFE).
- A carcinogenicity study conducted by the National Toxicology Program (NTP) with tetrafluoroethylene (a gas used in the synthesis of PTFE) exposed F344/N rats and B6C3F1 mice via inhalation for 104 weeks concluded “sufficient evidence of carcinogenicity in experimental animals” based on incidences of hepatocellular tumors in both species and sexes, renal tubule tumors in rats, vascular tumors of the liver, and hematopoietic malignancies. This finding pertaining to a precursor gas has no bearing on the toxicity of the PTFE polymer itself.

FDA subsequently expanded on the CIR review (FDA 2025b). Key additional studies mentioned by FDA are summarized below:

- In an oral toxicokinetic study in mice, PTFE particles (~5 µm and 10-50 µm) were not detected in the blood after oral administration, which FDA interpreted to mean low oral absorption of PTFE. The same study included a 28-day exposure to 500-2,000 mg/kg/day of the PTFE particles and reported no adverse effects.
- An immunotoxicity study in mice, in which mice were exposed to 500-2,000 mg/kg/day of PTFE particles, reported no effects on immune cell populations but potential effects on immune markers; FDA noted the biological significance of these effects were unclear.

Based on its review of all of the available data, FDA concluded that “there is no evidence indicating that PTFE induces developmental and reproductive toxicity, neurotoxicity, or immunotoxicity” and “that PTFE is not a skin irritant or a skin sensitizer” (FDA 2025b).

For PVDF, available peer-reviewed studies include:

- An acute toxicity study exposed mice to 2,000 mg/kg PVDF for 1–14 days, and reported no deaths and no treatment-related changes in behavior or clinical parameters (Allayarov et al. 2021).
- A 30-day inhalation study in Wistar rats using PVDF nanofiber filters reported no lung damage, inflammation, or systemic toxicity, as well as no accumulation in lung tissue. Study authors concluded that PVDF nanofiber filters are biocompatible and safe for use in respiratory applications (Kim et al. 2026).

Finally, *in vitro* studies of PVDF have examined biocompatibility in biomedical applications, including films, membranes, electrospun fibers, and nanofiber scaffolds. These studies generally report good cell viability, adhesion, proliferation, and minimal inflammatory responses across a variety of cell types, including mesenchymal stem cells, endothelial cells, and fibroblasts (Serrano-Garcia et al. 2023; Alvarez-Perez et al. 2021; Durán-Rey et al. 2022).

As we have now identified and as is shown in the references and articles cited above (copies of which are appended to our submission in a separate Addendum), this substantial body of evidence confirms that using fluoropolymers or using products containing fluoropolymers is safe and not dangerous to human health or the environment.

2. Fluoropolymers Can be Safely Controlled Throughout Their Life Cycle

As described in the previous section, fluoropolymers used in products exhibit minimal toxicity and are safe. Similarly, the evidence clearly demonstrates that fluoropolymers and products containing fluoropolymers can be safely manufactured and safely disposed. More specifically, as elaborated on below, potential releases of smaller molecules associated with the manufacturing process (“beginning of life”) and potential emissions associated with the disposal of fluoropolymers and potential degradation products (“end of life”) can be safely and effectively controlled with existing technologies.

A. Beginning of Life: Potential Exposures from Fluoropolymer Manufacture Can Be Adequately Controlled to Eliminate Risk

Available evidence demonstrates that emissions of fluoropolymer manufacturing-related raw materials, polymerization aids, residual monomers, and manufacturing byproducts from modern fluoropolymer production facilities can be reduced to very low levels through the use of engineered control technologies, including thermal oxidizers, carbon adsorption systems, process enclosure, capture systems, and other emission-abatement measures. For example, at

a fluoropolymer manufacturing facility in North Carolina, implementation of controls has resulted in substantial reductions in air emissions, including installation of a thermal oxidizer designed to destroy over 99.00% of PFAS air emissions directed to it. Testing of the thermal oxidizer conducted under state oversight has consistently demonstrated PFAS destruction efficiencies exceeding 99.99%, with average control efficiencies reported to be greater than 99.999% for PFAS routed to the unit.^{2,3,4} EPA has likewise confirmed that the facility's thermal oxidizer destroys more than 99.99% of PFAS in the incoming waste gas stream and that associated carbon-bed systems provide additional control of fugitive emissions, with overall controls achieving greater than 99% reductions in emissions.⁵

Since potential releases to the environment during "beginning of life" activities can be effectively managed utilizing existing technologies, imposing product bans as a means of mitigating potential emissions and exposures from the manufacturing process is not justified. Instead, if New Mexico is concerned with potential emissions from manufacturing, regulators can and should impose emissions restrictions and/or technology requirements that effectively eliminate potential emissions and exposures at the "beginning of life," since this is the most effective way to address any "beginning of life" concerns arising in New Mexico. Accordingly, the fluoropolymer exemption should not be modified due to any beginning of life concerns.

B. End of Life: Effective Destruction and Disposal Technologies Eliminate Potential Exposures from Fluoropolymer Disposal

Fluoropolymer wastes are generally managed through landfilling or incineration. Landfilling of fluoropolymers is not expected to result in significant future exposure concerns because fluoropolymers exhibit exceptional environmental stability, chemical inertness, and resistance to degradation. Recent environmental fate testing conducted using internationally recognized OECD methods found no evidence of PTFE degradation, transformation, or release of polymeric or non-polymeric PFAS in air, sunlight, seawater, soil, sediment, activated sludge, or simulated wastewater treatment systems (Henry and Timmer, 2025). In addition, PTFE was found to be insoluble in water, essentially non-volatile, and unlikely to partition into environmental media, with testing demonstrating negligible potential for movement through water or air and a low likelihood of adsorption to soils or sediments (Henry and Timmer, 2025).

² <https://www.chemours.com/en/-/media/files/corporate/fayetteville-works/2020-0320-thermal-oxidizer-efficiency-results-announced.pdf>

³ https://www.chemours.com/en/-/media/files/corporate/fayetteville-works/ncdeq_quarterly-progress-report_q22026.pdf?rev=9de8de59fbd748fbaf34cd7018ca46b2&hash=48A387EE59114D5BC70A0B1189478A1E

⁴ https://www.chemours.com/en/-/media/files/corporate/fayetteville-works/28_ncdeq_1q2026-quarterly-co-progress-report.pdf?rev=4a0998cc7b054fb298b051aed4732049&hash=9573E1DAD89E6DCD2E0BFF447FF0A90D

⁵ <https://www.epa.gov/research-states/epa-research-partner-support-story-air-emissions-pfas-industrial-facility>

These findings are consistent with earlier evaluations concluding that fluoropolymers such as PTFE and FEP are highly stable, are not susceptible to hydrolysis or oxidation, have extremely high molecular weights, exhibit negligible bioavailability, and contain very low levels of residual monomers and low-molecular-weight leachable constituents (Henry et al., 2018). Consequently, fluoropolymers are not expected to migrate in landfill leachate or landfill gas, and the bulk of disposed material is expected to remain retained within the landfill for extended periods. The EPA under President Biden studied this issue and concluded in 2024 that due to their stability, fluoropolymers are likely to remain retained in landfills for a long duration and therefore landfilling was an acceptable way to dispose of them (USEPA, 2024; Henry and Timmer, 2025). Reflecting these characteristics, EPA again confirmed in its updated PFAS Disposal Guidelines in 2026 that landfilling in facilities equipped with gas collection and control systems is an appropriate and acceptable disposal option for fluoropolymers (USEPA, 2026). These findings confirmed by EPA in the both Democratic and Republican Administrations provide compelling evidence that landfilling fluoropolymers is an effective and safe means of disposal and fully support the basis for the fluoropolymer exemption in the PPA.

When fluoropolymer wastes are incinerated rather than landfilled, available evidence indicates that thermal destruction can be highly effective under standard operating conditions. Peer-reviewed studies evaluating fluoropolymer combustion have reported near-complete destruction efficiencies for PTFE and PVDF during municipal solid waste incineration (Jappen et al., 2026; Corbin et al., 2026). Collectively, as summarized below, the body of scientific evidence shows that when incineration systems are operated under typical operating conditions, fluoropolymers are mineralized, destruction efficiencies are high, and PFAS emissions are non-detectable or negligible. The available evidence therefore supports the conclusion that thermal treatment is a viable option for managing fluoropolymers at their end of life in a manner that is protective of both human health and the environment.

Relevant studies addressing thermal destruction include the following:

- Gehrmann et al. (2024) evaluated incineration of a mixture of fluoropolymers, including PTFE, PVDF, PFA, and FKM, under pilot-scale conditions representative of European municipal and hazardous waste incinerators at 860°C and 1095°C. The study reported mineralization of fluoropolymers with reduction rates greater than 99.99% and found non-detectable to negligible concentrations of PFAS products across stack gas, wastewater, and residue samples. According to the study authors, the observed results demonstrate effective fluoropolymer mineralization and insignificant formation of PFAS as products of incomplete combustion.
- Jappen et al. (2026) evaluated PTFE destruction under conditions representative of municipal solid waste incinerators in the US. The study looked for a broad range of combustion products using targeted PFAS analyses, measurements of ultra-short-chain compounds, volatile fluorinated compounds, fluorine mass balance calculations, and EPA Other Test Method 50 (OTM-50) analytical methods. The authors reported a PTFE

destruction efficiency of approximately 99.99962% and observed non-detect or below-reporting-limit concentrations for analyzed PFAS species. Fluorine recovery values ranging from approximately 95.6% to 100.3% further indicated that the carbon-fluorine bonds were effectively converted to inorganic fluorinated products rather than PFAS.

- Yamada et al. (2026) evaluated the fluoropolymer PCTFE at 850°C and 1150°C using a comprehensive analytical approach that included both targeted PFAS analysis and measurements enabled through OTM-50. The study reported PFAS destruction efficiencies exceeding 99.9999% at 1150°C and over 99.9% at 850°C. The evaluated temperature ranges fall within the typical operating conditions for municipal solid waste incinerators, affirming that PCTFE can be incinerated while minimizing emissions of concern.
- Corbin et al. (2026) examined PVDF under full-scale conditions at approximately 950°C and reported destruction efficiencies greater than 99.99% and destruction-and-removal efficiencies approaching 99.9999%. Also, Warnecke et al. (2025) conducted a full-scale study in Germany that doped the incinerator's waste stream with different types of PFAS, including fluoropolymers, fluoroelastomers, and canisters of aqueous film-forming foam (which does not contain fluoropolymers). The authors found only very small amounts of non-toxic CF₄ as a product of incomplete destruction. Excluding the CF₄ from their destruction rate calculations, the authors report greater than 99.999999 weight % destruction rate as measured in flue gas leaving the plant's stack.

Together, the studies described above demonstrate that effective end-of-life management can be readily achieved across multiple commercially important fluoropolymers, including PTFE, PVDF, PFA, FKM, and PCTFE. Furthermore, the studies show that fluoropolymer waste will be mineralized and can be managed safely under typical incinerator operating parameters. Thus, existing thermal treatment facilities are capable of controlling emissions and mitigating potential environmental releases associated with fluoropolymer disposal through thermal treatment. Accordingly, any suggestion that the fluoropolymer exemption in the PPA should be modified or eliminated due to end-of-life concerns is not supported by sound science and not consistent with EPA's analyses.

3. Economic Consequences of Banning Fluoropolymer Products are Severe

Fluoropolymers are used across a wide range of industries because they provide a unique combination of properties that are difficult, and in many cases are impossible, to achieve with alternative materials. These properties include exceptional chemical resistance, thermal stability, low friction, electrical insulation, weatherability, and durability.

At a macroeconomic level, the economic importance of continued fluoropolymer availability is substantial. One recent analysis found that, for seven critical U.S. industrial sectors that rely on fluoropolymers, approximately \$2.413 trillion in output, \$988 billion in GDP, \$553 billion in labor

income, and 6.1 million jobs supported, along with \$140 billion in federal and \$69 billion in state and local tax revenues, would be at risk if fluoropolymers and other critical fluorochemistries were banned (USCC 2024). For New Mexico specifically, the combined economic exposure across those seven sectors totals approximately \$6.861 billion in output and approximately 17,900 jobs at risk.

In addition to these direct economic costs, the unavailability of fluoropolymers would have substantial **indirect** costs, in terms of reduced reliability and durability of products, as well as increased health and environmental costs resulting from equipment and infrastructure failures. Finally, it is misguided to expect that these adverse impacts can be avoided through the substitution of alternative materials to replace fluoropolymers since, in most instances, suitable alternative materials simply do not exist. Each of these issues is addressed in turn.

A. Direct Economic Impacts

Set out below is a summary of some of the critical applications that require the use of fluoropolymers, along with a discussion of the important functions of fluoropolymers in those applications, and the economic impacts in each sector if fluoropolymers were unavailable.

Semiconductor Manufacturing

Fluoropolymers such as PTFE, PFA, and PVDF play a critical role in semiconductor manufacturing because they combine exceptional chemical resistance with ultra-high purity performance (Glüge et al. 2020; Extrand 2003; Korzeniowski et al. 2022). These materials are widely used in chemical delivery tubing and fittings, wafer-processing equipment, valves, pumps, seals, gaskets, and ultra-high-purity fluid handling systems throughout semiconductor fabrication facilities. Their widespread use is driven by their ability to withstand exposure to highly corrosive acids, bases, and solvents commonly used during wafer fabrication and cleaning processes. In addition, these fluoropolymers help maintain the purity requirements of semiconductor manufacturing by minimizing particle generation, chemical leaching, and contamination risks. Their durability and stability under aggressive temperature and pressure conditions further support reliable operation in demanding process environments, making them essential materials for modern semiconductor production.

An analysis prepared by FTI Consulting for the US Chamber of Commerce indicates that in New Mexico, the semiconductor sector supports approximately \$5.36 billion in output and approximately 13,600 jobs (USCC 2024). These jobs and economic output could be lost if fluoropolymers are banned in New Mexico, especially given the foundational importance of fluoropolymers to the semiconductor industry. Based on FTI's analysis, semiconductors constitute the single largest sector of fluoropolymer-dependent economic exposure in the state.

Chemical Manufacturing and Processing

Fluoropolymers, particularly PTFE, PVDF, and PFA are widely used throughout the chemical manufacturing and processing industry because they combine exceptional chemical inertness with high-temperature stability and long-term durability (Jacobs & Kosson 2024). These materials are commonly employed in applications where conventional metals, elastomers, or engineering plastics may be susceptible to corrosion, contamination, or degradation. By preventing corrosion, maintaining chemical containment, and minimizing contamination of process streams, fluoropolymer-lined equipment helps reduce worker exposure and environmental releases of hazardous chemicals while supporting product quality and long-term operational reliability (Argazinski et al. 2010; Ebnesajjad and Khaladkar 2017). Fluoropolymer-lined pumps and valves help maintain containment of aggressive chemicals while minimizing equipment degradation and maintenance requirements and preventing catastrophic failures. In heat exchangers and process vessels, these materials provide a protective barrier that extends service life and reduces the risk of contamination from corroding metal surfaces.

Although estimates of the economic impact of fluoropolymer unavailability on the chemicals sector are not available for the US, in the European Union, the estimated impact of the loss of fluoropolymers on the chemical processing industry is €65.8–193.5 billion. (FPG 2023). In New Mexico, the chemicals sector is responsible for nearly \$800 million in economic output and nearly 2,000 direct and indirect jobs (ACC 2026), which would be put at significant risk if fluoropolymers were unavailable in the state.

Research and Development

Fluoropolymers are “used in every academic and clinical laboratory and in the manufacture of devices, diagnostic, and tools for research and development In fact, every type of analytical equipment used in detecting PFAS have a critical reliance on components which themselves contain PFAS (Thermo Fisher 2024). They are “essential” components of diagnostic equipment used in human and veterinary medicine, as well as diagnostic devices and equipment used for water quality testing (Idexx 2024). They are particularly important in these applications because of their resistance to harsh chemicals, their chemical inertness, and their resistance to cross-contamination (i.e., maintaining purity) (FPP4EU 2026). Common items of laboratory equipment that require the use of fluoropolymers include:

- **Tubing and Fluid Transfer:** FEP, PFA, and PTFE tubing safely transport reactive chemicals, strong acids, and organic solvents in HPLC and LCMS systems without leaching impurities.⁶

⁶ <https://kintek-solution.com>

- Vessels and Storage: Beakers, graduated cylinders, and leak-proof [Teflon PFA Labware](#) containers handle extreme heat and aggressive reagents where glass or standard plastics fail.⁷
- Funnels and Filters: Chemically resistant funnels made with PFA film and fluoropolymer-coated filters protect air and water purification systems.⁸
- Valves, Seals, and Fittings: Custom-machined PTFE and PFA components provide durable, low-friction seals and joints for automated liquid handling and gas analysis instrumentation.⁹

Research and development laboratories are outsized contributors to New Mexico's economy. Los Alamos National Laboratory alone employs nearly 17,000 workers and contributes more than \$2.7 billion to New Mexico's economy annually.¹⁰ Similarly, Sandia National Laboratories employs roughly 16,000 employees and contributes approximately \$5 billion annually to the economy in New Mexico.¹¹ Thus, if activities at these two laboratories had to be curtailed or halted due to the unavailability of fluoropolymers or of laboratory equipment utilizing fluoropolymers, the economic impacts on New Mexico could be severe.

Electronics and Electrical Equipment

Fluoropolymers such as PTFE and PVDF are widely used throughout the electronics and electrical equipment sector because they combine excellent electrical performance with thermal stability, chemical resistance, physical resilience, and flame resistance (Extrand 2003; Teng 2012; Korzeniowski et al. 2022). These materials are found in applications ranging from wire and cable insulation to printed circuit boards (PCBs), connectors, high-frequency communications infrastructure, and consumer electronic devices. One of the most important drivers for fluoropolymer use in electronics is their low dielectric constant and low dielectric loss, which help maintain signal integrity and minimize energy loss at high frequencies. These properties have become increasingly important as electronic devices operate at higher data transmission rates and frequencies, particularly in telecommunications, data centers, radar systems, and emerging 5G/6G technologies. PTFE is especially valued in high-frequency applications because it provides stable dielectric properties across a wide range of temperatures and frequencies. Fluoropolymer films, coatings and cladding may also serve as

⁷ See, <https://www.thermofisher.com>

⁸ See, <https://www.iltusa.com>; <https://www.polyflon.co.uk>

⁹ See, <https://www.polyflon.co.uk>

¹⁰ See, <https://www.lanl.gov/engage/community/economic-impact-new-mexico>

¹¹ See, <https://newsreleases.sandia.gov/sandias-economic-impact-sets-record-for-17th-consecutive-year-2/>

insulating layers and protective barriers that resist heat, moisture, physical stresses and aggressive chemicals encountered during manufacturing and service.

The computer and electronics manufacturing sector in New Mexico accounts for more than \$1 billion per year in economic output (BEA 2026) and more than 8,000 direct and indirect jobs ((PC 2026), which would be put at significant risk if fluoropolymers were unavailable in the state. By comparison, the economic impact of the loss of fluoropolymers for the electronics industry in Europe is estimated at €8.7–26.2 billion. (FPG 2023).

Medical Devices

Fluoropolymers, particularly PTFE and PFA, are widely used in medical devices and pharmaceutical manufacturing because they combine exceptional biocompatibility, chemical inertness, long-term stability, and compatibility with sterilization processes (Sastri and Plastics Design Library 2024; Modjarrad et al. 2014). Common applications include vascular grafts, catheters, surgical meshes, implantable devices, and pharmaceutical processing equipment. These applications rely on fluoropolymers' ability to remain stable, non-reactive and non-toxic in demanding biological and chemical environments.

In implantable medical devices, PTFE, particularly expanded PTFE (ePTFE), has been used for decades in vascular grafts, cardiovascular devices, hernia and surgical meshes, and other implantable applications. The material's combination of biostability, low tissue reactivity, and resistance to degradation allows it to remain in the body for extended periods without significant chemical or physical breakdown. The FDA notes that fluoropolymers such as PTFE are used in life-sustaining devices including vascular grafts, stents, pacemakers, and guidewires because they provide unique properties such as lubrication, electrical insulation, and long-term biostability that are difficult to replicate with alternative materials (FDA 2025a). FDA further states that these fluoropolymers have a long history of safe use in medical devices and that there is currently no reason to restrict their continued use. FDA's conclusion was informed by a review of more than 1,750 scientific publications and patient safety data, which found no conclusive evidence that PTFE itself causes adverse patient health effects.

Beyond direct patient-contact devices, PFA and PTFE are also important materials in pharmaceutical processing equipment, including high-purity tubing, fluid transfer systems, vessels, fittings, filtration assemblies, and other product-contact components. Their extremely low extractables, resistance to aggressive chemicals, and ability to withstand repeated cleaning and sterilization cycles help minimize contamination risks during the manufacture of pharmaceuticals and biologics. PFA is particularly valued in these applications because it retains much of PTFE's chemical resistance while being melt-processable, allowing fabrication of complex, high-purity components and tubing.

FTI estimates that, at a national level, approximately 365,400 health care and related jobs are dependent on the continued availability of essential fluorochemistries including, primarily,

fluoropolymers. According to the FTI analysis, in New Mexico approximately \$398.1 million in economic output and approximately 1,000 jobs would be placed at risk if fluoropolymers and other essential fluorochemistries were rendered unavailable (USCC 2024).

Automotive and Transportation

Fluoropolymers play a critical role in the automotive and transportation sectors because they combine chemical resistance, thermal stability, low friction, and durability in environments where conventional polymers often fail (FPG 2026; Glüge et al. 2020; Korzeniowski et al. 2022). Common automotive fluoropolymers include FKMs, PTFE, and PVDF, each of which is used in components such as fuel lines, seals and gaskets, bearings, power steering and transmission systems, and electric vehicle (EV) battery components that are routinely exposed to fuels, lubricants, hydraulic fluids, elevated temperatures, and mechanical stress.

In conventional internal combustion engine vehicles, FKMs are widely used in seals, o-rings, gaskets, and fuel-system components because they maintain elasticity while resisting degradation from gasoline, diesel fuel, oils, transmission fluids, and high operating temperatures. Their low fuel permeability helps reduce evaporative emissions and supports long service life under demanding operating conditions. PTFE is commonly used in bearing surfaces, valve seals, hose liners, and other moving components because its exceptionally low coefficient of friction reduces wear and enables reliable performance without significant lubrication requirements.

In electrified transportation, PVDF has become increasingly important due to its use in lithium-ion battery technology. PVDF is commonly used as a binder in battery electrodes because it provides chemical stability, electrochemical resistance, and strong adhesion to active battery materials. Fluoropolymer materials are also used in battery seals, wire and cable insulation, thermal-management systems, and other components that must withstand demanding electrical and thermal conditions over extended service lives. As electric vehicle adoption expands, demand for PVDF and related fluoropolymers has grown significantly because these materials contribute to battery performance, reliability, and longevity.

Importantly, there are currently no viable substitutes for essential fluorochemistries in the majority of automotive and mobility manufacturing, including in semiconductors and battery components, with research suggesting at least 15 years would be required to possibly develop some form of PFAS-free alternatives in key applications if it could ever be achieved. (FPG 2026). Even in that case, there is no guarantee any alternative could provide the performance, durability or safety functions that fluoropolymers do today.

At the national level, the transportation sector dependent on fluoropolymers and other essential fluorochemistries supports approximately 2,557,900 jobs. In New Mexico, the transportation sector supports approximately \$80.2 million in output and approximately 200 jobs that would be

placed at risk if fluoropolymers and other essential fluorochemistries were unavailable (USCC 2024).

Aerospace / Aircraft

Fluoropolymers such as PTFE, PFA, and FKMs, play critical roles in aerospace and aircraft systems where materials must withstand extreme operating environments while maintaining long-term reliability. Their unique combination of thermal stability, chemical resistance, low weight, electrical insulating properties, durability under vibration and environmental stress, and flame resistance has led to widespread use in commercial aviation, military aircraft, spacecraft, and aerospace manufacturing. Collectively, these characteristics help improve aircraft reliability and safety, reduce maintenance needs, and enable the performance demands of modern aerospace systems.

In aircraft fuel systems, PTFE and FKM materials are commonly used in hoses, fuel lines, seals, gaskets, and O-rings because they exhibit excellent resistance to jet fuels, lubricants, and aggressive hydrocarbon mixtures. These materials maintain their performance across wide temperature ranges encountered during flight, from sub-zero conditions at altitude to elevated temperatures near engines and auxiliary power units. Their low permeability and resistance to swelling help ensure the integrity of fuel delivery systems over long service intervals.

Hydraulic systems represent another important aerospace application. Aircraft hydraulic systems operate under high pressures and are exposed to specialized hydraulic fluids that can degrade conventional elastomers. FKM seals and O-rings are widely used in pumps, actuators, braking systems, landing gear, and fluid-control components because of their resistance to oils, fuels, high temperatures, and chemically aggressive fluids. PTFE is also employed in dynamic seals, bearings, and low-friction wear components where reliable operation under extreme pressure and temperature conditions are required.

In aircraft electrical systems, fluoropolymers are extensively used as wire and cable insulation materials. PTFE and related fluoropolymers possess excellent dielectric properties, thermal stability, and flame resistance, making them well suited for wiring in confined aircraft environments where safety and reliability are paramount. Aerospace standards such as SAE AS22759 specifically cover fluoropolymer-insulated aircraft wire constructions, reflecting the long-standing use of PTFE, and related fluoropolymers in aerospace electrical systems. These materials maintain flexibility and insulation performance across broad temperature ranges while providing resistance to chemicals, moisture, and mechanical wear. PTFE's exceptionally high limiting oxygen index (LOI greater than 95%) provides auto-extinguishing behavior, making it an outstanding material for cable coatings that enhance fire safety and reliability in aircraft electrical insulation systems.

In New Mexico, the aerospace manufacturing sector supports approximately \$183.1 million in output and approximately 500 jobs that may be at risk if fluoropolymers and other essential fluorochemistries were to become unavailable. (USCC 2024)

Construction and Infrastructure

Fluoropolymers, particularly PVDF and PTFE, are widely used in the construction and infrastructure sector because they provide a combination of long-term weatherability, UV stability, corrosion resistance, and low maintenance that is difficult to achieve with conventional materials (FPG 2026; Glüge et al. 2020). These properties enable their use in highly exposed outdoor environments where materials must withstand decades of sunlight, moisture, temperature fluctuations, pollution, and chemical exposure.

PTFE-coated fiberglass membranes and PVDF-coated architectural fabrics are commonly used in tensile membrane structures, canopies, stadium roofs, transportation hubs, public spaces, and other lightweight roofing applications. These materials offer a high strength-to-weight ratio, allowing large spans to be covered with significantly less structural support than conventional roofing systems. PTFE membranes are particularly valued for their exceptional UV resistance, resistance to weathering, and self-cleaning characteristics, which help maintain appearance and performance over decades of service. PVDF coatings are often applied to architectural fabrics to improve durability, stain resistance, and weatherability while reducing maintenance requirements.

Fluoropolymer coatings are also used to protect bridges, water towers, and other critical infrastructure from corrosion and environmental degradation. The combination of chemical inertness, resistance to UV exposure, and long-term outdoor durability helps reduce maintenance frequency and lifecycle costs compared with conventional protective coatings. For infrastructure owners, the ability of fluoropolymer coatings to withstand harsh environmental conditions while maintaining protective performance can extend service intervals and improve asset longevity. Resistance to radiation and weathering has been identified as a key differentiating property of fluoropolymers for outdoor applications.

Because fluoropolymer-based coatings last at least two to three times longer than alternative coatings, structures with fluoropolymer-based coatings need to be repainted and maintained much less frequently, which results in substantially reduced exposures to people and the environment, compared to alternative coating technologies. Indeed, the Organization for Economic Cooperation and Development (OECD) indicates that due to the superior weather- and corrosion resistance of fluoropolymer-based coatings, bridges painted with fluoropolymer paints are expected to require repainting only once every 60 years, compared to once every 15 years for non-fluoropolymer coatings. (OECD 2022). Furthermore, the superior protection and significantly longer life provided by fluoropolymer based paints allows for less frequent re-application, which ultimately results in much lower carbon and VOC emissions and less generation of waste than available alternatives. (PFP 2023).

Water Treatment and Environmental Applications

Fluoropolymers such as PVDF and PTFE are critical for key applications that help protect the environment, including filtration membranes, water treatment systems, landfill liners, and oil/water separation technologies because they combine exceptional chemical resistance, long-term durability, and membrane performance under demanding operating conditions.

PVDF is one of the most commonly used membrane materials in municipal and industrial water treatment systems, including microfiltration (MF), ultrafiltration (UF), membrane bioreactors (MBRs), and membrane-aerated biofilm reactors (MABRs). PVDF membranes offer a balance of chemical resistance, mechanical strength, and processability, enabling operation in water streams containing oxidants, salts, organic contaminants, and cleaning chemicals. PTFE membranes are utilized in more aggressive environments where superior chemical inertness and resistance to fouling are required. Studies evaluating PTFE and PVDF membranes for wastewater treatment have shown that both materials can effectively remove contaminants, while PTFE often demonstrates superior resistance to harsh chemical conditions and membrane fouling (Turk et al. 2024).

Fluoropolymer membranes are also widely investigated and deployed for the treatment of oily wastewaters generated by industries such as petroleum refining, metalworking, food processing, and manufacturing. The intrinsic hydrophobicity, low surface energy, and chemical stability of PTFE and PVDF make them well-suited for separating oil-water emulsions. PTFE membranes are particularly valued for their resistance to wetting and fouling, while PVDF-based membranes can be modified to optimize permeability and separation efficiency. Research has demonstrated that PVDF/PTFE membrane systems can achieve highly effective oil-water separation while maintaining performance through repeated use and cleaning cycles (Wang et al. 2018).

Beyond membranes, fluoropolymers are used as corrosion-resistant linings, tubing, seals, and components within water treatment facilities and chemical handling systems. Their resistance to acids, bases, oxidants, solvents, and weathering allows them to provide long service life in contact with challenging treatment chemicals. Fluoropolymer-based liners and barrier materials may also be used in specialized environmental containment applications, including landfill leachate management and hazardous waste handling systems, where long-term resistance to chemical degradation is essential.

Renewable and Conventional Energy

Fluoropolymers such as PTFE, FEP, PVDF, and PFA are widely used across renewable and conventional energy systems as they combine thermal stability, chemical resistance, weatherability, and durable performance under demanding operating conditions (Gluge et al. 2021; Korzeniowski et al. 2022; OECD 2025). In renewable energy applications, FEP and PVDF are used in solar collectors and photovoltaic panels, including protective covers and backsheets

that provide transparency, vapor-barrier performance, and resistance to weathering and dirt. The use of fluoropolymer protective covers has been shown to increase the electrical output of photovoltaic panels by as much as 6% (Li et al. 2026)

Fluoropolymer coatings, release films, and lubricants are also used to protect wind-turbine blades and support turbine operations. In hydrogen and fuel-cell systems, PVDF and other fluoropolymers are used in alkaline water electrolysis, while other fluoropolymers such as PTFE are used in gas-diffusion layers to control hydrophobicity and water management (OECD 2025). Fluoropolymers also support energy storage, with PVDF used as a separator, polymer electrolyte, and electrode binder in lithium-ion batteries, and PTFE, FEP, ETFE, and PFA used in electrode binders, surface treatments, module components, and battery gaskets (OECD 2025).

In conventional energy systems, PTFE is used in expansion joints at power plants, while fluoropolymer tubing, heat exchangers, and filters provide resistance to the heat and corrosive conditions encountered in coal-based facilities (OECD 2025). Fluoropolymers are also used in filtration systems that remove fly ash from hot stack emissions and in processes for separating carbon dioxide from flue gases (Gluge et al. 2021; OECD 2025). Fluoroelastomers, including FEP, are used in thermal power plants and oil and gas operations because their resistance to heat and chemicals supports a reliable performance, particularly in downhill applications (Korzeniowski et al. 2022). Across both renewable and conventional energy technologies, these applications rely on fluoropolymers to provide chemical inertness, temperature resistance, low friction, and long-term durability in conditions where less-resistant materials may degrade or lose functionality.

Recent data from the New Mexico Legislative Finance Committee indicates that from conventional energy production activities alone, revenue to the state exceeds \$11 billion per year.¹² Because fluoropolymers are critical components of oil and gas production equipment, including gaskets, valves, seals and pumps, the financial blow (and environmental damage) to the State of New Mexico could be significant if fluoropolymers were to become unavailable.

B. Indirect Economic Impacts

The unmatched capabilities of fluoropolymers across multiple areas of performance means that, for most applications in which fluoropolymers are used, attempting to substitute other materials for fluoropolymers will result in a loss of reliability and durability that in many instances will have negative effects on health, safety and the environment as well as other indirect negative economic impacts. For example, if a seal or gasket fails in a piece of heavy equipment or a heavy-duty vehicle due to temperature, chemical and/or mechanical stresses, the failure of that seal could: (i) threaten worker health and safety, perhaps resulting in increased medical costs or

¹² <https://www.nmlegis.gov/Handouts/ALFC%20061124%20Item%204%20Oil%20and%20Gas%20Revenue%20to%20the%20State%20of%20NM.pdf>

employee down time and (ii) result potentially dangerous releases of chemicals into the environment, resulting in increased remediation costs, in addition to causing economic losses due to costs of repairing the affected equipment and the lost productivity due to equipment down time.

To examine this issue more closely, we consider the use of fluoropolymers to coat the core of fuel hoses. Fluoropolymers are used in this application because of their resistance to harsh chemicals and high temperatures, which prevents permeation of fuel and thus reduces fugitive emissions (Goldsberry 1993; Duchesne et al. 1999). If fluoropolymer-coated fuel lines were no longer available for use in automobiles in New Mexico, forcing the use of more permeable materials for fuel lines, a likely result would be greater air pollution from fugitive emissions of volatile organic compounds (VOCs) and corresponding increases in ground-level ozone – which, according to NMED, is associated with increased respiratory and cardiovascular illness (NMED 2026). A similar result would be expected if fluoropolymer gaskets and seals are no longer available for oil and gas production and processing activities. A recent study from the University of New Mexico indicates that the economic burden from ozone-related illness in New Mexico (largely from oil and gas as well as automotive emissions of VOCs) averages around at least \$2 billion per year (Goodkind et al. 2022). That cost would likely increase substantially if fluoropolymers were to become unavailable in New Mexico and could no longer be used as seals in the oil and gas industry or fuel lines in automobiles.

The economic burden from the health impacts of increased ozone pollution is one of countless examples of the indirect adverse economic effects that could be expected to result if the fluoropolymer exemption were removed from the PPA. In aggregate, these indirect costs could easily dwarf the direct costs discussed in the previous section.

C. Unavailability of Suitable Alternatives

Fluoropolymers are critical components across a wide range of applications because of the unique combination of performance characteristics they provide. This combination of properties is also what underlies the lack of suitable substitutes for fluoropolymers. As discussed in Section B above, the use of substitute materials with inferior performance characteristics can have significant adverse economic impacts as well as adverse impacts to health and safety. The increase in ozone pollution that would result from fuel lines without fluoropolymer coatings is one example. A more dramatic example is the space shuttle Challenger, which exploded shortly after liftoff in 1986 due to the failure of poly(thiolether) seals. In all subsequent missions, those seals have been made with fluoropolymers (Ameduri 2023). Both examples illustrate how the use of “alternatives” to fluoropolymers can cause significant harm if those alternatives do not provide all of the same properties – and the same degree of protection – the fluoropolymers provide.

The lack of suitable alternatives to fluoropolymers is highlighted in a recent comprehensive report by Savannah River National Laboratory (Jacobs & Kosson 2024), which notes that:

Alternative materials and technologies have been identified for some specific uses of fluoropolymers. However, because of the combination of beneficial properties of fluoropolymers, no alternatives have been identified that could replace fluoropolymers in many, or over a broad range, of applications

More specifically,

While other polymers and non-polymers can resist chemical attack, be used at temperatures exceeding 260 °C, resist UV radiation, have low weight, and have considerable strength and durability, finding alternative materials that can meet multiple or all these requirements for the intended application is difficult.

In Jacobs & Kosson, the authors closely examine the use of fluoropolymers in seven critical industry sectors: chemical processing; microelectronics and semiconductors; construction and infrastructure; automobiles and aerospace; and renewable energy. For each of these sectors, the researchers identify specific applications in which fluoropolymers are used as well as the functions performed by fluoropolymers in those applications, and they evaluate whether suitable alternatives are available to perform those same functions. A “consistent theme” noted by the study authors is that in instances where fluoropolymers are utilized to provide a combination of several performance characteristics there are “***no industrial scaled materials [that] are currently available***” to perform that role.

- In the chemical processing sector, the study authors examine information on roughly two dozen potential alternatives to fluoropolymers, across applications such as seals, gaskets, pipes, tubes and liners, filtration membranes, lubricants, heat exchangers, and filters. The authors conclude that “there may be specific or even niche chemical industry applications where alternatives may exist” predominantly in “less challenging temperature and corrosion environments” but “possibly at the cost of lower performance and higher design, maintenance and replacement costs.”
- In the construction and infrastructure sector, the study authors examine the use of fluoropolymers, and potential alternative materials, across multiple applications, including: weather-protection coatings and structural materials, electrical cable insulation, piping, sealing, wastewater management, and drinking water treatment. The report finds that, for virtually all of the applications studied, potential alternative materials provide inferior performance compared to fluoropolymers.
- In the microelectronics and semiconductor sector, the authors conclude that “[b]ecause of the very stringent chemical, physical and in some cases electrical requirements of

materials used to fabricate microelectronics and semiconductors, very few viable replacement materials can be identified for fluoropolymers.”

- In the automotive and aerospace sector, the authors examine numerous applications where fluoropolymers are needed and they identify potential alternatives that might be utilized in these applications. However, for nearly all of the potential alternatives identified, the authors note significant performance deficiencies when compared to fluoropolymers. The authors conclude that the alternatives considered “often come with limitations, as fluoropolymers offer a range of critical properties essential for the automotive and aerospace industries.”
- In the renewable energy sector, Jacobs & Kosson examines the use of fluoropolymers in the following applications: binders, separators and gel polymers for lithium ion batteries; protective coatings for wind turbines; and front- and back-sheets for solar panels. The authors suggest that while alternative materials might be available for certain battery applications, but the availability of suitable alternatives for wind and solar panel applications is uncertain.

As Jacobs & Kosson makes clear, there are currently no suitable fluoropolymer alternatives available for a range of critical applications. More granular comparisons of fluoropolymers and potential alternative materials are provided in Appendix 1 and Appendix 2.¹³

Finally, when considering the lack of suitable alternatives to fluoropolymers, we urge MPCA to heed the admonitions of the US Department of Defense in a recent report surveying uses of PFAS compounds that are critical to the national security of the United States (U.S. DoD 2023). In that report, the Department concluded that certain types of “PFAS” materials:

are critical to DoD mission success and readiness and to many national sectors of critical infrastructure, including information technology, critical manufacturing, health care, renewable energy, and transportation. . . . Most of the structurally defined PFAS are critical to the national security of the United States, not because they are used exclusively in military applications (although a few are) but because of the civil-military commonality and the potentially broad civilian impact. (emphasis in original)

¹³ The analysis in Appendix 1 was prepared by AGCCA. The analysis in Appendix 2 is slightly modified from a document prepared by an independent consulting firm, Claigan Environmental, and included in public comments submitted to the Minnesota Pollution Control Agency. The Claigan Environmental analysis can be found at the following url: <https://minnesotaoah.granicusideas.com/discussions/39667-minnesota-pollution-control-agency-request-for-comments-on-pfas-in-products-currently-unavoidable-use-rule/topics/submit-a-comment-290>

Importantly, many of the critical PFAS applications identified by DoD are fluoropolymer applications. These include:

- subcomponents in modern Li-ion batteries: electrolyte solutions, cathode binders, separator coatings, casing materials, and gaskets;
- semiconductor fabrication;
- microelectronics applications, including base laminate materials used in Radio Frequency (RF) and microwave circuits;
- printed circuit boards;
- mold release agents and films typically used in composite manufacturing processes;
- hoses, tubing, hydraulic system lines, O-rings, seals and gaskets, tapes, and cables and connectors widely used in civil and military aircraft, space systems, vehicles, weapon systems, utility systems, and other applications;
- resins for specialty high-temperature or weather-/UVresistant composites; and
- specialty filters and membranes (e.g., aviation filters).

Notably, the Department highlighted that the information on critical uses contained in the report “represents a fraction of the mission critical PFAS uses.”

Other Considerations

Questions have been raised regarding the interplay between the product-specific bans in PPA Sections 3(B), (C) and (E) and the fluoropolymer exemption in PPA Section 3(A)(16) on the other hand. Specifically, some have suggested that as the statute’s product specific bans come into effect, manufacturers might replace the PFAS compounds currently used in those products with fluoropolymers – thus leading to greater use of fluoropolymers to replace those other (banned) PFAS materials. This concern is unfounded.

As discussed earlier, fluoropolymers have physical and chemical properties that are distinctly different from other compounds that fall under the broad definition of PFAS. Among other things, fluoropolymers are very large molecules that are inert (not chemically reactive) and are not water soluble. Because of these distinct differences, fluoropolymers are generally unsuitable for most of the applications in which other types of PFAS compounds are used.¹⁴

¹⁴ As illustrated in Gluge et al. 2020, different types of PFAS substances are used in different types of products to perform specific functions. They cannot be used interchangeably,

This conclusion is borne out in the marketplace, where replacements for phased out PFAS-containing products are nearly universally free of all PFAS, including fluoropolymers.¹⁵

D. Conclusions

A robust body of data confirms that fluoropolymers are safe. Fluoropolymers themselves present negligible risks to health or the environment, and potential life cycle risks associated with either the “beginning of life” or the “end of life” of fluoropolymers can be adequately controlled by existing technologies that have been proven effective. This fact alone – that fluoropolymers are safe – should be a sufficient basis for exempting fluoropolymers from the PPA.

Moreover, as documented herein, fluoropolymers are essential components of products that are critically important to New Mexico businesses and residents. Consequently, if fluoropolymers were to become unavailable in New Mexico, the adverse economic effects would likely be severe and the adverse impacts to the health and safety of New Mexico residents could be substantial.

The fluoropolymer exemption in the PPA is supported by sound, well recognized science. Fluoropolymers are unique, safe, non-toxic materials that are necessary to ensure the safety, performance and reliability of products critical to New Mexico and its citizens for which there are no suitable alternatives. For these reasons it is crucially important for the State of New Mexico to retain the exemption for fluoropolymers in Section 3(A)(16) of the PPA.

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We appreciate the opportunity to provide these comments and would welcome the chance to engage in further dialogue on this important issue. Please let us know if you have any questions or would like additional information regarding our comments.

Sincerely,



Christopher F. Correnti
President and CEO
AGC America, Inc.

¹⁵ See, e.g., <https://pfascentral.org/pfas-free-products/>

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Appendix 1

Representative Fluoropolymer Applications and Potential Alternatives

Sector	Representative application(s)	Tab
Transportation	• Cable and wire coatings and sheathing for civil and military aircraft, aerospace, motor vehicles, watercraft, and other transportation modes, including high temperature sensor cables (e.g., sensor cables for emissions reduction and improvement of engine efficiency) • Mold release film for composites used for aircraft and helicopter fuselage, wings, etc. • Coatings for aircraft exteriors and interiors and motor vehicle exteriors • Fuel cell components including: polymer electrolyte, catalyst ink binder for Proton Exchange Membrane Fuel Cell (PEMFC), as well as humidifier/drier in balance of system for fuel cell vehicle to control moisture of incoming hydrogen required for reliable and efficient operation of the fuel cell. • Hoses and tubes, including brakes hoses, hydraulic hoses and fuel hoses to reduce evaporative fuel emissions in combustion engine vehicles • Oil seal components, piston rings, shock absorbers, bearings and gasket • Lubricants where other lubricants are not suitable, such as bushings for car door hinges, and trunk lids • In ABS and braking systems because of safety needs • Coatings for engine parts, protection film	A
Electronics	<i>Semiconductors</i> • Molding assist film for power semiconductors packaging • Coating for electronic semiconductor wires • Air and liquid filtration filters used in the semiconductor industry • Molded products for semiconductor equipment, tubes/release sheets used during semiconductor processing • Advanced Semiconductor Packaging	B

Sector	Representative application(s)	Tab
	• Pellicles for Semiconductor chip manufacturing • Seals, gaskets, O-rings, packings, linings and coatings for pipes and joints for semiconductor manufacture • Encapsulating material for UVC LED chip • Surface coatings of fixing films Batteries • Solid-state lithium batteries for electric vehicles Printed Circuit Boards • Mold release film in compression lamination of printed circuit boards, in semiconductors, optoelectronics components, standard packaging to protect memory chips and sensor devices used for mobile devices, data centers, and LED lens production • Substrate for print circuit board • Sound transmission membranes in circuit boards, antennas for mobile phones, technical / industrial linings, electromagnetic flowmeters Cables & Wire, Other • Coating material for wires, coaxial cables and various other cables for chemical resistance conforming with international factory mutual standards (fire risk reduction) • Heat-resistant sheath wire in electronic equipment operating at high frequencies and high temperature • Optical fibers • Antifouling and mold-release coating agent for touch panel glasses, lenses and mirrors; functional anti-smudge coatings applied to various substrates (e.g. glass, metal, plastic), removing sebum and fingerprints on exterior parts (e.g. cover glass, housing, camera module in portable devices) especially smart phones and other touchscreen applications; coatings for automotive use (e.g. instrument panels with touchscreen interface); adhesion prevention for glass and parts for multifunctional printers	
Communications	• Plastic optical fiber (POF) in telecommunication • Coating of special optical cables called “buffer tubes” • Coating of signal cables	<u>C</u>

Sector	Representative application(s)	Tab
	• Tubes and machine or injection molded parts, printed circuit boards material for use in high-speed communication technology	
Medical devices and life sciences	<i>Tubes, catheters, etc</i> • Catheters for intravenous and inside body interventions; small “non-kink” tubes; endoscopy; pancreatic and biliary stents; foreign body retrieval devices; balloon dilators; needles, brushes and specialty items; single use snares in colonoscopies; endoprostheses • Gaskets; diaphragms in medical ventilators/respirators and sterile syringe filters; membrane filters for sterile venting of gases, aggressive fluids, acids & non-aqueous solvents, gas filtration and aerosol sampling; humidifier/drier membranes used in CPAP (Continuous Positive Airway Pressure) machines; breath gas analyzers. • Artificial blood vessels • Dialysis-related devices • Surface coating for medical devices • Packaging of terminally sterilized medical devices • Coatings for biochip devices <i>Equipment & Manufacture</i> • Laminate rubber stoppers • Wire sheath material for medical equipment • Humidification or conditioning of various medical gasses • Tubes, seals, gaskets, O-rings, lining of vessels, pipes, valves, hoses, process control devices, pumps, gas scrubbers, dryers, evaporators, heat exchangers and connectors for pharmaceutical manufacturing equipment • Coating for image plate of medical printing film	<u>D</u>
Construction and Infrastructure	• Roofing and façade material for membrane structures such as train stations, sport stadia, shopping malls, airports, exhibition centers, bridges, greenhouses for commercial-scale growth of fruits, vegetables, flowers, etc. • Sports facilities and sewage disposal facilities • Light weight and composite constructions (development / future application)	<u>E</u>

Sector	Representative application(s)	Tab
	• Heat-resistant flexible wire • Architectural coatings and paints • Sliding bearings • Anti-graffiti overlay for traffic signage / safety • Laminate films to provide antifouling and touch-proofing of metals, fire and heat resistance and oil resistance to kitchen hoods	
Food Contact and Processing	<i>Food industry</i> • Seals, O-rings, gaskets, tubing and pipes, valves and fitments, tank linings, sensor covers, and non-adhesive coating for food equipment • Lining of food cans • Ion exchange membranes • Industrial-scale food and feed processing equipment, in seals, tubes, pipes, hoses, o-rings, gaskets, valves and fitments, conveyor belting, tank lining, filter membranes, sensor covers, lubricants and equipment specific to food and feed transport.	<u>F</u>
Energy	<i>Oil & Gas and Mining</i> • Cables and cable outer “jackets”, including sub-sea heating cables and self-regulating heating cables. • Structural or fluid handling components • Coating resin material for electrical wires for crude oil drilling • Wire insulation for downhole sensor cables, extract duct coating, trace heating for cold production areas, and self-regulating heating cables for cold areas • Dehumidification of sample gas for analysis • Packers, blow out preventers, seals, gaskets and O-rings <i>Nuclear</i> • Cables and wires, including cables of control rooms, sensor cables, and general cables for the industry. <i>Photovoltaics and Wind</i> • Building integrated photovoltaic (BIPV) modules, solar panels, molding wind turbine composites	<u>G</u>

Sector	Representative application(s)	Tab
	• Next-generation solar cells for BIPV and megasolar projects • Coatings for PV modules • Coatings for wind turbine blades and towers Hydrogen • Proton Exchange Membrane Electrolyzer (PEMEL): water electrolysis, electromechanical hydrogen compressors and purification and electrolysis plant for renewable hydrogen production Other • Separator for REDOX flow batteries • Exchange Membrane Electrolyzer for anion exchange membrane water electrolysis (AEM) • Binders for electrode materials in batteries • Release films used for photovoltaic cells, proton exchange membrane of fuel cells, Li-ion batteries • Key polymer electrolyte, also used as a key ingredient of catalyst ink's binder for Proton Exchange Membrane Fuel Cell (PEMFC) • Coating of tidal power cables • Humidification or conditioning of various gases	
Manufacture/ Processing	Chemical Industry • Coating material for industrial wires, coaxial cables and various other cables • Hoses, tubes, gaskets and other seals • Distillation column packings • Rotolining or electrostatic coating, e.g., vessels, tanks, pipes, tubes, elbows, complex manifolds, pump casings and filter housings • Electrodialysis processes for wastewater treatment (desalination and salt concentration) and separation of organic components and inorganic salts (cosmetics, medicals, food, medicine, and purification of intermediates in inorganic synthesis) • Expansion joints, compensators and bellows • Bearings, ball joints, hinges, calipers, valves	H

Sector	Representative application(s)	Tab
	• Ion exchange membranes for production of caustic soda, potash, chlorine for use in end products such as: paper, aluminum, wind turbines, hydrazine used in fuel cells, rocket fuels, pharmaceuticals, antiseptics, nylon, EDTA, soaps, cleaning agents, household bleaches and germicides, and many organic and inorganic chemicals <i>Metal Plating</i> • Acid recovery (acid and metal salt separation process by electrodialysis/diffusion dialysis) <i>Water treatment</i> • Industrial water treatment; electrodialysis <i>Lubricants</i> • Solid lubricants where other lubricants are not suitable; thread seal pastes • Coatings for improved rub and scuff resistance, reduction of friction, chemical inertness and temperature resistance and to impart release characteristics (e.g., mold release agents) <i>Misc. Equipment</i> • Manufacturing equipment such as belts, rollers, heat-sealers in dying, laminating, drying processes • Dryers used to remove moisture from gas samples prior to analysis to improve signal resolution • Dehumidification or humidification pretreatment in pneumatics or compressed gas • Manufacturing equipment, including seals, hoses, gaskets, o-rings, valves, linings in vessels, pipes, reactors, process control devices, pumps, gas scrubbers, 3D printers	

Tab A -- Transportation Applications

Fluoropolymers are used for sheathing for cable and wire used in motor vehicles (on- and off-road), civil and military aircraft, spacecraft, watercraft, and other modes of transportation. Fluoropolymers are essential for this application because they provide flexibility plus durable and reliable protection against extreme temperatures, aggressive fluids such as hydraulic fluids and fuels, humidity, vibration and compression. For example, aircraft wires must comply with the international standard SAE AS22759, which requires temperature resistance of -65 ~ 200 °C, and similar high performance is required for electric vehicle (EV) cables. Potential alternative materials, such as polyvinyl chloride, polyethylene, alkane-imide and polyamide are not suitable for these applications due to one or more of the following deficiencies: inadequate heat resistance, poor arc resistance, poor moisture resistance, or cracking. Similarly, fluoropolymers are essential to satisfying international standard for automotive cables, ISO 6722-2, which cannot be satisfied by these potential alternatives. Only SIR (silicone rubber), polyether ether ketone (PEEK), mica, and ceramic can provide similar heat resistance as compared to fluoropolymers, however they fail to ensure similar mechanical strength and chemical resistance. Thus, the use of potential alternatives would lead to premature deterioration of the wire sheath material (insulation degradation or insulation breakdown), which could lead to electrical leakage, resulting in equipment failure, electrical shock and fire hazards. Furthermore, fluoropolymers have superior electrical properties (low dielectric constant and low dielectric loss tangent) compared to potential alternatives (dielectric constant below 2, 1 kHz and dielectric loss tangent below 0.0002 kHz). This becomes increasingly important as larger volumes of data are transmitted and the wavelengths used shift toward higher frequencies, which are more susceptible to attenuation during transmission. Fluoropolymers are the material with the least loss during this transmission and are the most suitable insulating material for high frequencies.¹

Fluoropolymers also provide critical functionality for hoses, fuel lines and gaskets and seals (such as crankshaft seals, transmission seals, pinion seals, and shock absorber seals) which require the following combination of properties: durability, heat resistance, oil and fuel resistance, flexibility and sealing. These properties are essential to assure that vehicle fluids do not leak, resulting in potential safety concerns, human and environmental exposures, decreased

¹ Notably, only fluoropolymers can meet the following international standards for automotive cables: ISO 6722-1; ISO 6722-2; LV 112-1; LV 112-2; LV 112-3; LV 112-4; LV 122; LV 212; LV 213-1; LV 213-2; LV 216-1 and LV 216-2.

reliability and increased repair costs. For consumers (and personal vehicles), increased repair costs would disproportionately impact disadvantaged communities. Only fluoropolymers can provide the required properties to satisfy the relevant standards for Rubber Products in Automotive Applications (ASTM D2000). According to the standard, in operating environments surpassing 250 °C, type H or higher (required heat resistance) and class K (required oil resistance) should be used, meaning that only fluoroelastomer-based rubber can meet the performance level. Non-fluorinated materials, such as silicone, do not provide the same level of performance, and do not fulfill industry standards. At the current time, there is no prospect of technically or economically feasible substitution.

In fuel lines, the use of fluoropolymers ensures the necessary flexibility without the need for a corrugated structure, which reduces the loss of efficiency due to air contamination and eliminates the need for replacement as there is no deterioration. The primary alternative, PA6 (polyamide 6), has poorer barrier performance therefore increasing the likelihood of fuel vapor leaking into the environment. This is essential as environmental requirements for motor vehicles, in terms of emissions reductions, become increasingly stringent.

Fluoropolymer membranes are also essential for fuel cells used in transportation, providing essential release properties, chemical durability to solvents of catalyst ink, and non-contaminating to platinum supported carbon and ionomer binders for suitable catalyst layer formation of fuel cells. The operating conditions inside fuel cells are harsh, with OH radicals being constantly generated at operating temperatures of 60 to 100 °C. Non-fluorinated polymer materials can only be used for short periods of time, as the polymer decomposes, rendering operation impossible. For example, the Fenton test (test method for fuel cells) shows that hydrocarbon-based materials degrade five times more than fluorinated materials. If non-fluorinated materials such as PEEK-based hydrocarbon electrolyte polymers are used in fuel cell vehicles, the critical components of the fuel cell (stack parts) will need to be replaced more frequently, which means that the operating time of the fuel cell vehicle would not be assured and the amount of waste generated considerably higher. Fluoropolymer membranes are the only materials that can withstand operation for tens of thousands of hours in the presence of radicals. They are also the only materials that allow the cell to operate at high power density.

The US Department of Energy (DOE)² standard for fuel cell vehicles includes high performance and continuous service life, and fuel cells using fluoropolymer ionomer membranes can be used

² Fuel Cell Technologies Overview, US Department of Energy, Arlington V.A., 2023. [Fuel Cell Technologies Subprogram Overview \(energy.gov\) https://www.hydrogen.energy.gov/pdfs/review23/fc000_papageorgopoulos_2023_o.pdf](https://www.hydrogen.energy.gov/pdfs/review23/fc000_papageorgopoulos_2023_o.pdf)

continuously for more than 25,000 hours. In addition, vehicles need to be able to generate electricity instantaneously, which solid oxide fuel cells are not able to do, making them unsuitable for automotive applications. Hydrocarbon-based electrolytes are not durable for the required length of operation time in stationary applications such as back-up power for data centers. Although other types of stationary power generation exist, such as SOFCs (solid oxide fuel cell) made of inorganic materials, they are not suitable for generating instantaneous power. Fluoropolymer humidifier/drier membranes are also essential in fuel cell electric vehicles to control moisture of the incoming hydrogen, which is necessary to ensure reliable operating conditions of the fuel cell.

Fluoropolymers are also essential to EV batteries, which need higher voltages and, in turn, require greater heat resistance and superior insulation properties for sealing materials. Fluoropolymers provide sufficient heat resistance and insulation to withstand high voltages associated with EV batteries. They are also essential for use as binders in EV batteries, due to their ability to function in strong oxidation environments. None of the potential alternatives to fluoropolymers simultaneously meet the required chemical, heat, and voltage resistance, as well as adhesion to the substrate. If used as binders, these alternatives will be oxidized and tattered. Fluoropolymers used as a binder in Li-ion batteries provide extended lifetime and performance over a broad range of conditions. Those batteries are the central component of EVs.

In addition, fluoropolymers are required to bring ORFBs (Organic Redox Flow Batteries) to the market, to provide superior performance to rechargeable batteries and reduce greenhouse gas emissions. The use of fluoropolymer anion exchange membranes will also offer high durability and stability in the ORFB application. These applications - highly dependent on the use of fluoropolymers - will be the cornerstone of the decarbonization of US transportation. Also, for power semiconductors used in fuel cell vehicles and battery electric vehicles, fluoropolymer film is essential to provide the required properties of non-adhesion, high melting point (200-280°C) and mechanical properties at molding temperatures (100-200°C). Those properties are needed to prevent contamination of semiconductors and protect molding equipment and therefore ensure high performance and energy efficiency of fuel cell vehicles and battery electric vehicles.

Fluoropolymers are also essential for aircraft exterior coatings, to protect the aircraft from harsh environmental conditions during flights at high speed of about 800 to 900 km/h (e.g., temperature spikes and drops, atmospheric pressure, friction, strong ultraviolet rays, dust, rain, hail, etc.). They also prevent oxygen seepage, reducing the likelihood of corrosion of the fuselage. Fluoropolymer

coatings also provide improved fuel efficiency due to reduced icing (wings and fuselage) and high resistance to physical friction (e.g., wind at the wing sections). Use of fluoropolymer exterior coatings also allows for reduced volatile organic compounds (VOC) and CO₂ emissions by lengthening the period of re-coating, and reducing the energy demand required for repainting. Fluoropolymers are difficult to replace for this application due to the exacting industry standards required to be met.^{3,4,5,6} Fluoropolymer coatings are also important for aircraft interiors, to provide excellent stain resistance as well as color and gloss retention, while satisfying applicable smoke and fire prevention criteria.

There are no suitable fluorine-free alternatives available that would provide the same level of protection as fluoropolymer coatings. Only two-component polyurethane paints, that were used before the introduction of fluoropolymer coatings, have been identified as readily available potential alternatives. However, using non-fluoropolymer materials that are less weather resistant than fluoropolymers will increase the maintenance frequency significantly. A comparison of high weather resistance, chemical resistance, and room temperature baking and manufacturing show that non-fluoropolymer material has a product lifecycle of approximately 5 years, compared to 10 years for fluoropolymer coatings.^{7,8}

Similarly, fluoropolymer-coated automotive films provide weather, heat and corrosion resistance that performs 3-5 times better than available alternative materials, ensuring the longest lifetime of vehicles and with less frequent need to remove and re-apply the film to protect the car's appearance in the long term. Non-fluorinated alternatives do not provide the same level of performance. For example, polyurethane film causes reduced performance (e.g., deteriorated dirt removal when insects adhere to the film), resulting in increased frequency of film replacement and manual cleaning. Acrylic films do not provide the same level of acid resistance that is required to protect the roof of a car. Finally, polyester films provide inferior protection of gloss in continuous

³ Aerospace Industry Standards, NQA, [What Standards Apply to the Aerospace Industry?](https://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.sae.org/standards/aerospacehttps://enhancequality.com/standards/aerospace-quality-standards/https://www.iso.org/ics/25.220/x/) <https://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.sae.org/standards/aerospacehttps://enhancequality.com/standards/aerospace-quality-standards/https://www.iso.org/ics/25.220/x/>

⁴ Aerospace Quality Standards, QSE. [Quality Systems Enhancement | Aerospace Quality Standards \(enhancequality.com\)](https://enhancequality.com/standards/aerospace-quality-standards/)

⁵ ISO-25.220, Surface treatment and coating including processes and equipment for surface treatment and coating. [ISO - 25.220 - Surface treatment and coating](https://www.iso.org/ics/25.220/x/)

⁶ ISO-25.220.60, Organic coatings. [ISO - 25.220.60 - Organic coatings](https://www.iso.org/ics/25.220/x/)

⁷ Wind Hullo Topcoat. [wind_hullo.pdf \(nttoryo.co.jp\)](https://www.nttoryo.co.jp/wind_hullo.pdf)

⁸ Wind Hullo Topcoat. [wind_hullo.pdf \(nttoryo.co.jp\)](https://www.nttoryo.co.jp/wind_hullo.pdf)

accelerated weathering tests and natural exposure tests, and is inferior to fluoropolymers in terms of weather, heat and corrosion resistance, stain protection, and self-healing.

Tab B – Electronics Applications

Semiconductors

Fluoropolymers are essential in the manufacturing of semiconductors, in wet cleaning and wet etch processing equipment, where high purity, high chemical and temperature resistance and low flammability are required. Fluoropolymer resins with an adhesive function provide the ability to bond to metals including copper and other polymers (e.g., polyimides and polyamides).

Adhesive fluoropolymers provide critical benefits as coatings for chemical resistance. They are essential because of their ability to not react with other chemicals, to not leach contaminants that could potentially negatively impact yield and to be stable under process conditions including elevated temperature. Fluoropolymer tubing additionally presents the advantage of being highly flexible, which allows for easier design and implementation in wet etch processing equipment and fluoropolymer coating on metal parts provides corrosion protection, allowing for increased efficiency as no primer or adhesive interlayer is needed.

Fluoropolymers are essential as pellicle films used in the photolithography process for the protection of photomasks from particle contamination in semiconductor lithography processing. They provide practical light resistance for the excimer laser in an environment that is irradiated with exposure wavelength ArF (193nm) and KrF (248nm), and achieve superior light transmittance through extremely high transparency (>95%). Additional essential performance requirements for pellicle film provided by fluoropolymers are uniformity of film thickness which helps avoid the tearing of the film, and low refractive index, and extinction coefficient which ensures that the light maintains a straight path without losing power. Fluoropolymer film coatings to a thickness of a few sub-microns, are essential for semiconductor innovation and associated node size reductions.

Fluoropolymers are critical as a UVC transparent window material or encapsulant for UVC LEDs to extract higher levels of light (i.e., to optimize the use of energy/electricity) from the UVC LED chip. Fluoropolymers are the only material that can simultaneously achieve the performance required for transparent encapsulants and for UVC LEDs, namely UVC durability, electrical insulation and water vapor barrier properties, which also ensure the proper functioning of the UVC LED. Synthetic quartz is not a suitable alternative for UVC-LEDs as it requires adhesives to be used as the encapsulation materials, which easily deteriorates with strong UVC light.

Other potential alternatives such as acrylic resin, generally absorb the UVC light and cannot be used for this application.

Top Anti-reflective Coatings (TARC) are widely used in the semiconductor industry, particularly in the manufacturing of semiconductors, integrated circuits, printed circuit boards, and other related components. TARC helps to reduce unwanted reflection of light from the surface of these materials, thereby improving optical performance and increasing efficiency. This coating is crucial for enhancing the functionality and quality of various electronic devices, ensuring better performance, and reducing the losses caused by reflections. The performance requirements of TARC material and its raw polymer are to simultaneously meet low refractive index, low surface energy, and solubility in water and developer. These performance requirements are directly related to the yield of commercial semiconductor manufacturing and process suitability. To our knowledge, there is no suitable alternative to fluoropolymer TARC material on the market. Similarly, BARC (Bottom Anti Reflective Coating) is an inadequate alternative to TARC, since BARC is only used for the production of certain semiconductors that have narrow patterning made by ArF immersion or EUV, as it requires a completely different manufacturing process and setting from those utilizing TARC made of fluoropolymers. Therefore, BARC is not considered a realistic and viable option for most semiconductor manufacturers to replace TARC. Furthermore, BARC is generally an inorganic layer stuck to the wafer and needs dry etching process to be removed from the wafer surface. On the other hand, TARC is easily removed together with photoresist at once due to performance requirements.

Thermal processes such as rapid thermal processing, Low Pressure Chemical Vapor Deposition, oxidation, diffusion and lamp annealing in semiconductor manufacturing processes require significant chemical and heat resistance. The ultra-high temperature (up to 260°C), plasma resistance (exposure to O₂ plasma, F₂ plasma or a mixture of both) and insulation properties (high breakdown voltage) of fluoropolymers make them invaluable for semiconductor fabrication processes (and other industrial extreme high-temperature areas) requiring elastomer seals. Also of critical importance, fluoropolymers do not form particle contaminants because they have high chemical bonding energy, making them resistant to plasma cleavage. This ensures that no particles adhere to the wafer, causing malfunctions. To our knowledge, there are no potential substitute materials that satisfy these requirements.

Fluoropolymers are also essential for the packaging of semiconductors, as they are the only material that can provide the necessary properties of high-temperature durability, anti-static, easy release, and mechanical properties (e.g. tensile elongation of 600% or above, elastic modulus of

70MPa or below) to package semiconductors without deforming or damaging chips, particularly at high temperatures ranging 150 – 220 °C. Other films, such as polyethylene, polybutylene terephthalate (PBT), and polyvinyl chloride (PVC) have inferior mechanical properties and less flexibility at high temperatures compared to fluoropolymer film and can cause damage/deformation of chips and decrease in productivity due to oligomer contamination.

Fluoropolymers also exhibit superior electrical properties (low dielectric constant and low dielectric loss tangent) compared to other potential alternatives (dielectric constant around 2,1 and dielectric loss tangent below 0.0002). Those properties maintain signal integrity and reduce transmission loss, and they also have a low thermal expansion coefficient as heat is generated. As increasing volumes of data are transmitted, the wavelengths used are shifting toward higher frequencies, with higher frequencies being more susceptible to attenuation during transmission. Modified polyimide and liquid crystal polymers have been evaluated as alternative materials, but none of these materials has achieved electrical properties comparable to those of fluoropolymers. The dielectric loss tangent of both “alternative” materials is more than 0.001. High-speed data communication requires higher frequencies, so there is a possibility that communication speeds may reach a ceiling if fluoropolymers are not used. To our understanding, no alternative has been found to be able to meet one or more essential functional quality characteristics of fluoropolymers such as adhesion, dielectric constant and ability to process, and there is no prospect of technically or economically viable alternatives at present.

In addition to the critical functions described above, fluoropolymers also play an essential role in assuring the “clean room” environment necessary for semiconductor manufacture. Specifically, fluoropolymer membranes are used to meet the high-performance filter standard EN 1822 (ULPA, HEPA) which is essential for semiconductor and LCD related plants and equipment. These fluoropolymer membrane filters combine high air permeability and collection efficiency, and can reduce power costs compared to non-woven filters and glass filters made of other materials. In addition to their superior performance, fluoropolymer filters do not have the potential to leach boron (B), which is present with glass filter media, and can adversely affect the performance of semiconductors. Similarly, filters with both high chemical resistance and filtration performance are required for filtration of chemicals used in semiconductors. Fluoropolymer membranes are among the few materials that can satisfy these requirements. Ceramic, a potential alternative, has high chemical resistance but is very expensive and therefore difficult to replace for economic reasons.

For more information on the importance of fluorine materials used in the semiconductor manufacturing process, please refer to the technical documents available on SIA (Semiconductor Industry Association) website.

Batteries

Fluoropolymers are essential components of high-performance lithium-ion rechargeable and lithium metal rechargeable batteries. High power and energy dense batteries require very thin high-performance gaskets. For gaskets to function optimally, proper thermal functionality is essential, for which a stable and compressive polymer providing a high degree of insulation to withstand very high currents of up to 280 amps is needed. Chemical resistance is also a requirement. The high compressive and moisture properties of fluoropolymers are required to enable adequate, reliable gasket performance. Other potential methods and materials such as multilayer construction do not provide long-term and leak-proof lining systems and would lead to frequent maintenance intervals. In addition, materials such as high-alloy steels (e.g., hastelloy, inconel, titanium, zirconium) are not sufficiently chemical-resistant.

For nickel-metal hydride batteries, the binder is required to have strong alkali resistance and the polymers need to be dispersed. This essential functionality is provided by fluoropolymers, which also may be used in the electrodes of lithium-ion batteries, where chemical resistance and low flammability are key requirements. Furthermore, to meet increasing performance demands, next generation batteries with higher functionality will need binder materials that can meet more exacting requirements in terms of alkaline solution concentration and voltage (oxidation potential of the cathode). Fluoropolymers are essential for providing these functionalities.

Studies assessing alternatives to fluoropolymer binders have been conducted without finding promising non-fluorinated alternatives.⁹ None of the potential alternatives simultaneously meet the required chemical, heat, and voltage resistance, as well as the adhesion to the substrate at a level comparable to fluoropolymer materials. Within battery applications, fluoropolymers are mainly used as binder because of their ability to function in strong oxidation environments. For lithium-ion batteries at positive electrodes, more than 4V is occurring, which causes oxidation. When applying non-fluorinated polymers as binder, these polymers will be oxidized and tattered. As holes are generated these polymers lose their function as a binder.

⁹ Application for Derogation from PFAS Restrictions For Specific Uses in BATTERIES, Battery association of Japan, available at: <https://www.baj.or.jp/about/ades5k0000001vxx-att/ades5k0000001wa9.pdf>

Printed Circuit Boards

Fluoropolymers are essential components of copper-clad laminates (CCL), the key material in printed circuit boards, because they combine the critical performance characteristics required for this application: heat resistance (solder reflow endurance temperature 300 °C), solder resistance, water resistance, good adhesion to copper foil, and low dielectric constant. We are not aware of suitable alternatives that provide equivalent performance and reliability. Fluoropolymers are also used to coat printed circuit boards to provide protection against moisture or other contamination that might lead to short circuit and device failure.

Wire & Cable

Insulating fluoropolymer coatings are essential components of wire and cable, to assure the safety of the structures within which wire and cable are used, and to comply with factory mutual standards including FM 4922 – the Global Specification for ventilation/duct extract systems. Fluoropolymer sheathing is essential for this because of their superior chemical and heat resistance and their non-flammability.

Fluoropolymer coated wire is rated to at least 260 °C, which provides the necessary protection for use in automotive, aerospace and industrial high temperature applications. These include thermocouples, self-regulating heater cables and any location where a temperature of above 200 °C is needed for extended periods of time. In addition, fluoropolymer coated wire is used in high voltage, high frequency heating cables, needed in many subsea applications that require high temperature resistance, low dielectric losses and the ability to withstand electrical and chemical breakdown over a long service life. Fluoropolymers are critical for achieving these performance requirements. Similarly, self-regulating heater cables are used for freeze protection and process maintenance. In high temperature and high chemical resistance heating, fluoropolymers are necessary to both conduct electricity in the inner layer of the cable, as well as provide insulation in the outer layers.

Because of their low dielectric constant, fluoropolymers used in wires and cables confer a low dielectric loss up to 250 °C. Potential alternatives such as polyolefin-based materials do not offer a viable substitution potential, as their applications are limited to temperatures below 80-100 °C. Polyimide (PI) and liquid crystal polymers (LCP) are also potential alternatives to fluoropolymers for wire and cable and electronics coatings more broadly. However, both PI and LCP are unsuitable for many applications, due to their high dielectric constant.

Finally, as a technology enabling future innovations, fluoropolymer coated wire and cable is ideally suited for use in electric engines in aerospace applications. These require high temperature, high voltage and high frequency low loss performance. Partial discharge issues affect these cables at high altitude so semi conductive fluoropolymers are a promising solution. As such, fluoropolymers will be a critical material in the long-term decarbonization of air-travel.

Other

Electronic equipment with touchscreen interfaces, such as smart phones and tablets, require a smudge-resistant, easy-to-clean surface to maintain optimal performance. Fluoropolymer-based functional coatings are both hydrophobic and oleophobic and provide excellent water- and oil- repellency to such surfaces by forming an extremely thin monomolecular layer on the surface. Moreover, fluoropolymer-based functional coatings impart these benefits with no change in optical properties and they provide high resistance to abrasion (e.g., steel wool), UV exposure (e.g., outdoor sun light), and chemicals (e.g., acid, base, and a set of solvents).

Conventional anti-fouling and mold-release coatings exhibit low abrasion resistance, which causes them to wear-off quickly from friction as they are used. This makes it necessary to apply overly thick coatings or reapply frequently to keep the desired effects. Additionally, some coating agents have no oil repellency, a drawback that makes them prone to build up fingerprints, sebum, and other oily smudges. Other possible alternatives include washing with mild soap or wiping with alcohol; however, these are liquid-based and moisture, or excessive wiping might cause damage to the equipment.

Tab C – Communications Applications

In the telecommunications sector, fiber optics is a critical technology allowing the fast transmission of large amounts of data. Amorphous fluoropolymers are used in plastic optical fiber cables due to their excellent light transmission. As data transmission speeds increase (>10Gbps), optical data transmission will become more efficient and low attenuation of light rays in the 650-1300nm laser wavelength range for data communication is required. Fluoropolymers provide this functionality. In addition, when wiring indoors or in automobiles or aircraft, data must be transmitted correctly and reliably even when the cable is bent because it passes through narrow spaces. Plastic optical fibers made of fluoropolymers enable the necessary flexibility and durability, whereas potential alternatives cannot provide that required functionality. For example, acrylic resin and quartz glass are considered as alternative candidates for optical fibers. However, acrylic resin is not suitable for high-speed data transmission due to its high transmission loss in the 650-1300 nm range. Meanwhile quartz glass is not suitable for installation in confined spaces, e.g., indoors, in automobiles and airplanes, because of safety risks stemming from reduced amounts of information being transmitted (i.e. information exchange in airplanes and cars is lost) and its intrinsic risk of fiber break due to bending.

Fluoropolymer “buffer tubes” are also used to hold and carry fiber optic cables to protect them from the potentially harsh adjacent environment and thereby enhance the reliability and integrity of data being transmitted. Similarly, fluoropolymer insulation is critically important for tidal power/signal cables, to provide temperature and chemical resistance necessary for protracted exposure to sea water. More generally, fluoropolymer sheathing also provides excellent dielectric properties and therefore improved performance for high-volume data transmission and connectivity.

Fluoropolymer coatings on circuit boards also ensure low signal loss, which is essential to the future of 5G or higher transmission speeds. By comparison, potential alternatives are inadequate. For example, Polyimide (PI) has a high dielectric constant of 3.0 due to the presence of polar groups in its structure and cannot be used for high-speed communications after 5G, while Liquid Crystal Polymer (LCP) has a high dielectric constant of 2.9 and also cannot be used. Fluorine has low dielectric loss due to its low polarity and is essential in the 28 GHz band used for high-speed communications after 5G. In high-speed wireless communication signal transmission, the characteristic impedance of printed circuit boards must

be matched to 50 Ω . For this purpose, it is important to have a low dielectric constant, as provided by fluoropolymers.

Tab D – Medical and Life Sciences Applications

Fluoropolymers are essential components of endoscopes, catheters, laparoscopic devices, stents, balloon dilators, needles, brushes, pacemakers, artificial blood vessels, dialysis-related devices, stent surface coating and other items inserted or implanted into the body for diagnostic or therapeutic purposes. Fluoropolymers are necessary for these applications because of the combination of properties they possess. Specifically, they are biocompatible, resistant to contamination and easy to clean, resistant to bodily fluids as well as chemicals (such as chemical sterilizers) and irradiation, do not degrade in heat (and are therefore autoclavable), corrosion resistant, and have a low dielectric constant and therefore superior electrical insulating capabilities. Similarly, fluoropolymers do not stick to surfaces and are anti-kinking. These properties are of utmost importance for devices requiring high lubricity and flexibility in navigating human physiology. Potential alternatives cannot provide the same functionality as fluoropolymers in these critical applications. For example, the low mechanical strength and tearability of silicone-based materials agents can lead to higher risks of contamination.

Fluoropolymers are also used as wire coating materials for medical equipment. Medical equipment has many hinge parts that bend and stretch, requiring high mechanical strength in addition to insulation and flame resistance. Silicone materials are known as alternatives, but they are not used due to their low mechanical strength and tear resistance.

Biochip or analysis chips (microfluidic devices) for medical and DNA diagnostic applications use fluoropolymers to impart water and oil repellence and electrical insulation. By forming a fluoropolymer coating on a glass surface, it is possible to produce fine hydrophilic / hydrophobic patterns that serves as a dielectric, hydrophobic surface in electrowetting. The fine patterns ensure that a fluorescence observation can be carried out. Fluoropolymers also provide low autofluorescence and a refractive index which is close to that of water (1.34), which ensures that it can easily be read with a microscope. Furthermore, due to its wettability control, fluoropolymers enable a change of wetness under an electric voltage, which allows for the manipulation of microscopic droplets. Potential alternatives studied to date demonstrate inferior or inadequate performance. For example, Parylene and PDMS lack the required water and oil repellency, anti-biofouling property, and chemical resistance for electrowetting on dielectric (EWOD) devices, and glass substrates lack the required high water and oil repellency, only reaching contact angle of 44 degree for water and 21 degree for oil (n-hexadecane).

Fluoropolymer membranes are also essential in gas analysis and applications requiring humidification and/or dehumidification. In the medical sector, breath gas analyzers are needed to monitor the effects of drugs on patients, metabolism and other diagnostic purposes. Humidifier / drier membranes have a key role in controlling the level of moisture in oxygen or other gasses administered to patients and can be used in moisture-wicking sampling lines for intubated and non-intubated patients in low-and high-humidity applications. There are no adequate substitutes for these applications. For example, hollow fiber humidification modules present risks of oxygen leakage. In addition, potential alternatives provide lower detection accuracy and response performance of capnography and asthma analyzers, leading to impaired patient monitoring. Fluoropolymers are needed for high water vapor selective permeability, high separation ratio with other component gases, and a non-porous membrane to prevent the permeation of bacteria.

Fluoropolymer coatings also play an important role in diagnostic imaging, by preventing contamination or soiling of the image plate. Without the protection of a fluoropolymer coating, if contamination occurs at the time of imaging, the patient may have to undergo additional imaging or, even worse, the distortion in an image may lead to misdiagnosis. To our knowledge there are no suitable alternatives for diagnostic imaging plates that provide the comparable protection against surface contamination.

Tab E – Infrastructure and Construction Applications

Reliable construction and infrastructure form the backbone of modern society and are essential to its continued functioning and existence. Fluoropolymers play an essential role in preserving and protecting infrastructure and enabling the reliable, effective and sustainable construction practices that are essential to the continuation of modern society.

Fluoropolymer-based coatings (FBCs) offer superior performance, service life, sustainability, appearance and value for applications on a wide variety of metal substrates used in commercial and monumental building projects. These fluoropolymer-based systems include film-forming binder resins used in settings where extreme durability and lifespan of several decades or more are needed to provide substrate protection. FBCs extend the lifespan of the underlying materials and are a critical specification for certain products and end markets. FBCs can be applied to a variety of components used in projects ranging from pre-engineered metal buildings to municipal arenas and skyscrapers. Important properties that FBCs enable for construction include, but are not limited to the following:

- Adhesion, flexibility, formability, abrasion resistance, hardness and impact resistance;
- Resistance to chemicals, flame spread/surface burning; and
- Durability as demonstrated by UV-resistance, film integrity, low film erosion rate, humidity resistance and corrosion resistance.

FBCs have been shown not to be susceptible to attack by UV light, which results in a coating that is highly resistant to degradation upon exposure to sunlight, unlike virtually all other polymers. This property provides a very high resistance to fading and chalking as well as very good long-term maintenance of gloss and color. Apart from being highly resistant to UV light, the FBCs are also highly resistant to many chemicals and can have excellent stain resistance. Due to these superior qualities, FBCs also tend to carry a premium price compared to most other coating systems. Because of their solar reflectance, FBCs used on roofing also offer the additional benefits of lower energy usage from higher solar reflectivity and lower roof temperatures and a lower carbon footprint, as well as lower maintenance costs and increased efficiency and longer lifespan of HVAC equipment.¹⁰

¹⁰ White Paper on Fluoropolymers in Infrastructure and Construction (December 2023), available at <https://fluoropolymerpartnership.com/wp-content/uploads/2023/12/PFP-White-Paper-on-Fluoropolymers-in-Infrastructure-and-Construction.pdf>

We are aware of no other coating technology that enables the performance parameters of durability and product longevity that are the defining characteristic of FBCs. Indeed, outdoor exposure testing demonstrates that FBCs have an erosion rate approaching 50 percent less than other coating technology options used in Infrastructure & Construction settings. This difference explains why FBCs have a life expectancy of 50 years or more in many settings compared to 20 years or less for some alternate technologies. This reinforces why FBCs are so unique and useful in the development of durable and essential building products.¹¹ In addition, the FBCs long lifespan means less recoating is necessary and less VOC's are emitted (as a result of the recoating process) as compared to other alternatives.

Bridge structures clearly need durable coating performance to protect the painted metal substrate below and maintain the bridge's structural integrity. Any coating system must last a long time given how difficult, disruptive and expensive the recoat process is. Bridges are subject to highly adverse environmental conditions including high intensity sunlight, fog, rain, saltwater (coastal areas) spray and constant automobile exhaust among other stressor factors. The superior anti-weathering performance of fluoropolymers allows the paint system to prolong the bridge's service life and decrease the number of re-painting cycles, contributing to lower life cycle costs for municipalities (and residents) and reduced VOC emissions and lower CO2 generation. The same is true for water tanks and other large pieces of infrastructure. Available data conclusively establish that FBC's substantially outperform potential alternatives with respect to weather and corrosion resistance. For example, compared to commonly used urethane resin paints, the service life of this product can be expected to be three times longer, while reducing CO2 emissions by approximately 38% over 100 years and VOCs by about 50% in 100 years.¹²

Fluoropolymer films are used as essential structural elements, such as roofing, wall panels and canopies in a variety of buildings and structures, including large public structures such as sports stadiums, airports and other transportation hubs. The use of fluoropolymer films in this application has several essential benefits, including, crucially, a substantial reduction in the volume of material, typically concrete, steel and/or glass, that would otherwise be required for a structure. The reduced use of concrete, steel and glass, in turn, results in lower CO2 emissions as well as less waste being generated and sent to landfill upon demolition of the structure. In addition, fluoropolymer films have excellent light harvesting properties for light with wavelengths

¹¹ Id.

¹² Id.

from 300 to 2100 nm and at all angles of incidence. Several properties of fluoropolymer films, together, cause them to be uniquely suited to this application and therefore essential. These include:

- Excellent resistance to temperature extremes, weather, chemicals, stains and fouling (“self-cleaning”);
- Superior durability -- retains at least 90% of its initial tensile strength and elongation after 30 years of exposure to rain and ultraviolet rays;
- Lightweight but strong, requiring minimal structural support, highly resistant to tear propagation, no breaking or splintering;
- Self-extinguishing, UL V-0 certified for combustion resistance, ASTM E 108 for Fire Test of Roof Coverings, designated as a non-combustible material (Japan), and European Combustion Test EU EN13501-1; non-flammable material certified B1 in DIN4202 part 1;
- Superior sound absorption.

Fluoropolymer film made of ETFE resin is also used in greenhouses, to improve the growth efficiency of fruits, vegetables and plants. This film has a higher light and UV transmission rate than glass, polyethylene or polycarbonate, allowing the full spectrum of sunlight to pass through the growing area. The result is increased production, earlier blooms, more colorful petals, sweeter fruit and higher quality vegetables.

Overall, potential alternatives to fluoropolymers (e.g., glass, PVC, fiberglass-impregnated membranes without a fluoropolymer layer for protection) are unsuitable. They present safety concerns in terms of increased flammability and degradation of components due to low flame resistance and low weatherability. They are also less weather resistant and require early replacement, which shortens the structure’s lifespan by 15-20 years. For example, with glass and PVC, the product life is 10-50% of fluoropolymer film and the frequency of replacement is 2-10 times higher. They also contribute to greater CO₂ emissions.

Tab F – Food Contact and Processing Applications

Fluoropolymers play an essential role in food production and processing, including in the applications listed below. Importantly, for all of these applications, the U.S. Food and Drug Administration (FDA) has extensively reviewed the safety and efficacy of the fluoropolymers in use, and has authorized their continued use.

- In food and feed production equipment, fluoropolymers are used as base film in ion exchange membranes for water treatment and separation of organic components and inorganic salts in the electrodialysis process.
- In linings of food cans, fluoropolymer film is laminated with steel plates and, due to their chemical and temperature resistance, function to prevent corrosion of the can.
- In tubes and hoses, fluoropolymers provide superior heat and water resistance and durability. This combination of properties is critical because sterile cleaning with high temperature steam is standard for food applications, and it is common to clean under high pressure steam conditions at 121 °C for 15 minutes (see, e.g., ISO 17665, JIS T 0816-1).
- In tubes, hoses, gaskets and other food processing and handling equipment, fluoropolymers provide excellent heat resistance, oil and chemical resistance, helping to assure the purity of foods being processed and prevent cross-contamination.
- In food contact surfaces including processing, storage and packaging, fluoropolymers provide non-stick efficacy, heat and chemical resistance, cleanability, wear (abrasion) resistance and superior friction coefficient. They are also highly effective mold release agents for plastic packaging, helping to assure the purity and physical integrity of the packaging.

Fluoropolymers are essential in these applications because of their unique combination of properties. For example, silicone materials have been tested but are not suitable due to their low mechanical strength and tearability. Ceramic coatings provide sufficient heat resistance, but their release properties are inferior and insufficient. They are also more difficult to coat than fluoropolymers, making it difficult to coat complex and fine shapes evenly, and they are more expensive than fluoropolymers to coat. To our knowledge, no non-fluorinated material has so far

been found with mold release and processability comparable to fluoropolymers coupled with heat resistance above 200 °C. Silicones and ceramics have been widely accepted and used for such applications in the past, but fluoropolymers have been used in applications where these materials are inadequate in terms of performance. Therefore, if the use of fluoropolymers is prohibited, the risk of process purity degradation, leakage and foreign material contamination due to accelerated component degradation will increase and have a significant impact on manufacturing control and maintenance systems.

Tab G – Energy Applications

Solar Panels

Fluoropolymers are critical components of solar panels. Lightweight, durable, transparent fluoropolymer films used on top of flexible or rigid solar modules have higher light transmittance than glass while providing long-term weather protection as well as a “self-cleaning” anti-fouling functionality. Moreover, because of their weather resistance, these fluoropolymer films retain their superior performance characteristics for more than 25 years. These functionalities combine to increase the electrical output of the solar panel by as much as 30%. In addition, because of their light weight in comparison to glass, fluoropolymer films open up more roof spaces to photovoltaic modules made with fluoropolymers, facilitating the expansion of solar panel deployment.

Because of their unique combination of properties, fluoropolymers are also uniquely well suited for use as back sheets (films) in photovoltaic solar panel construction. Back sheets are used on solar panels to help protect the solar cell from weather, humidity, and impact damage. They can also help provide electrical isolation for safety purposes. Thus, the proper choice of the back sheet can increase the panel life and reduce the cost of electricity generated from the panel over the solar panel cell's life. Materials used in this end-use should have significant UV resistance and stability, corrosion resistance and flexibility. Fluoropolymers satisfy all of these criteria. They are light in weight and have extended durability in full exposure to a variety of environmental conditions, including intense sunlight and heat.

Finally, fluoropolymers are essential components of mold release films and transport materials used in the production of solar cells. For example, in the production of solar cells, cell modules and surface materials such as glass are laminated with EVA (ethylene vinyl acetate resin) at 150 °C under vacuum. Because EVA is extremely adhesive under high temperatures, the materials used for lamination and transport must have excellent non-adhesiveness and heat resistance. Furthermore, they must be organic materials that will not damage surface materials such as glass. At present, the only technically and economically feasible materials that provide these functionalities are fluoropolymers. For example, a material with excellent non-stick properties (low surface tension) is high-density polyethylene, but it does not have a heat resistance of 150°C and therefore is not a feasible alternative. The use of multilayer film, where several types of film are laminated together, has also been proposed as an alternative, but the

technology to separate and recover each layer has not been established, making recycling difficult and reducing the recyclability after use.

Wind Turbines

Fluoropolymer coatings perform an essential function for wind turbines (both the blades and the turbine tower) by imparting weather resistance and durability as well as “self-cleaning” functionality. These properties are especially important for offshore windmills, to provide resistance to the corrosive effects of seawater. They are also especially important for the wind-cut parts of the blades in snowy locations, where snow would otherwise adhere to the blade and clump, forcing the turbine to stop operation due to the risk of falling snow.

Potential alternatives to fluoropolymer coatings are polyurethane and polysiloxane coatings. However, fluoropolymer coating systems are several times more durable than polyurethane resin coating system, meaning that polyurethane coatings would require several more re-coatings during the 20-year design life of the wind turbine, as compared to fluoropolymer coatings. For wind turbines, which are often installed at high altitudes and in harsh environments, durability is an essential factor in their usefulness and efficiency.

Finally, fluoropolymers are essential components of mold release films and transport materials used in the production of wind turbine blades.

Clean Hydrogen

Fluoropolymers are an essential enabling material for several hydrogen technologies, including electrolysis membranes, electrodes, as well as sealing and lining equipment for hydrogen storage and transport equipment. Hydrogen is a highly flammable gas; therefore containing any potential leaks is essential for the safety of personnel and equipment. For this reasons, seals and linings in hydrogen transport and storage demand the superior chemical, heat and electrical resistance and overall durability of fluoropolymers.

The electrolyte membrane used in the PEM (Proton Exchange Membrane) water electrolyser that produces hydrogen from water is made of fluoropolymer, which is essential for the realisation of a hydrogen society because the PEM water electrolyser can operate at high current density, has high responsiveness to voltage fluctuations and is compact. Alternatives to hydrocarbon-based membranes have been proposed but they lack practical durability due to low thermal and chemical stability, difficulty in achieving high proton conductivity, low

mechanical strength, etc. Without fluoropolymers, development and adoption of hydrogen generation, storage and transport technologies in the US will be severely constrained.

Batteries and Fuel Cells

As discussed more fully in Tabs A and B above, fluoropolymers are essential for use as binders, separator coatings, gaskets and seals, and electrolyte additives for batteries, due to their combination of chemical and heat resistance, dielectric properties, durability and adhesion to the substrate. None of the potential alternatives to fluoropolymers simultaneously meet these required performance characteristics.

In flow batteries, fluoropolymers provide the unique combined performance requirements for ORFB (organic redox flow batteries) systems, including (i) low voltage allowing for high energy efficiency; (ii) long lifespan, resulting in lower cost and environmental impact; and (iii) low activation crossover, allowing for higher efficiency and lower power consumption. Overall, fluoropolymers enable high retention of redox molecules, high chemical stability and good battery performance. ORFBs are set to replace vanadium-based RFBs (redox flow battery) on the market, with the following advantages:

- They do not use rare metals such as vanadium or rare materials
- The active materials can be synthesized organically, enabling significant cost reductions
- Higher voltage (up to twice)
- Higher durability, i.e. less waste generated
- Cost savings

Several non-fluorocarbon hydrocarbon anionic membranes have been tested for use in flow batteries. However, they cannot achieve the performance of fluoropolymers with respect to key parameters including voltage reduction, battery life and crossover reduction. Thus, there are no suitable alternatives for fluoropolymers in this application.

Nuclear

In nuclear generating facilities, fluoropolymers are essential for use in seals and wire jacketing, due to their heat resistance, chemical resistance, resistance to radiation, mechanical strength and insulation properties. This combination of properties is essential in the harsh environment of a nuclear reactor to mitigate against leakages and failure, and to assure safe and reliable operations. Potential alternatives are not suitable. For example, PE becomes brittle and breaks

after irradiation, rendering it unusable. By comparison, fluoropolymers tested according to ASTM D2587 show that physical durability and integrity are maintained after 10^8 rads of irradiation.

Oil, Gas and Mining

Fluoropolymers are essential in a broad range of applications in the oil and gas extraction sector, as well as downstream, in transport and refining of petroleum products.

The “down hole” applications in which fluoropolymers are essential include packers, blow out preventers, seals, gaskets and O-rings, where heat resistance coupled with chemical resistance are required. Resistance to hydrogen sulfide is particularly important since it is a natural, poisonous by-product in many gas/oil wells and is highly corrosive. Fluoropolymers provide superior resistance to this chemical at high temperatures. In addition, high temperature steam is sometimes used to enhance the efficiency of oil well extraction particularly in older wells or where oil viscosity is high. Also in down hole applications, seals must be able to cope with a rapid gas decompression without losing seal integrity. In the worst case this could lead to an environmental incident or other safety-related issues. Explosive Decompression (ED) resistance or rapid gas decompression resistance is also a key property of fluoropolymers in these very harsh conditions. Fluoropolymers are unique in their ability to resist for prolonged periods the combination of stresses – chemical, thermal, and pressure – that are present in “down hole” applications. In many cases oil needs to be pumped up to the surface and “electrical submersible bags” are used in the drilling systems to house the pump mechanism. Fluoropolymers are used in the construction of this “electrical submersible bag”, which needs to withstand the crude and other high temperature chemicals on the outside of the bag but also resist the “lubricating oil” from the pump on the inside. Fluoropolymers provide this dual resistance at high temperatures.

The internationally recognized industry standard for sealing materials used for oilfield equipment, i.e., NORSOK M-710, developed by the Norwegian Petroleum Industry, sets the qualification requirements of non-metallic sealing materials and manufacturers, referencing ISO 23936. Fluoropolymers are the only polymers that can resist rapid expansion due to compressed gas absorption, which can cause seal failure, while maintaining necessary chemical resistance performance in environments where heat resistance is required above 200°C. Fluoropolymers are also used for wire sheathing in equipment used in these harsh operating environments where high heat and chemical resistance is required. Sometimes

alternative materials such as polypropylene are mentioned, but they are poor at corrosion resistance and cannot be used in such environments, and no alternatives to fluoropolymers have been identified. Similarly, in the mining sector, fluoropolymers are essential to ensure the safe operation of equipment which needs to work continuously under extremely harsh and dangerous conditions with practically no margin for errors. Potential alternatives cannot meet the very high performance requirements for temperature (as high as 270°C), chemical and mechanical resistance.

Tab H – Manufacturing & Processing Applications

Fluoropolymers are used in critical applications throughout the manufacturing sector, including the chemical industry, where they are essential because of their unique combination of performance characteristics. This section describes a representative cross section of the manufacturing and processing applications in which fluoropolymers play a critical role.

Fluoropolymers are essential for use in valve seals, pipe packing, gaskets and other seals in industrial processes that entail the use of hot, hazardous or corrosive liquids and gasses. Potential alternatives such as polyethylene or polyamide cannot provide the same degree of temperature and chemical resistance and mechanical strength as fluoropolymers, and their use in high stress industrial processes would result in an increased risk for leaks or catastrophic failures that could result in threats to human health and the environment. Compared to potential alternatives, fluoropolymers provide superior corrosion prevention, leak prevention, chemical emission reduction, lower maintenance costs and downtime, increased component life span, cleaner flue gas emissions and lower CO₂ emissions, higher efficiency and production yield, improved quality and purity of products, and waste reduction.

In chemical, petroleum and pharmaceutical plants in particular, many systems need seals, linings, hoses, reactor vessels and other equipment that provide corrosion resistance, heat resistance, chemical resistance, mechanical strength and non-flammability. These critical functionalities are uniquely provided by fluoropolymers, which have a heat resistance of more than 250 °C, are chemically stable over a wide pH range of 1-13 and have virtually no leaching of impurities. In addition, fluoropolymers are particularly well suited to line complex shapes and parts in tanks, since they can be rotolined and spray coated. Fluoropolymers are similarly essential in for use as packing material in distillation processes, especially for very aggressive chemicals at high temperatures.

Potential alternative materials are not suitable, particularly for highly aggressive chemicals. In terms of heat resistance, ceramic and refractory fibers are sometimes used, but these materials create impurities and cannot be used in clean applications. Polyimide is inferior in terms of chemical resistance; silicones are inferior in terms of heat resistance; and PEEK which costs several times more than fluoropolymers, is difficult to process due to its high stiffness (flexural modulus 3,8 GPa) and high linear expansion coefficient (linear expansion coefficient 10.8).

Fluoropolymer ion-exchange membranes are essential for chlor-alkali electrolysis due to their low electric resistance and low susceptibility to impurities. These properties help achieve substantial energy savings, stable performance, and maintain 97-98% electrical current efficiency in the functioning of electrolyzers. Products made from chlorine and caustic alkaline are used in a variety of sectors, which include construction (PVC, aluminum, polyurethane thermal insulation), energy (e.g. wind turbines, hybrid car batteries purification, fuel cells), fertilizers and herbicides, health & personal care (water disinfection, soap manufacture, PVC blood bags, nylon surgical sutures), home care (dry cleaning, PVC windows, aluminum) pharmaceuticals (production e.g. aspirin, antibiotics, medicine packaging), safety (heat resistant and protective clothing police and fire services, Zinc chloride in forensic finger printing, sport (aluminum baseball bats, spandex, Aramid motor racing suits), technology (circuit boards, fiber-optics, semiconductors, smartphones), transportation (car parts, brake fluid, anti-freeze). This illustrates the importance and wide impacts of chlor-alkali electrolysis. The only potential alternatives to fluoropolymer ion-exchange membranes in this application require the use of either mercury or asbestos – both of which are highly restricted substances that present substantial risks to human health and the environment. Moreover, the mercury and asbestos technologies provide inferior performance (e.g., higher energy consumption, lower purity) than fluoropolymer ion-exchange membranes.

As discussed in Tab G, above, fluoropolymer-based electrolysis membranes are also essential to the production of clean hydrogen, since membranes from alternative materials have lower chemical resistance and a much lower life span as well as significantly higher energy consumption (up to 50% higher) than those made from fluoropolymers. In addition, potential alternative hydrocarbon-based ion exchange membranes have low mechanical strength and are easily damaged during assembly, while fluoropolymer-based membranes have high mechanical strength which resists damage during assembly and maintenance (i.e. disassembly, cleaning, and inspection) and, thus, result in the creation of much less waste compared to non-fluorinated membranes. This is true for applications in all downstream sectors. Fluoropolymer membranes are also critical in wastewater treatment applications, for desalination of wastewater (where they can concentrate salinity to high concentrations while requiring low energy consumption, compared to potential alternatives) and metal plating (where due to their durability under oxidizing acid conditions and their chemical resistance more generally).

Fluoropolymers are also essential for various components used in a wide array of industrial applications, including:

- **Plate heat exchangers**, where fluoropolymers are typically used as gaskets or seals. Plate heat exchangers are used in many industrial applications to transfer heat between two fluids. Typical applications include: heating, ventilation and air conditioning (HVAC); refrigeration; engine or other mechanical cooling; food processing; oil production; boilers; aerospace, cryogenics; and pharmaceutical manufacturing. In many applications – particularly those involving corrosive chemicals and high temperatures – there are no suitable alternatives to fluoropolymers – which, among other benefits, allow complex plate heat exchanger systems to run for much longer times at higher temperatures – extending plant/production operation, reducing maintenance downtime and generating far less waste (spent gaskets) over the life of the production plant.
- **Stator/Mono pumps**, ranging from laboratory- to industrial-sized, particularly for operations involving corrosive chemicals, high temperatures or steam, where the chemical and temperature resistance of fluoropolymers is essential.
- **Compressed gas storage and transportation equipment** which relies on the exceptional properties of fluoropolymers at cryogenic temperatures -- essential for equipment used in transporting, handling and storing liquefied gas (e.g., liquefied natural gas or liquefied hydrogen). At cryogenic temperatures (- 161 °C for liquid methane gas, -253 °C for liquid hydrogen) no other elastomeric materials are adequate.
- **Hoses, tubes, gaskets and seals** used in all types of industries for applications and processes that require durability, flexibility, heat resistance (greater than 200 °C) and chemical resistance.
- **Rubber rollers** utilized in material handling, assembly, and manufacturing operations, especially those involving the use of acidic or alkaline chemicals and high temperatures, such as processes used in the manufacture of steel and aluminum.
- **Wire and cable** used in aggressive industrial environments. As discussed in Tab A, above, fluoropolymers are essential in these applications because their unique combination of properties including durable and reliable protection against extreme temperatures, harsh chemicals, humidity, vibration and compression, as well as their flexibility and strength.

- **Lubricants** used in bearings, ball joints, hinges, calipers, valves and other components utilized in a wide range of industries including automotive, aerospace, chemical processing, packaging, medical and mining, among many others. Fluoropolymer lubricants impart superior surface lubricity and reduced wear over a wide temperature range; they are virtually immune from chemical attack, do not absorb water, have a wide temperature range (-190 °C to +260 °C), and have excellent weathering and aging characteristics.
- **Conveyor belts, coaters, and thermal processing devices** used in various manufacturing and processing applications where chemical and temperature resistance are necessary – for example, in textile, upholstery, and carpet manufacture.
- **Humidifier / dryer membranes** used for compressed gasses, metals manufacturing and refrigeration units. Fluoropolymer membranes have high selective permeability to water vapor and high separation ratio with other component gases.