Sustainable Electrochemical Technologies: Replacing Critically Raw Materials

Critical Raw Materials (CRMs) are the cornerstone of Europe's economic and industrial framework, forming a strong industrial base that supports the creation of a myriad of goods and applications integral to daily life and cutting-edge technologies. Ensuring a steady and reliable supply of these materials is increasingly seen as a strategic challenge within the European Union and the global market. In response to this, the European Commission has identified and regularly updates a list of CRMs, which are essential to the EU's economy and carry a high supply risk.

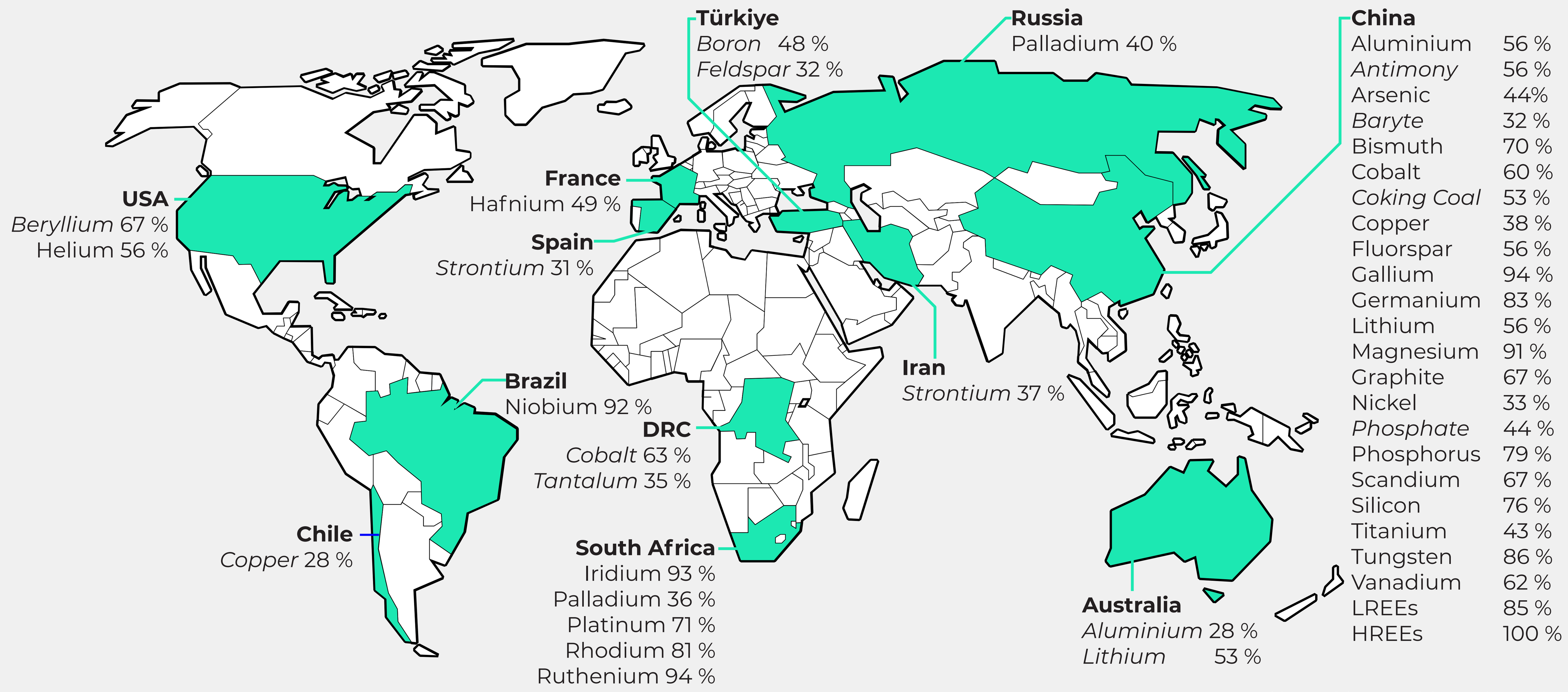

Figure 1: world map of the main global producers of the raw materials listed as critical for the EU in 2023

The significance of CRMs is multi-faceted: they are deeply intertwined with all industries and are present at every stage of the supply chain. Their importance is further amplified by their role in modern technology, where they are key to advancements and the improvement of quality of life. For instance, a smartphone may contain up to 50 different kinds of metals, contributing to its functionality, compact size, and light weight. Beyond their industrial and technological utility, CRMs are vital for environmental sustainability; they are irreplaceable components of clean technologies such as solar panels, wind turbines, electric vehicles, and energy-efficient lighting, which are central to the transition to a green economy.

Development of Alternative Materials

Innovating and developing new materials that can serve as substitutes for CRMs in electrochemical applications is a key strategy. These substitutes must not only mimic the functionality of CRMs but also be more abundant or more easily sourced, ensuring security of supply and reducing dependency on materials with high economic and geopolitical risks.

Efficient Use of CRMs

To optimize the use of CRMs, processes must be refined to minimize waste and extend the life of the materials within the products. This includes designing products for durability, promoting the use of lesser material without compromising quality, and enhancing the materials' lifecycle through innovative manufacturing techniques.

Design for Longevity and Recyclability

This strategy focuses on the design phase of electrochemical products, prioritizing longevity, repairability, and recyclability. By designing products that are easier to repair and disassemble, the demand for new CRMs can be decreased. Additionally, creating products with the end of their life cycle in mind ensures that CRMs can be recovered and reused, thus supporting a more sustainable usage cycle.

Recycling and Recovery of CRMs

Strengthening the processes for recycling and recovery of CRMs from products that have reached the end of their life, as well as from industrial waste, is essential. This involves developing and implementing efficient, cost-effective recycling technologies that can recover CRMs without significant loss of material quality, thereby closing the loop on CRM usage.

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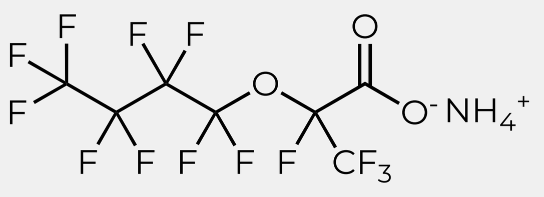
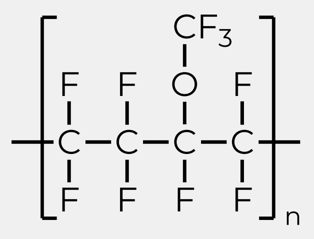
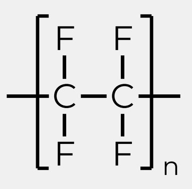
Sustainable Electrochemical Technologies:
Replacing Per and Polyfluoroalkyl Substances

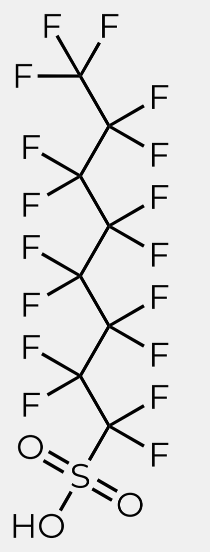
Per and polyfluoroalkyl substances (PFAS) are a collection of chemicals that contain a perfluorocarbon group. These chemicals can be found everywhere, including cookware, cosmetics, packaging, and clothing. They have unmatched stability, which arises from the robust carbon-fluorine bonds, rendering PFAS compounds resistant to degradation.

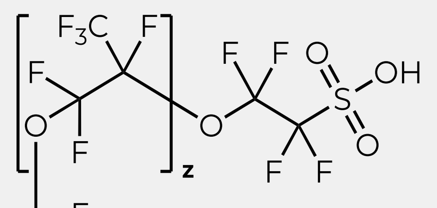
The environmental concerns associated with PFAS are profound, primarily due to their environmental persistence, mobility in water, and resistance to degradation. These characteristics enable PFAS to remain in the environment for extended periods, often leading to widespread distribution through water systems. Health concerns linked to PFAS exposure are equally alarming, with studies indicating an increased risk of cancer, thyroid disruption, and adverse effects on the endocrine, metabolic, and immune systems. These health risks, underscored by research, have led to heightened public, governmental, and industrial awareness and concern.











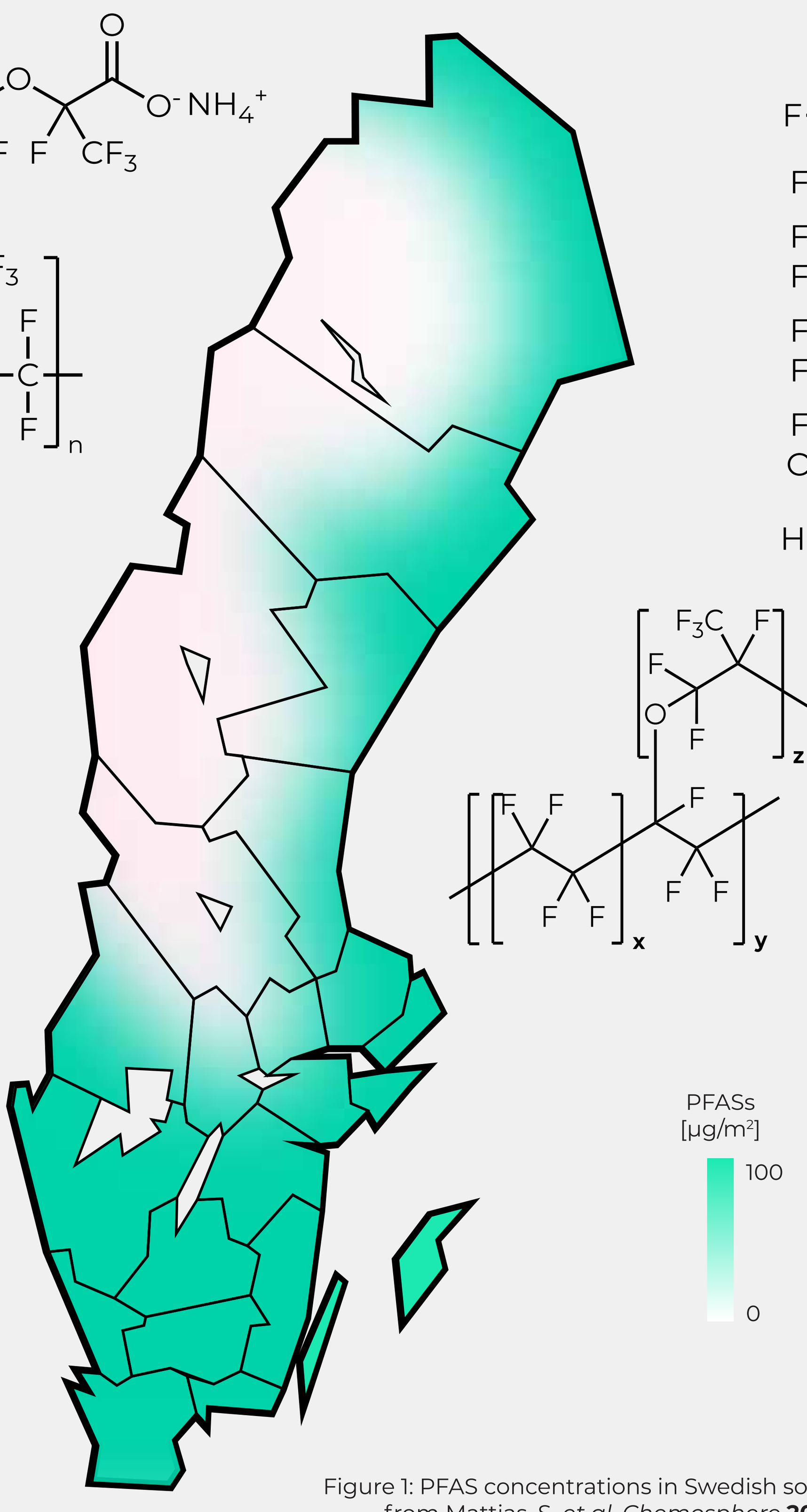
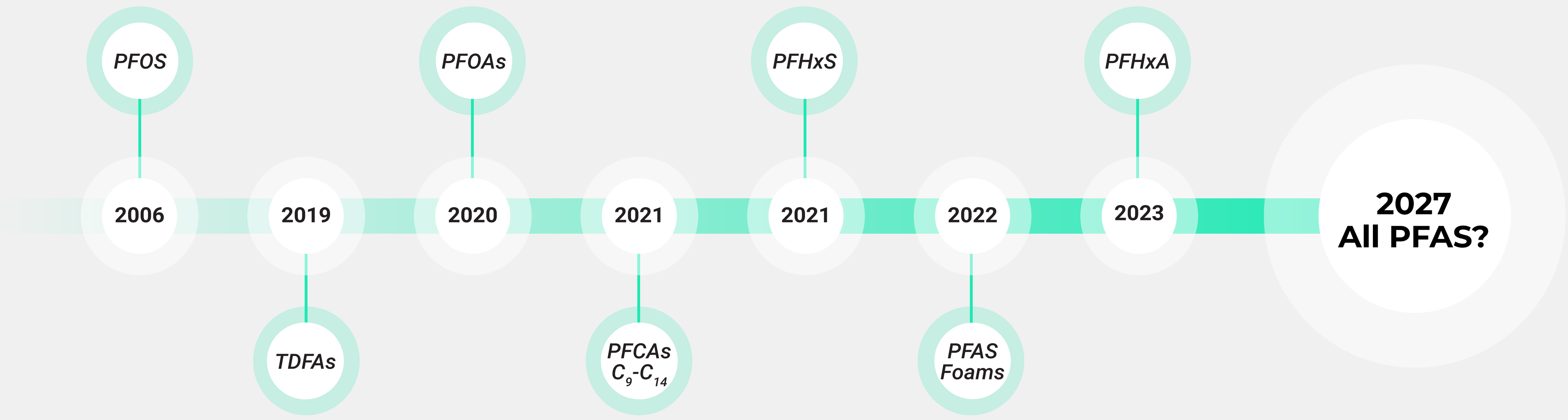


Figure 1: PFAS concentrations in Swedish soils. Data from Mattias, S. *et al. Chemosphere* **2022**, *295*.

In response to these growing concerns, there has been increased regulatory scrutiny and a push from consumers for safer alternatives. The public's perception of PFAS has shifted significantly, prompting governmental bodies and industries to reconsider their use of these substances. As a result, the demand for and development of safer, more environmentally friendly alternatives have become a critical focus for researchers and policymakers alike, aiming to mitigate the environmental and health impacts of PFAS.

PFAS Restrictions Under the Reach Timeline



Under the Stockholm Convention, PFASs are being considered for global restrictions, with a proposal for limitation of their use (under REACH) put forth by Sweden, Germany, the Netherlands, Norway, and Denmark. This proposal, which encompasses a vast array of over 10,000 PFAS compounds, advocates for a comprehensive ban on the manufacture, usage, or market placement of these substances. The ultimate objective of the Swedish Chemicals Agency is to completely phase out PFAS.

The Future of PFAS

The phasing out of PFAS poses significant challenges due to the absence of universally applicable alternatives, despite the availability of alternative materials for certain specific applications. This gap underscores the complexity of finding replacements that can perform across the diverse uses that PFAS currently serve.

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