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SEA of restricting use of PFAS in electronics and telecommunication

Final Report

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September 2022

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Executive summary

This Socio-Economic Analysis (SEA) has been prepared in response to a potential REACH restriction on the manufacture and use of per- and polyfluoroalkyl substances (PFAS) within the EU. It covers specific products made with PFAS that are used within "**electronics and telecommunication**". Whilst this SEA has been commissioned by Gore, impacts are assessed from a societal perspective and includes both Gore products and similar products placed on the EU market by other companies.

The products covered within this SEA include product such as PFAS-containing cables and cable assembly products that serve industries, such as semiconductor manufacturing which requires ultra clean and reliable high flex cables to deliver increasing amounts of data and power to the capital equipment needed to support cutting edge semiconductor production. These small and flexible cable assemblies can operate in harsh environments where cables can be exposed to vacuum conditions, broad temperature ranges, continuous rapid flexing, and harsh chemicals. Gore Microwave / RF assemblies are rugged, lightweight assemblies for testing in laboratory, production, and field test environments. Gore's products are used across many industries, including, but not limited to, chemical manufacturing, defence, electronics, and mining, which themselves impact further downstream industries.

Gore uses four types of PFAS (e.g. Polytetrafluoroethylene (PTFE) being one) for the products covered within this SEA, all of which are defined as polymers of low concern (PLC). Gore believes that around 50% of similar products on the EU market contain PFAS, more specifically fluoropolymers. For the high-performing market segment, around 95% contain PFAS, or more specifically, fluoropolymers, whilst Polyethylene (PE) dielectric material is mostly used for lower performance microwave cables as they are cheaper.

Gore continually follows external developments of new materials while also pursuing an R&D program to develop novel materials that meet the market's needs. In addition, semiconductor equipment companies have been performing trade studies and investing in non-PFAS alternatives that can be used with cables and cable assemblies in clean environments for a number of years. However, no suitable materials have been identified that can replace PFAS in all of Gore's products. PTFE is understood to be the only substance that can handle the high frequency requirements of modern cables. However, the industry continues to look for alternative materials for cost saving opportunities but has yet to find any suitable alternative materials that have the same chemical/physical properties as PTFE.

Restricting the use of PFAS in products covered within this SEA may, in fact, result in net costs (rather than benefits) to the environmental and human health. For example, one critical use of cables containing PFAS are in the processing of nuclear waste. Reducing the reliability and performance of nuclear waste processing tools could increase the risk of nuclear waste leaks and consequently increase the public health risk associated with radiation poisoning as well as damaging animal and plant life for generations. Cable coatings containing PFAS also protect products against harsh chemicals, which allows these cables to reliably function in harsh environments such as during the exploration and extraction of oil.

The socio-economic analysis clearly shows that restricting (and not granting a derogation for) the use of PFAS in products similar to those in **Table 2.1** will have large and wide-reaching impacts on the EU. The adverse impacts induced by a potential restriction includes significant economic costs throughout the value chain, impacts on employment (lost jobs) as well as adverse impacts on human health and the environment. A key benefit of using industrial cables and assemblies containing PFAS is their superior durability. Changing to non-PFAS products will therefore increase resource use and waste generation, which results in both costs to the users and adverse impacts on the environment (e.g., through CO_2 emissions).

It has only been possible to (partially) quantify a few of the identified impacts, due to data limitations. This also extends to the calculations of emission and emission reductions, which is detailed in Section 2.5.3. A key aspect to highlight is that a conservative approach has been chosen throughout analysis, in the sense that the monetised costs of a potential restriction have been underestimated and quantified emission reductions are believed to be overestimated. Emissions are overestimated, as the analysis uses conservative emission data from the DSs (National Institute for Public Health and the Environment (RIVM) et al., 2021), even though Gore reported significantly lower emissions for all stages of the product lifecycle. The costs, on the other hand, are underestimated, as key costs elements could not be quantified.

It is not possible to determine the nature of impacts associated with a reduction in emissions and exposure to the PFAS used to manufacture products covered within this SEA. It is therefore not possible to monetise potential benefits so as to directly compare these to the costs. Instead, a cost-effectiveness analysis has been carried out.

The minimum annuity costs, including lost profits and impacts on employment, of restricting the use of PFAS in products covered within this SEA is estimated at €3.8 billion per year. The analysis shows that despite taking a highly conservative approach, the cost per kg PFAS emission is significant – in the range of €10,900 – €29,300 per kg PFAS emissions reduced. The substances involved are not mobile in the environment, are demonstrated to be non-toxic and extremely stable, and are also identified as PLCs. This, combined with the conservative approach taken throughout the analysis, indicates that the costs of restricting the use of PFAS within the products covered by this assessment will likely outweigh any benefits.

Considering the lack of suitable alternatives to PFAS, combined with the significant economic and social costs as well as the adverse impacts to human health and the environment of using inferior alternatives, it is believed that a derogation is justified for the products covered within this SEA.

Contents

Tables

Figures

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Abbreviations & Acronyms

B2B	Business to Business
BPA	Bisphenol A
C	Carbon
CAGR	Compound annual growth rate
CARACAL	Competent Authorities for REACH and CLP
CLP	Classification, Labelling and Packaging of Substances and Mixtures Regulation
CMR	Carcinogenic, Mutagenic and Reprotoxic Chemicals
DS	Dossier Submitters
EAV	Equivalent annual values
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Environment Agency
EERA	European Energy Research Alliance
EiF	Entry into Force
ELV	End-of-life-vehicles
EoL	End of Life
ETFE	Ethylene tetrafluoroethylene
EU	European Union
F	Fluorine
FEP	Fluorinated ethylenepropylene
FFU	Fit for use
GHG	Greenhouse Gases
HFP	Hexafluoropropylene
Kg	Kilogram
KIT	Karlsruhe Institute of Technology
LCD	Liquid Crystal Display
LCP	Liquid Crystal Polymer
MVP	Minimum Viable Product (associated with New Product Development)
Mwe	Megawatt electrical
OECD	The Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PBT	Persistent Bioaccumulative Toxic
PE	Polyethylene
PFA	Perfluoroalkoxy alkane
PFAS	Per- and polyfluoroalkyl substances
PFPE	Perfluoropolyether
PLC	Polymers of Low Concern
Ppm	Parts per million
PTFE	Polytetrafluoroethylene
PV	Present Value
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
R&D	Research and Development
RAC	Committee for Risk Assessment
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals

[redacted]

RF	Radio Frequency
RIVM	National Institute for Public Health and the Environment
RMOA	Risk Management Option Analysis
SAGA	Suitable alternatives generally available
SEA	Socio-Economic Assessment
SEAC	Committee for Socio-economic Analysis
SHF	Shredder heavy fraction
SLF	Shredder light fraction
SME	Small and medium-sized enterprises
TFE	Tetrafluoroethylene
TULAC	Textiles, Upholstery, Leather, Apparel and Carpets
USD	US-Dollar
UV	Ultraviolet
V	Volts
vPvB	Very Persistent and very Bioaccumulative
WEEE	Waste, electrical and electronic equipment
WWTP	Wastewater Treatment Plants

[redacted]

1 Introduction

1.1 Background

In July 2021 Member State Competent Authorities for Germany, the Netherlands, Norway, Sweden, and Denmark registered their intention to submit a REACH restriction proposal, which aims to limit the risks to the environment and human health from the manufacture and use of per- and polyfluoroalkyl substances (PFAS) (ECHA, 2020a). The aim of the restriction proposal is to ban the entire group of PFAS substances to avoid regrettable substitution where one PFAS is replaced by another similar PFAS of potentially similar concern (RIVM, n.d.). Recent communication from the DS indicates that the restriction dossier will be submitted to the European Chemicals Agency (ECHA) on the 13th of January 2023. **Figure 1.1** below provides an indicative timeline for the REACH restriction for PFAS (adapted from timeline presented by ECHA at a webinar in October 2020).

Figure 1.1: Indicative timeline for the REACH restriction proposal for PFAS

There are at least 6,000 currently known PFASs (RIVM, n.d.), and the substances are in widespread use in a large number of industries (e.g., automotive, medical, chemical and oil & gas) and have numerous applications (e.g., textiles, electronics, pharmaceuticals, wire and cable insulation, gaskets and hoses, and medical devices). Due to the broad scope of the restriction, there may therefore be potentially long-ranging impacts on manufacturers, importers, and users of PFAS and PFAS-containing products. The DSs initially envisaged derogations for 'essential uses' of PFAS, however, the definition and criteria for what makes a use 'essential' have yet to be finalised. Recent communication from the European Commission indicates that the EU definition of 'essential use' will not be ready in time, hence, will not be included in the restriction proposal (Chemical Watch, 2022).

[redacted]

1.2 Objective and Scope

The aims of this socio-economic assessment (SEA) were to provide information on (i) specific applications of PFAS, (ii) the availability of suitable alternatives, and (iii) the impacts of banning the use of PFAS in these applications, which can be utilised by the DSs when finalising the restriction proposal as well as in the assessments later carried out by RAC and SEAC.

This assessment focusses on impacts of restricting PFAS for specific products used within "**Electronics and Telecommunications**". The assessment is limited to the European Union (EU) over a twenty-year period (2022 – 2041). This SEA does not cover all potential applications of PFAS within electronics and telecommunication. The assessment includes Gore products and similar products placed on the EU market by other companies. Types of electronics and telecommunication products and their uses included in the scope of the analysis are detailed in Section 2.2.

1.3 Approach

This SEA builds upon the 'use assessment' note submitted to the DSs during February and March 2022, which was based solely on readily available information at the time. The assessment presented in this report is a continuation of the analysis presented in the previous report, but with more focus on the impacts of a possible restriction. Additional data gathering was carried out in relation to the SEAs, both as a validation exercise as well as providing more details than what was provided in the use assessment. The information set out in this SEA thus supersedes the information provided in the use assessment, should the two reports conflict.

The socio-economic analysis (SEA) has been carried out in accordance with ECHA's SEA Guidance for restrictions (ECHA, 2008) and the Better Regulation Toolbox (European Commission, 2021a). An overview of the approach taken is shown in **Figure 1.2.**

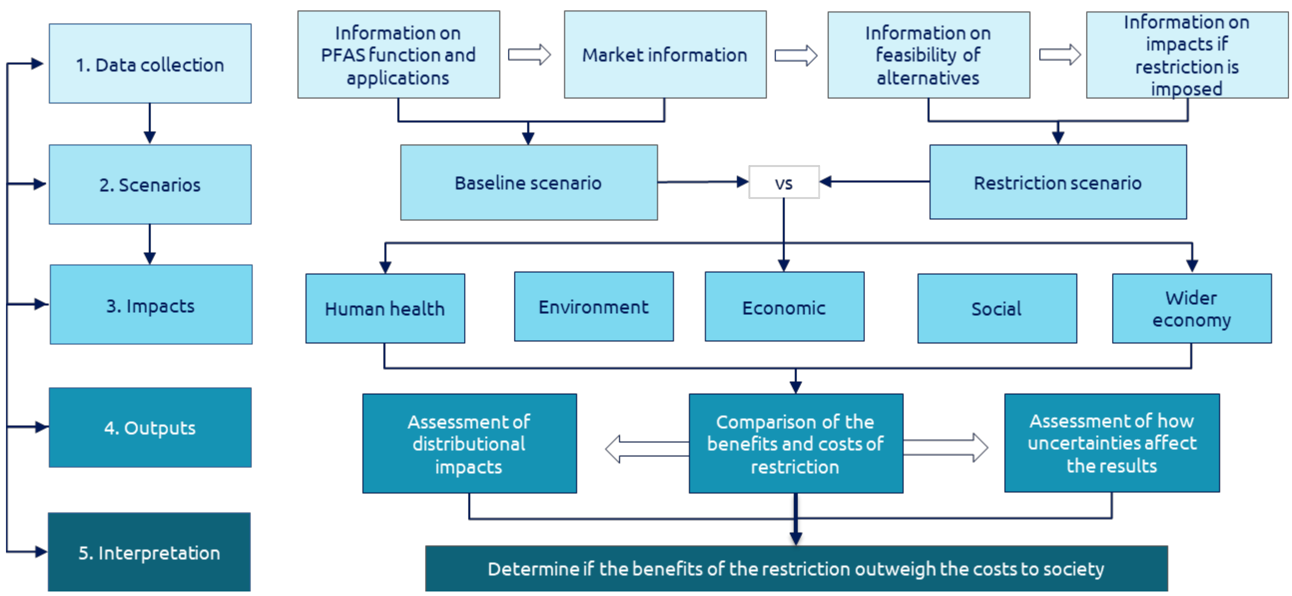


Figure 1.2: SEA approach

[redacted]

The SEA seeks to assess the impacts, i.e., costs and benefits, of a potential restriction relative to the baseline scenario, which is the current situation in the absence of a restriction. The assessment is focussed on affected Gore products, but where possible the data has been extrapolated to the entire EU market. As per ECHA's Guidance, the analysis has been carried out from society's perspective rather than the perspective of the chemicals sector.

The price year used in the analysis is 2022, meaning that all numbers have been adjusted for inflation using GDP deflators (ECB, 2022; World Bank, 2022). Monetary impacts are expressed as present values (PVs) and as annuities using a 4% discount rate. PVs represent the discounted value of a stream of future costs and/or benefits and are the most common method used to compare costs and benefits over time (ECHA, 2008). Annuity values represent the annualised cost/benefit, or the equalised yearly value of an impact over its discounted lifetime and is particularly helpful for understanding impacts that are commonly measured on a yearly basis or comparing impacts that occur over different lifetimes (ECHA, 2008).

Further details on the approach are also provided in the relevant sections where the results are presented.

Figure 1.3 provides an overview of the data sources used for this study. The main source of information is Gore's responses to a bespoke questionnaire developed for this SEA where quantitative and monetary data as an annual average over the period 2016 - 2021. This covered a variety of topics such as impacts on Gore, its customers and society if PFAS could no longer be used in specific products used within electronics and telecommunication products in the European Union (EU). Data was also collected by eftec from publicly available sources via desk-based research, including information on the wider electronics and telecommunication market in the EU. The study also required some assumptions and professional judgements to be made where data was not available, but these were kept to a minimum. The report highlights where such assumptions had to be made and uncertainties induced by these.

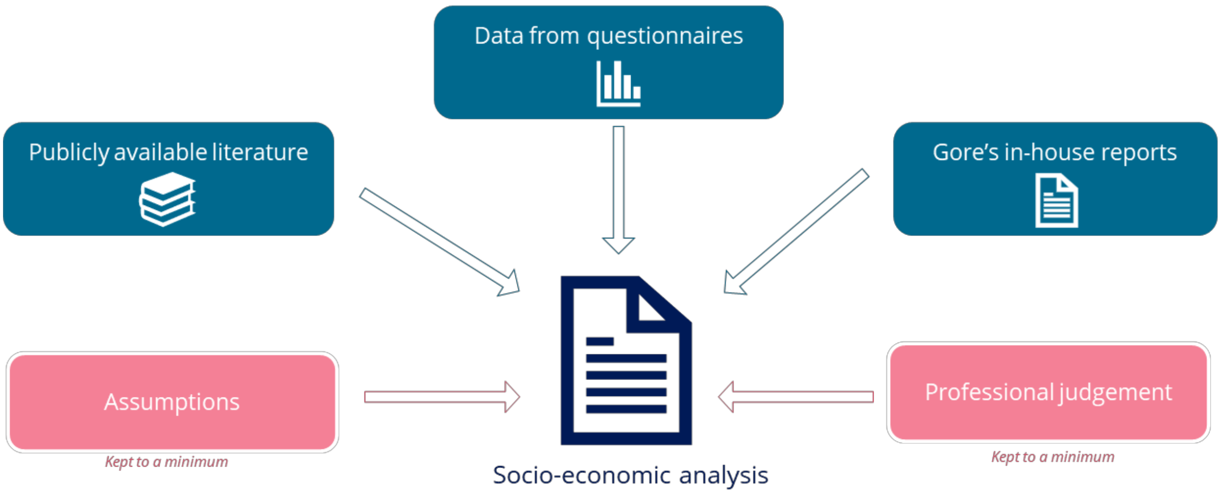


Figure 1.3 Data sources used in this socio-economic analysis (SEA)

1.4 Structure of the report

The remainder of the report is structured as follows:

- Chapter 2: Baseline scenario
- Chapter 3: Availability of suitable alternatives
- Chapter 4: Restriction scenario
- Chapter 5: Comparison of costs and benefits
- Chapter 6: Conclusions and recommendations

[redacted]

2 Baseline scenario

2.1 Introduction

The baseline scenario (also called the business-as-usual scenario) refers to the situation where PFAS is not restricted for the types of affected products listed in **Table 2.1**. This would be the case if the potential PFAS restriction is not adopted or if these products receive a time-unlimited derogation (with no conditions imposed on their continued use).

The baseline was derived in a stepwise manner where Gore's use of PFAS serves as a starting point. Section 2.2 presents the Gore products used within electronics and telecommunication that could be affected by a potential REACH restriction and their downstream uses. These products and similar products manufactured by other companies are the only type of products covered within this SEA. Gore sales and supply chain linked to the affected products is covered in Section 2.3. Section 2.4 sets out the type and volumes of PFAS used by Gore and their technical functions within Gore products. It also provides an overview of the PFAS material flow in terms of manufacture, service life and disposal of the products.

Section 2.5 provides a broader perspective on the use of PFAS in the EU, covering manufacture of PFAS as well as production, use and end-of-life of products. This provides some context for the EU baseline for the products covered within this SEA, which is derived in Section 2.5. This is done by using data from Gore combined with the broader data from Section 2.5 as well as using professional judgement and assumptions. Risk indicators, including the hazard profile of the PFAS in question is also covered within this section.

2.2 Products and downstream uses

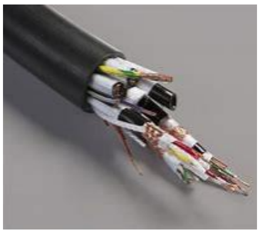
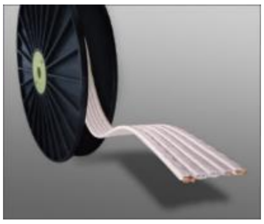
2.2.1 Gore products affected by a possible restriction

Gore manufactures cables and cable assemblies for electronics and telecommunication. The products serve industries, such as semiconductor manufacturing which requires ultra clean and reliable high flex cables to deliver increasing amounts of data and power to the capital equipment needed to support cutting edge semiconductor production.

Small and flexible cables are required to operate in harsh environments where cables can be exposed to low pressures, broad temperature ranges, continuous rapid flexing, and harsh chemicals. This includes automated manufacturing and inspection capital equipment used to operate harbour cranes, transport nuclear waste, inspect piping, and detect petroleum. Increasing data and power requirements drive the need for small, flexible, and reliable cables to operate with extreme temperatures, continuous rapid flexing, and harsh chemicals.

[redacted]

Table 2.1: Gore electronics and telecommunication products and descriptions

Product	Illustrations	Description
GORE® Ultraclean Cables		Data cables, power cables, radio frequency cables, and hybrid cables for semiconductor manufacturing, and test capital equipment.
GORE® Trackless Cables		
Round and Planar Cables conveying data and power for semiconductor manufacturing and testing capital equipment.		
Round and Planar Cables conveying data and power for harsh environment industrial manufacturing and testing capital equipment.		Data cables, power cables, radio frequency cables, and hybrid cables for Industrial harsh environment manufacturing and test capital equipment.
GORE® Microwave / RF Assemblies		Rugged, lightweight assemblies for testing in laboratory, production, and field test environments (Gore, 2021a).

Source: Gore (2021b, 2022)

Notes: Images are taken from Gore's website: https://www.gore.com/products/categories

2.2.2 Affected downstream user industries

There are five products that fall under the category of electronics and telecommunications, which can be grouped according to two broad uses. The first category includes the products that act as cables conveying data and power for semiconductor manufacturing and testing capital equipment, and the second use category includes Microwave / RF Assemblies which are used in the manufacturing of semiconductors and LCPs.

[redacted]

Figure 2.1 offers a non-exhaustive overview of the downstream uses and industries that may be affected by a potential restriction. The inner circle (teal) represents the products containing PFAS that are set out in Table 2.1 and similar products manufactured by Gore's competitors. The second circle (dark pink) shows some of the downstream uses that rely on these PFAS-containing products. Lastly, the outer circle (lighter pink) lists some of industries utilising the downstream products and thus would be affected by a potential restriction.

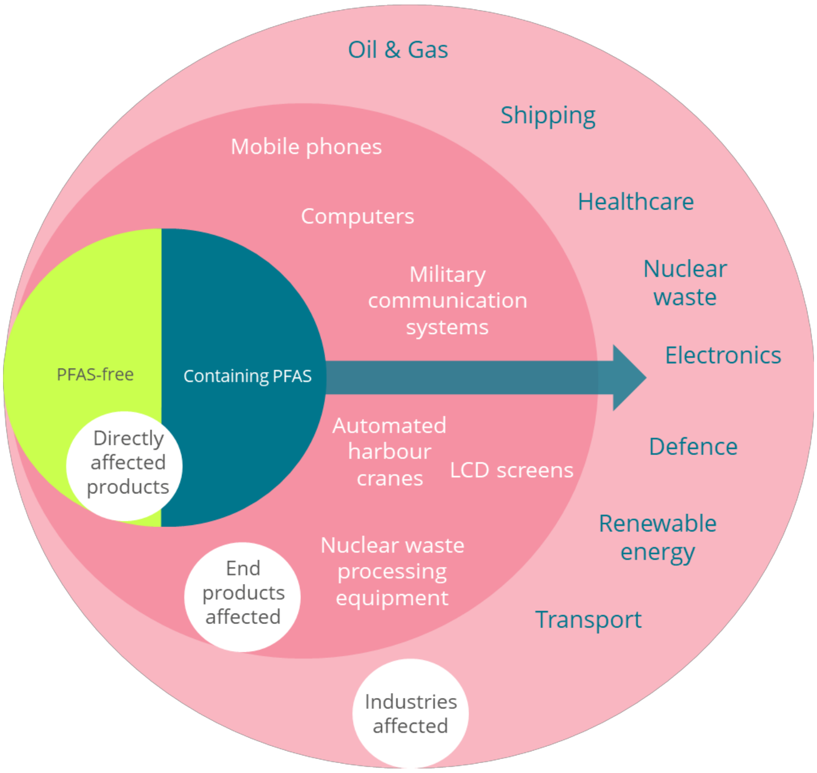


Figure 2.1: Products containing PFAS and effected end-uses and industries
Notes: Directly affected products refers to products listed in Table 2.1 and similar products by other manufacturers.

Gore believes that 50% of products similar to those set out in Table 2.1 contain PFAS. For high performance microwave cables around 95% of cable and cable assembly products contain PFAS, whilst PE dielectric material is mostly used for low performance microwave cables as they are cheaper. The products containing PFAS are durable, flexible, and chemically inert, offering high quality performance important for the function of certain high performance uses. For example, PTFE allows for high-speed data transmission while cables are under high flex conditions and enables low particulation during processing or inspection, making higher throughput and yield possible for end users. The non-PFAS products cannot be used in business to business (B2B) capital equipment applications that require long lasting materials that demand robust materials to avoid premature failure but is rather used in consumer products that do not need functional properties such as high temperature resistance, crack resistance, low friction, or high signal integrity. More detailed information on technical functions and usability of non-PFAS cables is provided in Section 2.4.1 and Section 3.3.

Most of the downstream industries illustrated in Figure 2.1 utilise cables and cable assemblies during fabrication of **semiconductors** and other electronic devices. Cables containing PFAS are used in the production of **computer chips**, of which the chips are a crucial component to allow the **computer** to function. It is well known just how important computers are to modern society, with almost all modern-day jobs involving computers in some form. The economy relies on these devices to function, and without them there would be large socio-economic impacts. Other examples include **digital clocks, calculators** as well as everyday electronic items like **TVs and smartphones**.

Cables containing PFAS support appropriate processing of **nuclear waste** to avoid negative impacts on human health, such as radiation poisoning, or environmental damage to habitats and biodiversity that could occur if there were leakage into the environment from equipment failure. Cable coatings containing PFAS protect products against harsh chemicals. These cables perform in harsh environments such as during the exploration and extraction of **oil.** Oil remains important to the functioning of society as it still makes up a large share of the EU energy mix. Society is still very reliant on oil for the likes of transport and manufacturing, as renewables are currently not able to fill the void that would be left if oil was no longer able to be extracted and used in the EU.

Additionally, cables containing PFAS are used in **automated harbour cranes**. The automated cranes increase efficiency of ship loading/unloading, which is crucial for the chemical manufacturing industry, but also increases safety for workers as they can be controlled from a safe distance. Gore wires and cables improve equipment reliability and safety in the downhole energy market (exploration and extraction), which provides a large share of the EU energy mix. This market also serves critical feedstock to a much broader chemical/plastics manufacturing industry.

Microwave / RF assemblies that contain PFAS are used in the measuring and testing of **semiconductors**. Semiconductors are an essential component within electronic devices, which enable advances in communications, computing, healthcare, **military systems**, transport, renewable energy, and numerous other applications. Without semiconductors there would be no TVs, smartphones, computers, or many types of advanced **medical equipment**. All of which are of high importance for the functioning of the modern economy.

2.3 Gore sales and direct supply chain

2.3.1 Gore sales of products affected by a potential restriction

[redacted]

[redacted]

Table 2.2: Gore sales of products for electronics and telecommunication containing PFAS, annual average [redacted]

[redacted]	[redacted]		[redacted]		[redacted]	
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]					
[redacted]	[redacted]					
[redacted]						
[redacted]						
[redacted]						

[redacted]

[redacted]

2.3.2 Gore's direct supply chain

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

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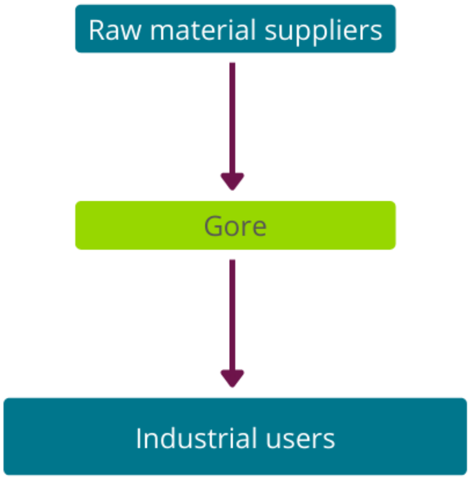

Figure 2.2: Gore's supply chain for electronics and telecommunications products

[redacted]

[redacted]

[redacted]

Table 2.3: Gore customers associated with electronics and telecommunication

[redacted]	[redacted]	
	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]		

[redacted]

Notes: The number of customers was counted per product; therefore it is possible that some customers overlap between different products.

[redacted]

Table 2.4: Total employment associated with electronics and telecommunication

[redacted]	[redacted]		
	[redacted]		
[redacted]			
[redacted]			
[redacted]			
[redacted]			

[redacted]

Notes:

[redacted]

[redacted]

[redacted]

2.4 Gore's use of PFAS

2.4.1 Technical functions of PFAS

Gore uses the following four PFAS substances in their electronics and telecommunications portfolio:

- polytetrafluoroethylene (PTFE);
- ethylene tetrafluoroethylene (ETFE);
- perfluoroalkoxy alkane (PFA); and,
- fluorinated ethylene propylene (FEP).

PFAS provide a number of different functions depending on the end products they are used in. For example, high performance electronics for semiconductor and harsh environment industrial manufacturing utilise PTFE to fulfil requirements (such as remaining durable and stretchable at 300-370°C) when providing hybrid cable insulations. In addition, for high performance microwave/RF coaxial cable targeting in space (including A&D) applications, over 95% of companies use PTFE due to its functionality as a dielectric material. Moreover, ETFE is a component in jacketing material used in the jackets of microwave (MW) cables for space applications. This material has properties which are critical in space applications, e.g. radiation resistance, durability and electrical insulation . It is also extremely common for FEP or PFA to be used as a jacket material in A&D / space applications. **Table 2.5** below details some of the more high-level functions of PFAS.

Table 2.5: Gore electronics and telecommunications products, high-level function, and detailed description

Gore product types	High-level function	Detailed description
High Performance Electronics	• Chemically inert • Temperature resistant • Durable • Flexibility • Low dielectric constant[1]	PTFE offers superior performance because of its purity, electrical strength, insulation properties, mechanical toughness, and chemical inertness. Those properties enable cables to maintain signal and power even in the most demanding environments and high-speed data transmission minimises the need for additional signal amplification. Also, PTFE shows increased durability compared to other materials and can resist crushing, abrasion and being cut-through – while remaining flexible. Lastly, the low dielectric constant[1] (εr of 1.3 – compared to air's εr of 1.0) enables smaller size cables with greater insulation at a reduced weight.
Mobile Electronics	• Durable • Temperature resistant	PTFE demonstrates an excellent combination of liquid tightness, good airflow, durable acoustic performance, and excellent particle protection even after multiple reflow processes at very high temperatures.

[1] The dielectric constant is a physical measure of the electric polarizability of a material (i.e., the tendency of a material to allow an electric field induce dipoles (separation of positive/negative charge). A low dielectric constant refers to the material not readily being impacted by electric fields (Saraswat, n.d.).

[redacted]

Gore product types	High-level function	Detailed description
Semiconductor & Microelectronics	• Chemically inert • Temperature resistant • High filtration efficiency • Low resistance to flow • Durable • Flexibility	PTFE is chemically inert, and therefore is not affected by chemicals that can cause other materials to lose their mechanical properties or release particles at high temperatures. PTFE is pure and does not readily leach into other substances, even in presence of aggressive chemicals. PTFE is microporous and has extremely high filtration efficiency, very low resistance to flow and extremely long filter life as well as being UV resistant. Lastly, PTFE has great mechanical strength, dimensional stability long service life, and a high flexibility even at high temperatures.

Source: Gore (2021b, 2022)

2.4.2 Types and volumes of PFAS used

[redacted]

[redacted]

Table 2.6: Type and volume of PFAS used in Gore products manufactured in EU and non-EU counties

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]				[redacted]
	[redacted]				
[redacted]	[redacted]				[redacted]
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[redacted]	[redacted]				[redacted]
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[redacted]		[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]				
[redacted]					
[redacted]					

[redacted]

2.4.3 PFAS material flow and product life cycle

The lifecycle of PFAS can be divided into four stages, namely PFAS production, product manufacturing, product use and waste management, as detailed in **Figure 2.3**. This provides a framework for understanding the movement of PFAS throughout the economy and where there is potential for release to the environment. This SEA primarily focusses on product manufacturing, but high-level information is also provided on product service life and disposal. [redacted]

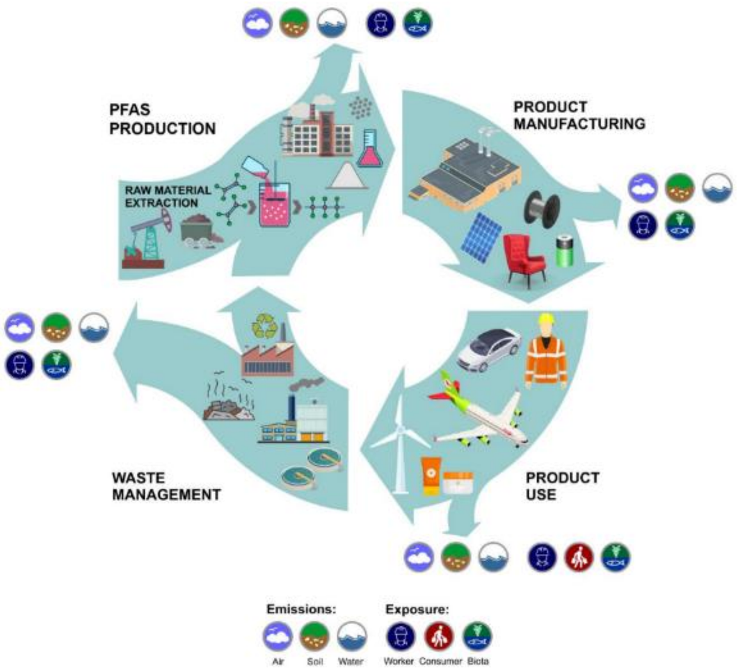

Figure 2.3: PFAS lifecycle *(European Commission, 2020)*

Manufacture or products containing PFAS

[redacted]

[redacted]

[redacted]

[redacted]

Table 2.7: PFAS material flow through manufacturing process

[redacted]	[redacted]	[redacted]	[redacted]		
			[redacted]	[redacted]	[redacted]
[redacted]	[redacted]				
[redacted]					
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Product service life

[redacted]

[redacted]

- [redacted]
- [redacted]

Disposal of end products

[redacted]

To understand the effect of the incineration of waste containing PFAS, Gore evaluated scientific resources worldwide and commissioned the Institute of Technical Chemistry at the Karlsruhe Institute for Technology (KIT), Germany, to conduct a study on the incineration of PTFE in its pilot size municipal incineration plant at temperatures typical of a municipal waste incinerator. Based on Gore's current scientific understanding, incineration is an acceptable way to dispose of fluoropolymers and does not show significant generation of a range of PFAS that would be relevant to environmental concerns. For PTFE this was confirmed by a paper published in the July 2019 issue of Chemosphere, a peer reviewed scientific journal (Aleksandrov et al., 2019). This paper is based on the above-mentioned KIT study, which found that municipal incineration of PTFE shows no significant generation of the studied PFAS. It is likely that other PFAS show similar characteristics in the combustion process, and incineration of waste is therefore believed to be a small contributor to the overall emissions.

Gore further notes that landfilling of fluoropolymer products is not expected to contribute to emissions associated with landfill leachate, since fluoropolymers are not water soluble, not biodegradable and do not degrade in the environment. In addition, these substances are not precursors and are stable substance that do not degrade across a wide range of conditions, suggesting that they would not break down into any other PFAS when in a landfill. The stability of fluoropolymers is further highlighted in the varied applications for which they are used, including their use in outdoor environments, in high and low temperatures, and with exposure to many harsh chemicals.

[redacted]

[2] Off gas refers to a gas which is given off, typically emitted as the by-product of a chemical process.
[3] The source does not specify the EoL treatment for the remaining 5% of PFAS-containing waste.

[redacted]

2.5 EU baseline

2.5.1 Introduction

This section seeks to set out the EU baseline (i.e. the situation in the absence of the proposed REACH restriction), whereby the assessment goes beyond Gore and includes information on all affected actors in the EU who make similar products to those presented in **Table 2.1**. The baseline derived for this SEA consists of three main components: (i) Projections for the EU market value of the products affected (products similar to those in **Table 2.1**), (ii) Projected EU use volumes associated with these products, and (iii) indicators of risks.

There is limited publicly available data on the EU market for the affected products covered by this SEA, which is why Gore's best estimate for the EU market size has been used. **This market size should be considered indicative ('best guess')**, as Gore does not have accurate information on production and sales for other companies.

The location of manufacturing facilities (EU vs. non-EU) and the type and volume of PFAS used by other companies than Gore are also not known. The volume of PFAS used within the EU has therefore been extrapolated using market share assumptions and must be used with caution. It is possible that the DS will have received information on other companies affected (i.e. other than Gore) and may therefore be in a better position to understand if these extrapolated estimates are a reasonable reflection of the overall size of the EU markets affected.

Indicators of risks of using PFAS is partly based on publicly available information and partly based on information from Gore. The substance hazard profile has been assessed using information found on ECHA's website and literature provided by Gore, whilst consideration of emissions is based on information from Gore and the DSs. Risks cannot be derived for the substance involved, but some broad conclusions can be made by synthesising the available information on hazards and emissions.

All information has been provided in good faith and uncertainties and caveats are further highlighted within the assessment.

2.5.2 Market information[4]

EU market for affected products

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Table 2.8: Impacted sales and EU market, annual average [redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]				

[redacted]

PRODCOM product categories

As highlighted above, only a small set of products (listed in **Table 2.1**) and similar products made by other companies) is included in this assessment. To provide some broader context, data was also collected from the statistics on the production of manufactured goods within the EU (PRODCOM[5]), presented in **Table 2.9**. Note that this list is non-exhaustive and PRODCOM codes does not reflect the total market for the products covered within this SEA.

Table 2.9: EU sales statistics for relevant PRODCOM categories

Broader product group	Broader product group	Average market size 2015-2019 € million	Gore product(s) within the broader product group
Other electric conductors, for a voltage ≤ 1 000 V, not fitted with connectors.	27321380	11,281	Data and Power Cables for: • Lithography & Semiconductor Manufacturing and Testing Capital Equipment; and • Industrial Harsh Environment Manufacturing and Testing Capital Equipment
Other electric conductors, for a voltage ≤ 1 000 V, not fitted with connectors.	26405200	1,256	Gore® Microwave / RF Assemblies in Semiconductor and Electronic Assembly Testing
Total	**All**	**11,565**	**All**

Notes: Values are given in 2022 prices.

EU supply chain and end-use industries

Gore and manufacturers of similar products to those in **Table 2.1** purchase large volumes of PTFE from

[5] Eurostat (2015-2019). PRODCOM Annual Data 2015-2019. Available at: https://ec.europa.eu/eurostat/web/PRODCOM/data/excel-files-nace-rev.2; https://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-066342_QID_664BB658_UID_-3F171EB0&layout=INDICATORS,C,X,0;DECL,L,Y,0;PRCCODE,B,Z,0;PERIOD,L,Z,1;&zSelection=DS-066342PERIOD,202052;DS-066342PRCCODE,08111133;&rankName1=PRCCODE_1_0_-1_2&rankName2=PERIOD_1_0_-1_2&rankName3=INDICATORS_1_0_0_0&rankName4=DECL_1_0_0_1&sortR=ASC_-1_FIRST&sortC=ASC_-1_FIRST&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=NONE&time_most_recent=false&lang=EN&cfo=%23%23%23%2C%23%23%23.%23%23%23&lang=en

raw material suppliers both within and outside the EU, estimated at close to 10,000 tonnes per year (average 2016-2021). This amounts to 20% - 30% of the total fluoropolymer market in the EU. The total value of the fluoropolymer market in 2020 was around €799 million[6] (Fluoropolymer Product Group of PlasticsEurope, 2022). A potential restriction on PFAS prohibiting the use of PTFE in products intended for electronics and telecommunications may therefore lead to significant impacts on these upstream suppliers.

Table 2.10 presents the total quantity sold and total value across relevant industries in the EU fluoropolymers market. Note that the list is non-exhaustive, i.e., not all affected industries may be covered in the table. The fluoropolymers market is expected to grow by a compound annual growth rate (CAGR) of 6.5% from 2020 to 2027 (Fluoropolymer Product Group of PlasticsEurope, 2022).

Table 2.10: EU market for fluoropolymers

Sector	Total quantity sold (tonnes)		Total value (€ million)	
	2020	2015	2020	2015
Chemical and power	11,000	16,500	213	253
Electronics	3,500	3,500	75	58
Transport	15,500	18,500	298	345
Renewable energy	500	500	21	6
Total relevant industries	**30,500**	**39,000**	**607**	**662**
Total EU market	**39,500**	**52,000**	**799**	**881**

Notes:

1. Monetary values are given in 2022 prices and rounded to the nearest € million. Totals may therefore not sum up.
2. The figures are for the fluoropolymer market at large, of which Gore's and similar products are a proportion.

Electronic and telecommunication cables and cable assemblies are essential devices and are interlinked with many downstream industries. For example, round and planar cables are used during fabrication of semiconductors, which are essential devices for the function of many end-uses across many industries.

Table 2.11 **Table 2.11** presents key economic indicators (turnover and employment) for some of the downstream industries that would be affected by a restriction on products containing PFAS in the electronics and telecommunications industry. Note that the list is non-exhaustive, i.e., not all affected industries are covered in the table.

Table 2.11: Economic overview of downstream user industries in the EU

Industry	Turnover (€/billion)	Employment (million)	Year of publication	Source
Chemical manufacturing	641.9	1.2	2019	(Eurostat, 2022a)
Defence	126	0.5	2019	(Statista, 2020)
Electronics	310.1	1	2014	(Eurostat, 2022a)

[6] Values are uplifted to 2022 prices.

[redacted]

Electrical equipment	335	1.5	2020	(Eurostat, 2022a)
Mining and quarrying	82.4	0.7	2020	(Eurostat, 2022b)
Semiconductors	1.2	unknown	2020	(PRODCOM, 2020)
Telecommunications equipment	1.3	unknown	2020	(PRODCOM, 2020)
Total	**1,497.9**	**2.3**		

Notes:

1. There is likely some overlap between semiconductors and telecommunications equipment, and electronics.
2. Values are given in 2022 prices and rounded to the nearest € billion.

2.5.3 PFAS use and product life cycle

PFAS use volumes

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Table 2.12: Extrapolation of volumes of PFAS placed on the EU market, annual average [redacted]

	[redacted]	[redacted]	[redacted]
[redacted]			
[redacted]			
[redacted]	[redacted]		

[redacted]

PFAS material flow and product lifecycle

As detailed in Section 2.4.3, there are several stages in the lifecycle of PFAS and PFAS containing products. This begins with the production of PFAS to the manufacture of PFAS-containing products, the use or service life of PFAS-containing products and the end of life of PFAS-containing products. It should be noted that Gore do not produce fluoropolymers for the uses in this SEA itself, but rather manufacture fluoropolymer-containing products (in REACH terms they are a "downstream user" of PFAS). The analysis is therefore focussed on the product lifecycle, from manufacture of products containing PFAS to their end-of-life.

Section 2.4.3 presented information from Gore related to the PFAS material used during their manufacturing process and information on the service life and end-of-life of their products. In order to map out the PFAS material flow associated with products similar to those presented in **Table 2.1**, complementary information from "*investigation report summaries*" published by the DSs in 2021 (National Institute for Public Health and the Environment (RIVM) et al., 2021) has also been utilised. It should be highlighted that this information relates to broader product groups and are therefore not fully representative for the products covered in this SEA**.** Further, the emissions stated in the *investigation report summaries* are much higher than the emissions reported by Gore. **In the opinion of Gore, the emissions provided by the DSs are significantly overestimated** which might be based on the fact that the **BAT for emission reduction during manufacturing** was not taken into account by the DSs. Gore also believes the emissions provided by the DSs for the service life and end-of-life of PFAS-containing products are overestimated. This is because, as explained in Section 2.4.3, **PTFE does not react, degrade, or erode**, even when exposed to aggressive chemicals or relevant chemical process temperatures, which suggests that emissions during service life are negligible. Furthermore, based on Gore's current scientific understanding, **incineration, which is the most common EoL treatment, does not show significant generation of a range of PFAS that would be relevant to environmental concerns**. Nonetheless, the data will be used in the following as a basis for conducting the socioeconomic analysis**.** A summary of information from all the "*investigation report summaries*" published by the DSs is presented in **Appendix 1: PFAS volumes and emissions across multiple sectors**.

Figure 2.4 presents an overview of the PFAS material flow through the various lifecycle stages for the products included in **Table 2.1** and similar products on the EU market. It also shows the share of PFAS (as a percentage) that is carried over from one stage of the life cycle to the next, and the share of PFAS (as a percentage) that is released to the environment and the share that ends up in waste at each of the lifecycle stages. **All emission factors presented in Figure 2.4 and detailed in the proceeding section are based on information from the DSs and do not reflect Gore's data on emissions**. The EU use volumes[8] derived in the previous section (PFAS use volumes), was extrapolated from information provided by Gore. The share of PFAS ending up as production waste (5%) is also based on data provided by Gore and assumed similar for other companies manufacturing similar products. The share of PFAS volume being sent for incineration (80%), landfill (15%) and other waste treatment (5%) is based on information from a study prepared for Plastics Europe on fluoropolymer products (ChemService, 2021). The estimates presented in **Figure 2.4** are associated with a high level of uncertainty. The approach and assumptions used to derive the estimates are further detailed below **Figure 2.4**.

Figure 2.4 shows that of the 9,841 tonnes PFAS that is estimated to be placed on the EU market in products similar to those in **Table 2.1**, and almost all of this remains in the products until end of life. The majority of PFAS in waste streams (relevant for this SEA) is believed to be incinerated, for which emissions are likely negligible (Aleksandrov et al., 2019). The "*Investigation report summaries*" indicates that overall emissions from fluoropolymers in waste streams is <1%.

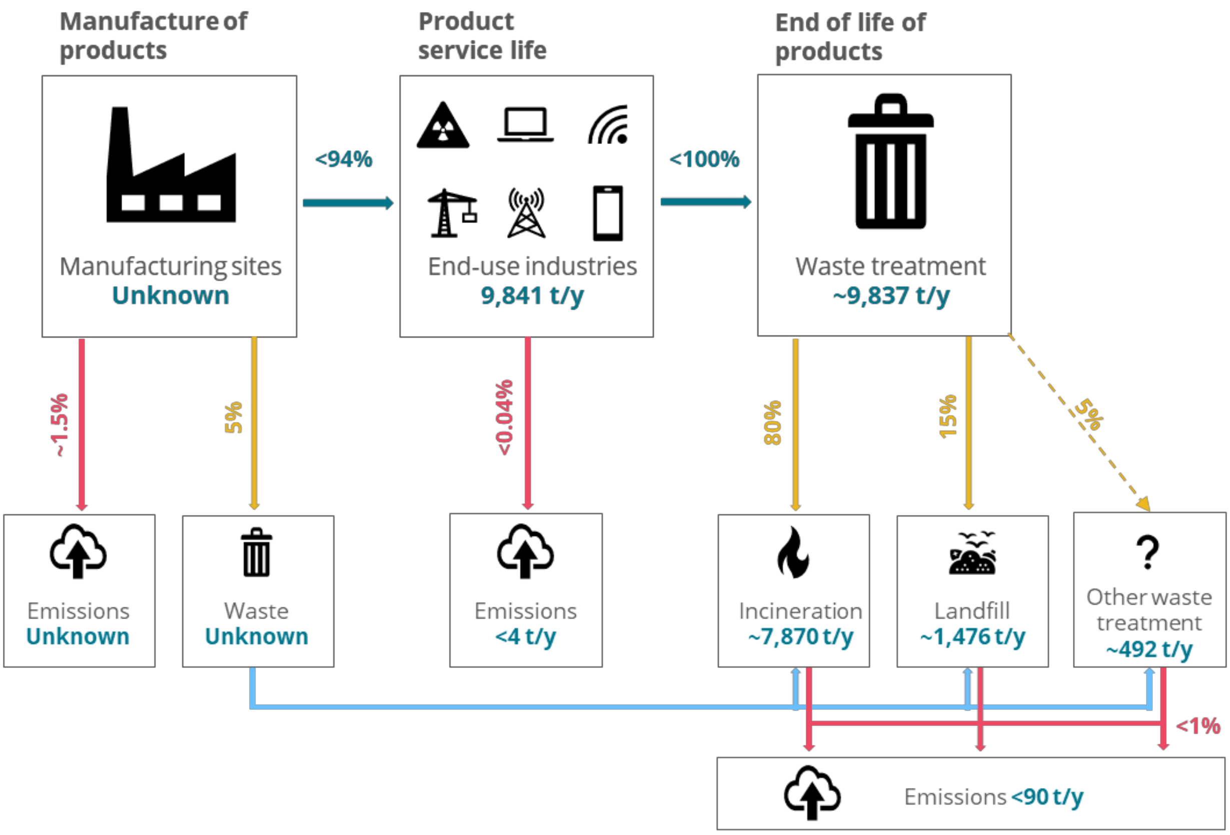

Figure 2.4: PFAS material flow for the EU market for products covered within the SEA

Notes:

1. The emission factors have been estimated based on the fluoropolymer volumes and emissions in the energy sector, taken from the electronics and energy sector report of the *"investigation report summaries"* published by the DS. The

[8] Note that PFAS contained in production waste are only included for Gore, i.e. these have not been extrapolated to the EU – see further explanation in the previous section

emission factors were adapted to each lifecycle stage by subtracting the share ending up in waste (as reported by Gore).

2. The volume of PFAS in end-use industries in the EU has been extrapolated based on the direct sales of PFAS-containing products placed on the EU market, and therefore excludes the volume of PFAS used in manufacturing and potential volumes of PFAS placed on the EU market via indirect sales (for Gore this is zero).
3. The share of PFAS contained in products that ends up in waste at the products' EoL is in the figure rounded to 100%. The actual share is, based on information from the DS, is 100% - 0.04% = 99.96%.

Manufacture of products containing PFAS

Gore manufactures these products both within and outside of the EU, however, information is not available on the location of the production sites of other companies manufacturing similar products, which means that there is no basis for deriving volumes used for the manufacture of electronic and telecommunication products. The indicative share of PFAS used in the manufacture of such products that is released into the environment and the share that ends up in production waste are available, albeit the resulting EU volumes are unknown.

- Gore states that there are negligible (~0%) PFAS emissions from the manufacturing of their products, due to the use of emission control technologies at their manufacturing sites. Gore believes that if similar or equally efficient emission control technologies are used by other companies (which may have production sites located in the EU). Emissions from product manufacture are likely negligible (i.e., ~0%). See Section 2.4.3 for further details.
- The "*investigation report summaries*" published by the DSs in 2021 (National Institute for Public Health and the Environment (RIVM) et al., 2021) (summarised in Appendix 1), provide estimates for PFAS volumes and emissions in the electronics and energy sectors. This report covers a significantly broader range of products than the products covered in this SEA and involve a wider array of manufacturing processes. The emission factor derived based on the DS data is therefore unlikely to be fully applicable to the products covered in this SEA. Despite these uncertainties, the report was considered more representative than the other "*investigation report summaries*", as it specifically estimates emissions from fluoropolymer products.

  The DS estimated that the upper bound for emissions from fluoropolymers is around 1.5% w/w of the fluoropolymers/PFAS contained in the products during manufacturing. **Even though these emissions are significantly higher than the emissions reported by Gore**, they are – following a conservative approach – used as basis for this SEA.

The share of PFAS used to manufacture the products covered by this SEA in the EU that ends up in production waste, is reported by Gore to be around 5% (see Section 2.4.3). The "investigation report summaries" published by the DSs do not go into the same level of detail with regards to the production waste, so the Gore estimate is used as the best available indicator for PFAS ending up in production waste at an EU level.

Lastly, the share of PFAS that comprises the products after the production process waste was derived by subtracting the share ending up in waste (5%) reported by Gore and the DSs' emission share from product manufacture (1.5%). Since the locations of manufacturing sites for other companies are not known, the PFAS used for manufacturing in the EU that do not end up in products (primarily production waste) could not be estimated.

Service life of products containing PFAS

The information provided on emissions from service life of the products differ between Gore and the DS:

- Gore reported (see Section 2.4.3) that it is unlikely that there will be any significant releases of PFAS during the product service life, and that similar PFAS-containing products on the EU market would also exhibit this feature. Due to the reasons stated above in Section 2.4.1, neither the release of relevant quantities of non-polymeric residuals nor the release of degradation products of PTFE during service life is to be expected.
- Based on the "*investigation report summaries*" for the electronics and energy sector, it was estimated that an average of 0.04% of fluoropolymers comprising products used in these industries are emitted during the products' service life. This emission factor is based on emissions from fluoropolymers in the energy sector and is therefore unlikely to be fully representative of the emissions from service life of products covered within this SEA.

To keep the analysis conservative, the share of PFAS emitted throughout the service life of products similar to those set out in **Table 2.1** is assumed to be 0.04% (i.e., aligned with information provided by the DS).

Product end of life

Since the amount of PFAS in the products that then ends up as waste at the products' end of life is assumed to be close to 100%[9], the volume of PFAS from the products similar to those in **Table 2.1** that ends up in waste streams is estimated at approximately 9,837 tonnes per year. ChemService, 2021, reports that 80% of PFAS-containing end-products are incinerated (~7,870 tonnes per year), 15% are landfilled (~1,476 tonnes per year), whilst the waste treatment route for the remaining 5% is not specified in the study.

Based on Gore's current scientific understanding, incineration of fluoropolymers will not generate significant emissions and landfilling of fluoropolymer products is not expected to contribute to emissions associated with landfill leachate, since fluoropolymers are not water soluble, not biodegradable and do not degrade in the environment. See further details in Section 2.4.3.

In the "*investigation report summaries*" for waste it is also noted that incineration of PFAS-containing products at the end-of-life make a negligible contribution to overall emissions from waste streams. Information from the DSs further indicates that the emissions from fluoropolymers in waste streams is <1% of the fluoropolymers entering the waste stream per year. Using this emission factor, the volume of PFAS in the EU at the EoL for the products covered by this SEA is estimated at <90 tonnes per year.

Total emissions throughout the lifecycle

As explained above, Gore believes that the emission factors derived based on the DSs' data are not representative and their use leads to significantly overestimated emissions at all life-cycle stages. Despite this, the DSs' data will be used to calculate emissions for this SEA, to ensure that a conservative approach is taken.

[9] Exact number is 99.96%.

[redacted]

Two emission scenarios have been defined:

- **Reasonable worst-case emissions**: This is derived using the DSs' emission factors for service life and EoL but excludes potential emissions from manufacture of products. According to Gore, who has first-hand knowledge of the manufacturing process and emission from the specific group of products contained in this SEA, the emissions from manufacture of these types of products are negligible, and the overestimation of emissions from service life and EoL will by far outweigh the omission of emissions from manufacture. It is therefore believed that the reasonable worst-case emissions will be higher than actual emissions from all lifecycle stages for products covered within this SEA.
- **Worst-case sensitivity emissions**: To construct a worst-case sensitivity scenario, the DSs' emission factors have been used at all life cycle stages, whilst also assuming that all manufacture of products similar to those set out **Table 2.1** will be manufactured in the EU. It should be noted that this is not considered a realistic scenario but has been included as a conservative sensitivity that can inform the decision-making process.

Table 2.13 presents the two emission estimates alongside the best estimate for EU PFAS contained in products. Based on the argumentation presented above, the volumes and emissions presented in **Table 2.13** will be conservatively assumed as emissions of PFAS into the environment throughout the lifecycle of products similar to those set out in **Table 2.1**.

Table 2.13: Estimates of EU emissions, average 2016-2021

Estimate	Description	Volumes in tonnes/year
PFAS contained in products in the EU	PFAS volumes contained in product similar to those in **Table 2.1** (excluding manufacture and indirect sales).	9,841
Worst-case sensitivity emissions	Based on high emissions factors (DS' factors) for all sources (this includes emissions from manufacture of products containing PFAS assuming all manufacture occurs in the EU).	93
Reasonable worst-case emissions in the EU	Based on high emissions factors (DS' factors) for service life and EoL, excluding emissions from manufacture and indirect sales.	250

Notes: Volumes have been rounded to the nearest tonne.

2.5.4 Indicators of risks under the EU baseline

The DSs have communicated that the key risk indicator for PFAS is the substances' persistency. Another concern is that some of the substances are also highly mobile and can accumulate in biota. They note that "*the consequences of this persistence include that the presence of these substances in the environment is practically irreversible and pose an unacceptable risk to the environment and humans. All uses of PFAS (professional and industrial uses, consumer uses of mixtures and articles) result in emissions into the environment and contribute to the overall concentrations of PFAS in the environment*" (RIVM) et al., n.d.). Toxicity has also been confirmed for some PFAS, which adds to the overall concern for this group of substances.

Hazard profile

Four types of PFAS are used to manufacture the products set out in **Table 2.1** PTFE, ETFE, PFA and FEP.

[redacted]

Similar to other PFAS, these are persistent, but data demonstrate that it does not meet the criteria for being mobile, bioaccumulate or toxic (Barbara J Henry et al., 2018).

PTFE, ETFE, PFA and FEP do not have any harmonised hazard classifications (CLH) and fall under the OECD definition of Polymer of Low Concern (PLC), which the OECD Expert Group on Polymers "*deemed to have insignificant environmental and human health impacts*" (OECD, 2009). During the 5th meeting of the Competent Authorities Sub-Group (CASG) on Polymers (17 November 2021) industry and the Commission discussed as to how PLC should be defined in the EU. A complete set of definition criteria was not agreed, however, it was discussed that if certain fluoropolymers do not breakdown into degradants of concern, this could indicate that the fluoropolymer was a PLC (European Commission, 2021b). Examples of characteristics discussed include molecular weight, stability, and leachability (European Commission, 2021b). Moreover, (Barbara J Henry et al., 2018) found that PTFE, ETFE, PFA and FEP are PLCs based on widely accepted criteria,[10] one of which being that they do not break down into degradants of concern. **Table 2.14** sets out the criteria used and key results from this study, where the conclusion is that PTFE, ETFE. FEP and PFA are PLCs.

A more recent study (Korzeniowski et al., 2022), building on the research conducted by Barbara J Henry et al. (2018), found that 14 additional fluoropolymers[11] (including polyvinylidene fluoride (PVDF) and ethylene-chlorotrifluoroethylene (ECTFE)) are also PLCs – having passed the same 13 criteria (tests) outlined in the original 2018 study.

Table 2.14: PLC criteria from study by Barbara J Henry et al. (2018)

Assessment criteria	Fluoropolymers			
	PTFE	ETFE	FEP	PFA
CAS number	9002-84-0	25038-71-5 68258-85-5	25067-11-2	26655-00-5 31784-04-0
Polymer composition (must have C, H, Si, S, F, Cl, Br, or I covalently bound to C	Yes	Yes	Yes	Yes
Molecular weight	389 000– 8 900 000	-	-	-
(Mn > 1000 Da and oligomer content < 1%)	520 000– 45 000 000	530 000–1 200 000[12]	241 000– 575 000[12]	200 000– [redacted]
Molecular weight distribution MW / number average M_n (M_n and heterogeneity of MW distribution indicate if majority are >1000 or <1000 Da, which could penetrate the cell)	2.3	1.4-2.7	1.55-2.09	1.7

[10] These criteria represent the combined experience and knowledge of global regulatory authorities on factors demonstrated to be predictive of health and environmental hazards of polymers.

[11] The full list of polymers is as follows: polyvinylidene fluoride (PVDF) homopolymer; PVDF copolymer; ethylene-chlorotrifluoroethylene (ECTFE) copolymer; ECTFE terpolymer; polychlorotrifluoroethylene (PCTFE); fluoroethylene-vinyl ether copolymer (FEVE); terpolymer of ethylene, tetrafluoroethylene, and hexafluoropropylene (EFEP); terpolymer of chlorotrifluoroethylene, tetrafluoroethene, and perfluoroalkyl-vinyl-ether (CPT); and terpolymer of tetrafluoroethylene, hexafluoropropylene and vinylidene fluoride (THV), tetrafluoroethylene-propylene co-polymer (FEPM); hexafluoropropene-vinylidene fluoride co- and terpolymers (FKM); and a tetrafluoroethylene-perfluoromethyl vinyl ether perfluoroelastomer (FFKM).

[12] Molecular weight is weight average molecular weight.

[redacted]

Assessment criteria	Fluoropolymers			
	PTFE	ETFE	FEP	PFA
Wt % oligomer (<5% for <1000 Da oligomers, <2% for <500 Da oligomers)	Negligible	Negligible	Negligible	Negligible
Ionic character (cationic polymers associated with aquatic toxicity; polycationic with adverse human health effect)	Neutral	Neutral	Neutral	Neutral
RFGs[13] (some highly reactive functional groups associated with adverse human health and ecotoxicology effects, e.g., acrylates, isocyanates, anhydrides, aziridines)	<1 (see section Reactive functional groups and RFG ratio to MW)	<1 (see section Reactive functional groups and RFG ratio to MW)	<1 (see section Reactive functional groups and RFG ratio to MW)	<1 (see section Reactive functional groups and RFG ratio to MW)
FGEW[1313] (typical value) (the lower the FGEW, the more reactive the polymer and the higher the potential for health and environmental impact)	$>10^5$-10^7	$>10^5$-10^6	$>10^5$	$>10^5$
Low molecular weight leachables (MW < 1000 Da able to enter cell)	<1 ppm	No active leachables by USP class VI[14] (121˚C)	No active leachables by USP class VI[14] (121˚C)	No active leachables by USP class VI[14] (121˚C)
Residual monomers (monomers have lower MW than polymers; typically more hazardous than polymers)	<1 ppm	<50 ppb	<50 ppb	<50 ppb
Ratio of residual monomers to molecular weight (typical value) (more low MW monomer content per mole increases bioavailability and hazard potential)	$\sim10^{-13}$ to 10^{-15}	$\sim10^{-13}$ to 10^{-14}	$\sim10^{-13}$	$\sim10^{-13}$
Structural similarities to RFG of concern (increases potential risk of adverse effects)	None	None	None	None
Reference standard see also ISO 1133 (ISO 2011), ISO 12086 (ISO 2006)	ASTM D 4894 (ASTM, 2015a) D 4895 (ASTM, 2016a)	ASTM D 2116 (ASTM, 2016b)	ASTM D 3159 (ASTM, 2015b)	ASTM D 3307 (ASTM, 2016c)
Physical–chemical properties				
Water solubility (per USP 2011) (water solubility <10mg/L showed generally low health concerns;	Practically insoluble or	Practically insoluble	Practically insoluble	Practically insoluble

[13] For definition of reactive functional group; lists of low-, moderate-, and high-concern functional groups; and FGEW limits, see US EPA Polymer Exemption Guidance Manual (USEPA, 1997), (De Toni, A., Saïdi, s., Santos, L. R., And Mudga, 2015, p 191–192), and (USEPA, 2010).

[14] In the USP<88> testing for "class VI," 2 g of the plastic (e.g., FEP, ETFE, or PFA) were extracted at 121˚C in: 1) 0.9% sodium chloride solution, 2) sesame oil, NF, 3) alcohol saline, and 4) polyethylene glycol. The acute systemic toxicity and intracutaneous reactivity tests were conducted with those extracts. The intramuscular implantation was conducted with the plastic. Passing these 3 tests indicates that any leachables were not released in concentrations capable of causing these adverse effects but does not result in a quantitative concentration of leachables (US Pharmacopeia, 2018).

[redacted]

Assessment criteria	Fluoropolymers			
	PTFE	ETFE	FEP	PFA
10mg/L to 10000 mg/L had potential health concern)	insoluble (1 * 10^{-5} mg/L)	or insoluble	or insoluble	or insoluble
Octanol–water partition coefficient, K_{OW} (higher K_{OW} associated with lipophilicity and a high potential to bioaccumulate or bioconcentrate)	N/A	N/A	N/A	N/A
Particle size (median mass aerodynamic diameter, MMAD, should be >5μm)	100-500 μm (powders)	50-250 μm (powders)	150-250 μm (powders)	50-250 μm (powders)
		2-4 mm (pellets)	2-4 mm (pellets)	2-4 mm (pellets)
Stability				
Hydrolysis (breaking into M_n< 1000 Da increases hazard potential)	Stable	Stable	Stable	Stable
Light (hν) (breaking into M_n< 1000 Da increases hazard potential)	Stable	Stable	Stable	Stable
Oxidation (breaking into M_n< 1000 Da increases hazard potential)	Stable	Stable	Stable	Stable
Biodegradation (aerobic and anaerobic) (breaking into M_n< 1000 Da increases hazard potential)	Stable	Stable	Stable	Stable
Thermal stability at normal foreseeable use maximum continuous temp (˚C) (breaking into M_n< 1000 Da increases hazard potential)	260	150	200	260
Meets PLC criteria (Y/N)	Yes	Yes	Yes	Yes

Source: (Barbara J Henry et al., 2018) based on OECD (2009) and (De Toni, A., Saïdi, s., Santos, L. R., And Mudga, 2015)

Risks

PFAS is, as mentioned, a large group of substances (>6,000) which is being proposed for a REACH restriction due to persistence. The four PFAS (fluoropolymers) used by Gore in products covered by this SEA, have no harmonised classification (CLH). Data demonstrate that they do not meet the criteria for being mobile, bioaccumulate or toxic and it has been categorised as a PLC (Barbara J Henry et al., 2018; OECD, 2009). Although information on the type of PFAS used by other companies is not available, Gore considers it likely that they will be similar or the same as the fluoropolymers used by Gore and thereby fall under the PLC definition.

Overall, it is therefore considered unlikely that products covered by this SEA that are produced using these types of PFAS will lead to significant adverse impacts on the environment or human health.

2.5.5 EU baseline summary and projections

[redacted]

[redacted]

Table 2.15: Extrapolated projection of sales, volumes for Gore to the EU market (2022-2041)

[redacted]

[redacted]

3 Availability of suitable alternatives

3.1 Introduction

Information on the suitability of possible alternatives is essential when assessing possible restrictions under REACH. The assessment of alternatives within this SEA is primarily based on information from Gore.

This chapter covers the following topics related to possible alternatives (either being tested or already on the market):

- R&D (Section 3.2)
- Technical feasibility (Section 3.3)
- Availability (Section 3.4)
- Cost and timeline (Section 3.5)
- Hazard comparison (Section 3.6)

In order for an alternative substance (or process) to be viewed as a viable substitute, it needs to be able to deliver a similar technical function as the restricted substance, be economically feasible to implement, be available in sufficient quantity to replace the restricted substance, and not have a worse hazard profile (i.e., increase risks).

3.2 R&D undertaken by Gore to date

Gore continually follows external developments of new materials while also pursuing an R&D program to develop novel materials that meet the market's needs. In addition, semiconductor equipment companies have been performing trade studies and investing in non-PFAS alternatives that can be used with Cables and Cable Assemblies in clean environments for a number of years. However, no materials have been identified that can replace PFAS in all of Gore's products.

Gore has not carried out R&D specifically to replace PFAS in their products supporting semiconductor manufacturing, harsh environment industrial manufacturing and testing capital equipment. The main reason for this is that PTFE is understood to be the only substance that can reach the performance required to be >300% expandable at 300°C and be releasable after expansion. However, the industry continues to look for alternative materials for cost saving opportunities but has yet to find any suitable alternative materials that have the same chemical/physical properties as PTFE. The same conclusion has been reached for Gore's Microwave / RF Assembly products, as other (alternative) materials have been tested in the past, however, these materials have not been able to handle the high frequency requirements of modern cables.

3.3 Technical feasibility

Gore operates within markets that require the performance characteristics provided by PFAS. As a result, Gore developed products to meet customer's performance specifications that could not met by using other materials. PFAS are generally more expensive than other polymers, so customers have an economic incentive to use other materials, when it is possible to meet their performance requirements. Despite these strong economic incentives to substitute, no alternatives that can replace the type of products set out in **Table 2.1** (for the use in electronics and telecommunications) have been identified.

Gore highlights that no material has been developed since the introduction of fluoropolymers to the market in the late 1950s that has performance characteristics that could displace this material without a significant drop in performance and an increase in health and safety risk to the end user. Additionally, there would be significant economic impacts to both manufacturers and end users of Gore's products where alternative products would be required.

The market reflects the lack of viable alternatives, as 95% of high-performance (i.e., most demanding) microwave/RF coaxial cable targeting in A&D and space applications utilises PTFE as dielectric material. Also, over 95% of the same sectors use FEP or PFA as jacket material. For low performance (i.e., less demanding) microwave/RF coaxial cable targeting products used for residential and consumer applications (such as satellite television and radio), PTFE is still used; however, PE is a sufficiently dielectric material (and is used most frequently due to the reduced cost). In terms of jacket material, PVC is the most popular for low performance products. **Table 3.1** shows the advantages of PTFE and PE (respectively) when used as a dielectric material. Gore notes that SiO_2 can also be used as a dielectric material, but only for niche low-performance applications.

Table 3.1: Relative advantages of PTFE and PE when used as a dielectric material

Substance	Advantages
PTFE	• Lower (i.e., better) dielectric constant • Larger operating temperature range, which is ideal for a variety of mission critical applications under harsh conditions • Mechanically/electrically stable under mechanical, chemical, and environmental stresses
PE	• Low cost (relative to PTFE) • Sufficiently low dielectric constant, suitable for low performance, non-mission critical applications

For a few selected applications, Gore has been able to transition to alternative materials and still meet customer requirements. However, these are exceptions, as the alternative materials used are not able to successfully substitute PFAS in most of Gore's electronics and telecommunication products. This is because the products Gore provides require the functionality that only fluoropolymers provide. For example, Gore's Round and Planar Cables conveying data and power (for both semiconductor manufacturing and for harsh environment industrial manufacturing) and testing capital equipment must be small, flexible, and reliable. This allows them to operate in extreme temperatures, ensuring continuous rapid flexing and resilience to harsh chemicals. Additionally, Gore's Round and Planar Cables conveying data and power for semiconductor manufacturing must enable the delivery of increasing amounts of data and power to the capital equipment needed to support semiconductor production. For Gore's Trackless cables, the durable nature of fluoropolymers allows the cables to have low particulation properties when used in automated machinery equipped with durable, high flex cables and cable assemblies. As these are under constant motion and stress (to produce and inspect semiconductor chips), without highly durable, fluoropolymer-based cables, fabricators of semiconductor chips will produce lower yields. As semiconductor chips are a necessity to everyday life, and there is already a global chip shortage, the consequences of lower yields would result in further global shortages of both business to business (B2B) and business to customer (B2C) products worldwide. While in Microwave / RF Assemblies, PFAS allows for rugged, lightweight assemblies for testing in laboratory, production and field test environments. More information on the function of Gore's Microwave / RF Assemblies can be found on Gore's website (Gore, 2021a).

According to Gore, there are no drop-in alternatives for any of their electronics and telecommunications products set out in **Table 2.1**. There are also no alternative substances (that are not drop-in replacements) or alternative processes that can replace Gore's Round and Planar Cables conveying data and power for harsh environment industrial manufacturing and testing capital equipment, or Gore® Microwave / RF Assemblies. Although there are alternative non-PFAS products for Ultraclean Cables, Trackless Cables, Round and Planar Cables conveying data and power for semiconductor manufacturing and testing capital equipment, these products are not viable replacements of the products manufactured by Gore.

With regards to Ultraclean Cables, Trackless Cables, Round and Planar Cables conveying data and power for semiconductor manufacturing and testing capital equipment, Gore is unaware of any alternative substances (that are not drop-in) or alternative processes that could be used to replace fluoropolymers. The DSs have published multiple documents summarising information gathered during the Risk Management Option Analysis (RMOA) process for PFAS substances and potential alternatives. The 'Report summary Electronics and Energy' (RIVM et al., 2021) assessed the following substances and technologies in the electronics and semiconductor industry:

- Hydrocarbon-based greases, molybdenum disulfide, graphite for photolithograph, and
- Atomic Layer Deposition / Atomic Layer Etching technologies.

The assessment concluded that a few (non-PFAS) alternative substances were technically feasible alternatives to PFAS and could replicate the properties necessary for semiconductor manufacturing and process chemistries. However, as already confirmed by Gore, there was no single 'drop-in' replacement feasible for all semiconductor applications; thus, every product / use would need to be re-engineered to determine if a replacement was able to meet the application's requirements.

It was thought that Atomic Layer Deposition / Atomic Layer Etching technologies would have the potential to reduce the number of photolithography process steps required when manufacturing semiconductors, but results were unsatisfactory as the necessary manufacturability to support high volume manufacturing was not realised (i.e., the commercial scale-up was unsuccessful). In addition, although hydrocarbon-based greases may work for older generation photolithograpy machines, the next generation of extreme ultraviolet lithography (EUV) machines that are currently entering the market utilise a high vacuum environment. Hydrocarbons are completely forbidden elements in this environment and thus, cannot be viewed as a viable alternative to Gore's use of fluoropolymers (Garg et al., 2008). It should also be noted that both hydrocarbon-based greases, molybdenum disulfide, graphite for photolithograph, and Atomic Layer Deposition / Atomic Layer Etching technologies to be non-PFAS alternatives, all would be required to use a non-PFAS insulation/jacket material for the required cable solutions.

3.4 Availability

As there are no alternative substances (including drop-in substances that mimic the role of PFAS, and substances that have different functions to PFAS) or alternative processes to the Gore products that contain PTFE, ETFE, PFA or FEP. It is not possible to assess the availability of a potential alternative substance (or substances).

3.5 Cost and time required to transition to alternatives

Gore states that even if significant investments are made, it would take 12 years to substitute PFAS in their electronics and telecommunication portfolio. However, this is based on the assumption that a viable alternative material (to fluoropolymers) is identified, which Gore notes is unlikely, as they have not become apparent yet.

Substitution of Gore products with non-PFAS alternative materials is a very difficult task. As mentioned in Section 3.3, there is no other alternative material that Gore are aware of that could replace PTFE in their Microwave / RF Assemblies that is fit for use. **Table 3.2** details Gore's substitution steps and actions, the time needed per step and the associated one-off cost. For the *Qualification and/or Validation* and *Certification* steps, Gore were less certain about the precise actions that would be required, so they have provided assumptions as to how they would proceed. In total, at this point in time, Gore estimates that ceasing the use of PFAS for their entire electronics and telecommunications portfolio would take around 12 years and cost approximately €27 million. This is based on the assumption that viable alternative materials are identified. The time needed to identify materials could not been taken into account as such materials are not apparent yet.

Table 3.2: Gore's substitution steps / actions, time needed and one-off costs

Substitution steps	Actions	Time needed	One-off costs
Planning - Would require a broad scan of potential replacement materials for multiple business groups.	Impact assessment and viability study need to be completed. If decision to move forward, begin multi-year exploration process.	1 year	Approximately €1 million
Development - Approval needed from Board of Directors	Material substitute studies to be completed. Purchase capital equipment and assets for prototyping, execute prototyping and performance evaluation for MVP.	5 years	Approximately €10 million
Qualification and/or Validation - Material and product specifications to be defined	*Gore's assumption is that they would conduct laboratory and field tests to guarantee that the alternatives are fit for use (FFU).*	2 years	Approximately €5 million
Certification - Submit material for qualification	*Gore's assumption is that they would work with credible 3rd parties to review / test their (new) products.*	1 year	Approximately €1 million
Production - Reconstruct whole supply chain and technology road	New processes and new capital equipment to be purchased and constructed. End user	3 years	Approximately €10 million

[redacted]

Substitution steps	Actions	Time needed	One-off costs
map and capabilities based on unknown potential substitute	validation and performance validation would need to be achieved.		

Source: Gore (2021b, 2022)

3.6 Hazards comparison

As there are no alternative substances (including drop-in substances that mimic the role of PFAS, and substances that have different functions to PFAS) or alternative processes to the Gore products that contain PTFE, ETFE, PFA or FEP, it is not possible to compare the hazard profile of a potential alternative substance (or substances) to their respective PFAS.

4 Restriction scenario

4.1 Introduction

This chapter assesses impacts of a potential REACH restriction on the use of PFAS in cables and cable assemblies for electronics and telecommunication products included in **Table 2.1** and similar products placed on the EU market by other companies. As the exact scope of any possible restriction is unknown, this assessment assumes that all cables and cable assemblies for electronics and telecommunication products containing PFAS are restricted within the scope of a possible REACH restriction following entry in force (EiF) + 12 months. For the purpose of this assessment and its quantitative analysis, this is assumed to occur in 2025.

The chapter covers:

- A description of the restriction scenario assessed and how we assume affected actors along the supply chain will react to this restriction (Section 4.2)
- The economic impacts of the restriction (Section 4.3)
- The environmental and human health impacts (Section 4.4)
- The social and wider economic impacts (Section 4.5).

Information on behavioural responses to a possible restriction on PFAS was gathered from Gore and publicly available sources, combined with professional judgements. All relevant impacts are assessed where possible at an EU level (i.e., covering the whole market). Any monetary estimates that have been discounted are accompanied with the following bracket: (PV - present value). A 4% discount rate has been used, as recommended by the European Commission (EC, 2017), and values are shown in 2022 prices.

4.2 Behavioural responses

4.2.1 Introduction

When faced with a REACH restriction without any derogations, affected actors typically have a few options of actions they can consider, henceforth called “behavioural responses”. These can broadly be divided into:

- **Option 1:** Transition to an alternative (substance, material or technique/process, and in some cases a change of ‘service’ may be possible[15]), before the Entry into Force (EiF) of the restriction;
- **Option 2:** Temporarily cease production of the affected products in the EU, until an alternative is implemented;
- **Option 3:** Permanently cease production of the affected products in the EU (with or without increasing production outside the EU).
- **Option 4:** Cease all operations in the EU (with or without relocation outside the EU).

[15] A change in service would be to remove the need for the product itself. For example, instead of using a BPA in thermal paper receipt, electronic receipt could be used instead. The paper receipt would then no longer be needed, but it requires other broad-reaching societal changes.

[redacted]

For the purpose of this analysis it is assumed that companies using PFAS in the manufacturing of products similar to Gore will be in a similar situation, and the most likely behavioural options will be the same.

The behavioural responses for the following actors are considered:

- *Gore and manufacturers (including importers) of similar products made with PFAS*. These include Gore and manufacturers of similar products to those set out in **Table 2.1**.
- *Upstream raw material suppliers* include all suppliers of PFAS intended for the use in products similar to those set out in **Table 2.1**.
- *Industrial downstream users* include all companies using products similar to those set out in **Table** 2.1.

4.2.2 Gore and manufacturers (importers) of similar products made with PFAS

As detailed in Section 3, changing the substance/material or the production process to avoid using PFAS is not currently technically feasible, due to the high performance required for the products covered in the SEA. Gore also explained that alternatives will not be available in the foreseeable future (see Section 3.5). Parts of the market which do not have as stringent performance criteria may be able to substitute, however, it is believed that most high-performance products contain PFAS (i.e., the ones that are affected by a potential restriction).

Without a derogation, the only options therefore involve ceasing the production of such products in the EU, until suitable alternatives have been found (it will be a permanent cease of production if suitable alternatives are not found). Whether or not all operations will have to cease depends on each company's reliance on PFAS in their product portfolio, and whether other products affected by a potential restriction would be granted a derogation.

4.2.3 Upstream raw material suppliers

Manufacturers and suppliers of fluoropolymers will be heavily affected by a restriction of PFAS, since they manufacture and sell the PFAS that are subject to a potential REACH restriction, and production of these will have to cease (unless derogated). If derogations are granted for some uses, manufacture of PFAS may still continue in the EU, but at a reduced capacity (i.e., supply PFAS for derogated uses only). In a best-case scenario, PFAS suppliers that also manufacture other substances can increase their production of these substances, and thereby reduce some of the profit losses. If a REACH restriction removes a large share of their EU business, it is likely that at least some raw material suppliers will cease all operations in the EU.

4.2.4 Industrial downstream users

The industrial downstream users are companies within industries that require small and flexible cables and assemblies that can operate in harsh environments where cables can be exposed to vacuum condition, broad temperature ranges, continuous rapid flexing, and harsh chemicals and contaminants (e.g., semiconductor industry, defence sector and chemical manufacturing). Considering that the fluoropolymer-based products are many times more expensive than their non-PFAS counterparts, which cannot match the performance characteristics of fluoropolymers in these use exposure conditions (e.g., Polyethylene (PE)), it is believed that only downstream users for which high performance is critical will choose to use

[redacted]

cables and fibres containing PFAS. These companies manufacture products that are critical for a large number of end-use industries, described in Section 2.2 and Section 2.5.2. It is not realistic to assume that downstream user industries will collapse (Option 3 and Option 4), but the industrial downstream users as well as some end-use industries may temporarily need to cease production until they are able to find alternatives (Option 2). Since no alternatives with equal performance are available, they may have to redesign their production process to use lower alternatives, which will take some time.

4.3 Economic impacts

4.3.1 Introduction

Restricting the use of PFAS in products similar to those set out in **Table 2.1** will induce significant economic impacts for upstream suppliers, product manufacturers (Gore and other companies), downstream industrial users as well as the actors in end-use industries. There is limited information available to estimate impacts throughout the value chain, so the quantitative analysis focusses on impacts on products manufacturers. Other economic impacts are assessed mostly qualitatively, with a few numerical examples to illustrate potential order of magnitude of non-quantified effects.

The quantitative analysis is estimated based on the behavioural assumptions set out in Section 4.2. All impacts are presented as total present value, average annual present value and equivalent annual values (EAV), using a discount rate of 4%, an analytical period of 20 years, and 2022 as the monetary base year.

4.3.2 Economic impacts on Gore and manufacturers (importers) of similar products made with PFAS

Lost profits

[redacted]

[redacted] SEAC has recently published guidance that streamlines the approach to estimating lost profits, which is linked to premature retirements of assets (SEAC, 2021). Assets may be intangible (e.g., R&D and patents) or tangible/physical (e.g., production equipment or a production plant). If a company, production plant or a production line has to shut down (e.g., due to a regulation) the associated assets will no longer generate value. The main assumption behind this methodology is that "*in the short run there is a fixed availability of tangible and intangible assets and in the long run incumbent or rival firms can augment assets by making investments*" (SEAC, 2021). The guidance provides a default time period over which profits lost should be estimated, which is dependent on whether suitable alternatives are generally available in general (SAGA) or not (no-SAGA). For SAGA cases, 2 years of profits is used to approximate producer surplus losses, whilst a 4-year period is recommended for no-SAGA cases. If a longer time period is to be used (5 years is suggested in the guidance), this must be "*justified by robust supporting evidence*" (SEAC, 2021).

It should, however, be noted that it is deemed unlikely that new assets (after the end of life of the 'old'

[redacted]

assets) can be redeployed in equally beneficial or income-generating uses. Hence, it is believed that parts of the losses will remain way beyond the 4-year default period. Albeit likely significant, it is not achievable to quantify the losses associated with deploying resources in less beneficial (second-best options) applications, so a conservative approach with a 4-year period has been used.

[redacted]

Substitution costs

Section 3.5 details the necessary steps as well as the minimum time and cost Gore needs to transition to alternatives for the products set out in **Table 2.1**. The necessary steps include planning, development, qualification/validation, certification, and production (see **Table 3.2**). It is important to recognise that it is currently unknown what alternative could be used, hence it is difficult to predict the exact time needed for substitution.

It is reasonable to assume that companies that manufacture similar products would have to go through a similar process, so these costs have been extrapolated to the EU market. This implicitly assumes that substitution costs will eventually be passed through to the price of the products, i.e., the substitution costs will be borne by actors on the EU market. It should be noted that the substitution costs are not likely to be equally distributed across all EU actors. Some companies may choose to exit the market, i.e., permanently cease their production and thus not incur substitution costs. Other companies may be willing to undertake large investments over an extended period of time, in order to capture current or new markets. These companies would thereby incur higher substitution costs, but less profits lost. As explained above, these distributional effects have been accounted for in the estimation of lost profits (i.e., net profit lost is estimated), which means that substitution costs can be added to the estimated profits lost. [redacted]

4.3.3 Upstream raw material suppliers

Suppliers of PFAS will be severely impacted by a potential restriction on PFAS, as the substances themselves are the products being restricted. The only options for these suppliers will be to permanently cease manufacture and sales of PFAS in the EU associated with all restricted uses. If derogations are granted for some uses, manufacture of PFAS may still continue in the EU, but at a reduced capacity (i.e., supply PFAS for derogated uses only).

As a minimum, the PFAS suppliers will lose their sales and corresponding profits associated with supply for all restricted uses of PFAS. Some companies may be in a position to start or increase production of other substances that can be used in the production of (inferior) downstream alternatives, but the sales of such substances will first be possible after alternatives have been identified, tested, and implemented, which may take a significant amount of time. If a REACH restriction removes a large share of their EU business, it is likely that at least some raw material suppliers will cease all operations in the EU.

[redacted]

The volume of PTFE placed on the EU market in products covered by this SEA was estimated at an average of 9,841 tonnes per year between 2016-2022, which excludes production waste and products placed on the EU market by non-EU customers. The total volume of fluoropolymers sold in the EU for relevant industries uses (**Table 2.10**) comprised 30,500 tonnes in 2020, with a corresponding sales value of €607 million (Fluoropolymer Product Group of PlasticsEurope, 2022). The profits lost for these suppliers will be small compared to other quantified costs, so these have not been estimated or included in the total cost estimates.

4.3.4 Industrial downstream users

One of the key benefits of using PFAS in cables and assemblies is that it provides reliability and durability in harsh environments. As mentioned in Section 4.2.4, it is not realistic to assume that downstream users will (or can) wait a long period of time until equivalent performing cables are on the market. If PFAS can no longer be used, downstream users will therefore need to modify their processes and products to adapt to reduced performance such as changes in cleanliness, flexibility, performance, and durability of cables made without PFAS. Furthermore, they will need to acquire product and regulatory approval to use different products until non-PFAS products have been found. This will induce costs of R&D, investments, testing, and regulatory approvals, to mention a few, resulting in significant costs for these downstream users. It has, however, due to data limitation not been possible to estimate these substitution related costs.

If downstream users are not able to redesign and change their production processes to fit the lower performing electronics and telecommunication products by the end of the transition period, there is a risk of temporary production halt for products relying on PFAS-containing cables and assemblies. The EU industrial base, such as the chemical industry, mining industry and electronics sector, would then be faced with significant disruptions, for which the duration is difficult to predict.

It is also uncertain if manufacturers of lower performing non-PFAS industrial cables and assemblies will be able to increase their product supply to meet the 'new' demand coming from downstream users switching from products containing PFAS, after the end of the transition period. Any delay in the supply of non-PFAS electronics and telecommunication products could result in a temporary shortage in such products being available and therefore increase the risks of production halts and disruptions in downstream user industries.

Predicting the length and the extent of production halts, as well associated impacts on sales within downstream user industries is challenging. Available information does not allow for a full quantification of such impacts. Looking at only some relevant sectors[16] can give an indication of the minimum order of magnitude of profits loss due to production halts in downstream user sectors. As shown in **Table 2.11**, the turnover in these industries was close to €1498 billion[17] in 2019 and the total employment around 2.3 million people in the same year. To keep the example conservative, it is assumed that only 1% of sales in these industries is affected and that the profit margins are 50% lower than for Gore and similar manufacturers. Again, using the no-SAGA approach (SEAC, 2021), as there are no suitable alternatives on the market, the resulting **loss amounts to over €17.8 billion (PV) over the period 2022-2041, which**

[16] Relevant sectors are detailed in Section 2.5.2 and include: chemical manufacturing, defence, electronics, electrical equipment, mining and quarrying, semiconductors, and telecommunications equipment.

[17] Values given in 2022 prices.

[redacted] annualised over the 20-year analytical period is close to €1.3 billion per year.

In addition to substitution costs and lost profits, there will be economic impacts associated with using lower performing cables and assemblies. Alternative products cannot match the durability of the fluoropolymer products, which may force companies to operate at lower temperatures or pressures, dropping efficiencies and increasing energy use. Furthermore, one of the key benefits of using PFAS in electronics and telecommunication products is that it provides reliability and durability in harsh environments.

A recent report published by PlasticsEurope, "Socio-economic Analysis of the European Fluoropolymer Industry", found that products in the chemical and power industry (e.g., cable coatings) made with fluoropolymers are believed to have twice the lifetime of other similar products, potentially yielding savings in the order of €100 million annually (Fluoropolymer Product Group of PlasticsEurope, 2017). In the electronic industry, fluoropolymer components can withstand aggressive etching chemicals and provide the necessary purity required in the production of microchips and other electronics (Fluoropolymer Product Group of PlasticsEurope, 2017). The analysis also found that using fluoropolymers prevents corrosion in demanding environments, and that each percent reduction in corrosion is estimated to deliver savings of some €150 million per year across Europe. Amongst other benefits, they support savings in maintenance through increased component lifetime (Fluoropolymer Product Group of PlasticsEurope, 2017). This is, of course, not only related to cables and cable assemblies, but it shows that performance loss may induce significant costs for the downstream users.

4.3.5 Total economic impacts

[redacted]

Table 4.1: Summary of quantified economic impacts in the EU

	[redacted]	[redacted]
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

[redacted]

[redacted]		
[redacted]		

[redacted]

4.4 Impacts to human health and the environment

4.4.1 Introduction

Certain individual PFAS substances (e.g., PFOA, PFOS and PFHxS) are listed as Substances of Very High Concern (SVHC), due to vPvB and/or PBT properties, and their use have therefore been restricted in the EU. Not all PFAS, however, are substances of concern or very high concern. As shown in Section 2.5.4, the PTFE and additional fluoropolymers used by Gore have all been established to meet the OECD criteria for Polymers of Low Concern (PLC) and are thus not expected to impact human health or the environment (Barbara J. Henry et al., 2018; S. H. H. Korzeniowski et al., 2022; OECD, 2009). The exact composition of PFAS (fluoropolymers) used by companies manufacturing similar products to Gore's is not known, but it is considered likely that these will have similar properties. The approach used to assess potential benefits of reducing exposure to PBTs and vPvBs (ECHA, 2016) may therefore not be appropriate to use for PFAS as a group, or more specifically the type of PFAS covered within this SEA.

4.4.2 Risk reduction indicators

Reductions in the use and emissions of PFAS from not derogating the uses within this SEA are set out in **Table 4.2**, and these estimates are integral in assessments carried out by the DS as well as by RAC and SEAC. However, caution must be taken when interpreting what these emission reductions mean in terms of actual impacts on human health and the environment. PTFE and other fluoropolymers are not mobile in the environment, are demonstrated to be non-toxic, and are extremely stable. Individual PFAS can have very different properties, and the assessment of risks associated with potential emissions should ideally consider both the amount and specific type of PFAS.

Table 4.2: Reduction in PFAS contained in products and emissions in the EU

[redacted]		
[redacted]		
[redacted]		
[redacted]		[redacted]

[redacted]

[redacted]

[redacted]

4.4.3 Other impacts on the environment and human health

Other impacts on the environment and human health may include potential impacts on the safe processing of nuclear waste, fire safety, and increased consumption of raw materials and waste from reduced durability.

Human health impacts

Increased risk of fire hazards

Fluoropolymers enable improved fire safety, reliability and performance of cables, notably data transmission cables (Fluoropolymer Product Group of PlasticsEurope, 2017). A combination of high dielectric properties, high heat resistance and fire resistance is necessary to produce acceptable products that are able to operate in harsh environments where cables can be exposed to low pressures, broad temperature ranges, continuous rapid flexing, and harsh chemicals (Fluoropolymer Product Group of PlasticsEurope, 2017). The use of non-PFAS cables which do not provide the same properties of heat resistance in downstream industries could lead to greater risks of fires and the associated human health risks of such fire hazards for workers. In 2017, work-related injuries and illnesses cost €476 billion in the EU (EHS Today, 2017). Increased risk of fire hazards and/or extreme temperatures due to, for example, wearing of cable covers by chemicals or harsh environments and causing potential electrical fires at the workplace could increase these costs over time, which would negatively impact the EU economy.

Increased public health risk from exposure to nuclear waste

Cables containing PFAS support appropriate processing of nuclear waste. Reducing the reliability and performance of nuclear waste processing tools could increase the risk of exposure to nuclear waste, potentially causing increased public health risk associated with radiation poisoning. There are currently 104 nuclear plants in operation in the EU, with a further three plants under construction (European Nuclear Society, 2022). Over its lifetime, the EU[18] nuclear reactor fleet is estimated to produce around 4 million cubic meters of nuclear waste from a combination of operational waste, spent nuclear fuel and decommissioning of nuclear plants (Manon, Besnard, Marcos, Buser, Ian, Fairlie, 2019). All EU countries generate radioactive waste, and 20 of them also manage spent fuel on their territory (European Commission, n.d.), making the safe processing of nuclear waste critical to the public health of the EU population.

Environmental impacts

Increased consumption of raw materials and waste

PFAS-containing electronics and telecommunication products are more durable than their non--PFAS counterparts. The products containing PFAS are durable, flexible, and chemically inert, offering high quality performance important for the function of certain high performance uses across a breadth of critical systems, such as nuclear waste processing. PFAS-containing products are used in business to business (B2B) capital equipment applications that demand robust materials to avoid premature failure. If these products were not available, downstream manufacturers would be forced to use lower-performing cables

[18] The amount of nuclear waste in the EU has been estimated by excluding non-EU countries in Europe, such as the United Kingdom and Ukraine.

[redacted]

and assemblies that would need to be replaced more frequently. A shorter product life puts further strain on the environment by increasing the volume of raw materials needed to manufacture those products, including an increased use of chemicals, water and energy. Further, failures in critical systems like nuclear waste processing can cause excessive material loss in other systems, such as nuclear power generation. The increased use of energy to extract raw materials and manufacture a higher volume of products has the subsequent impact of emitting greenhouse gases.

Higher consumption of electronic and telecommunication products through shorter use life and more frequent replacement would consequently increase the amount of waste generated, which itself has potential environmental impacts. The amount of waste electrical and electronic equipment (widely known as WEEE or e-waste) generated every year in the EU is increasing rapidly (European Commission, n.d.). It is now one of the fastest growing waste streams (European Commission, n.d.). The EU has introduced the WEEE Directive and the RoHS Directive to tackle the issue of the growing amount of WEEE. One of the primary priorities of these Directives is to prevent the creation of WEEE (European Commission, n.d.). This can be achieved, in part, by extending product use life.

Greenhouse gas emissions from reduction in nuclear power generation

The EU depends on nuclear power for one-quarter of its electricity, and a higher proportion of base-load power. Nuclear provides half of low-carbon electricity, and therefore plays a key role in providing reliable energy in the green transition (World Nuclear Association, 2022). Cables containing PFAS support appropriate processing of nuclear waste. Processing this waste safely is crucial in public acceptance of nuclear energy generation and in reducing the risk nuclear power plant developers and investors are willing to take in developing these energy generation sites. Both of these aspects, namely public acceptance and financial investment are crucial in ensuring that nuclear power plants continue to be developed or are not decommissioned prematurely in the EU and continue to provide the EU with a source of zero emission energy.

Habitat and biodiversity impacts from nuclear waste leaks

In addition to ensuring the continued generation of zero emission energy in the EU, the safe processing of nuclear waste, supported by cables containing PFAS, reduces the risk of nuclear waste leaking into the environment. In the same way that exposure to radioactive waste can have highly damaging human health impacts, the release of nuclear waste into the environmental can have a drastic impact on animal and plant life, including causing cancerous growths and genetic problems for multiple generations.

4.5 Social and wider societal impacts

4.5.1 Social impacts

This section explores the social impacts that may occur as a result of restricting the use of PFAS in products similar to those set out in **Table 2.1**. Social impacts are impacts which may affect workers, consumers and the public that are not covered under health, environmental or economic impacts (ECHA, 2008). These include impacts on employment, working conditions, job satisfaction and education of workers and social security. This subsection covers employment, energy supply and semiconductor supply disruptions, which were identified as the most relevant social impacts to assess.

[redacted]

Employment

The products affected by a potential restriction, e.g., cables, serve critical functions in a number of downstream user industries – for more information, see Section 2.2.2 and 2.5.2. A restriction of PFAS may induce impacts on employment along the entire supply chain to the end-product. Manufacturers of similar products to Gore's, are believed to have similar supply and value chains.

Restricting the use PFAS in products may reduce employment in both upstream and downstream industries, which can induce large impacts since 50% of companies manufacturing similar products to those set out **Table 2.1** currently also use PFAS (see Section 2.2). It is still expected that some jobs lost will be displaced with new jobs created by manufacturers and users of inferior non-PFAS products, which would be considered distributional impacts.

Impacts on EU employment are closely linked to potential production halts and/or relocation of production outside the EU following a PFAS REACH restriction. As set out in the SEAC guidance on calculating costs associated with unemployment (SEAC, 2016), it is assumed that increases in unemployment, due to a restriction on the use of specific chemicals, will be temporary as resources will be redeployed to the production of other goods and services after a certain period of time. The SEAC approach thus accounts for the distributional effects.

The first step in calculating impacts on employment is to model how the number of people employed at the different levels of the value chain develop over time. The underlying assumption used for these projections is that the number of people employed will grow in line with the market for the products covered within this SEA (see Section 2.5.5). To derive the number jobs at risk it was further assumed that the job losses will occur during the period of production halts (see Section 4.3). The first column in **Table 4.3** below shows the projected number of people employed.

It has not been possible to extrapolate the employment of Gore's direct supply chain to other companies manufacturing similar products. This is because the location of production sites and suppliers of competitors is not known to Gore, and there might be some overlap in the customer base which could lead to double counting.

The industrial downstream user base is assumed to be shared between all manufacturers of products similar to Gore's, hence no extrapolation has been carried out. Gore's customers, alone, are believed to employ around 545,000 employees. It is not realistic to assume that all the employees working for Gore's customer will be at risk of losing their job, although a large share will be at risk due to production halts. As a conservative approach it has been assumed that only 10% of Gore's customers are at risk of losing their jobs if PFAS can no longer be used for the products covered within this SEA.

[redacted]

[redacted]

Table 4.3: Summary of employment impacts in the EU

[redacted]		[redacted]	[redacted]	[redacted]
[redacted]				
[redacted]				
[redacted]				
[redacted]				

[redacted]

As shown in Section 2.5, the wider impacted industry is broader than what has been possible to capture in this section indicating that the knock-on employment effects may be even higher.

Energy supply

Cable coatings containing PFAS protect products against harsh chemicals, which allows these cables to reliably function in harsh environments such as during the exploration and extraction of oil. Although there is a move to transition to renewable energy sources, oil remains an important part of the EU's energy mix making up approximately 35% of energy consumption in 2020 (Eurostat, 2020). Maintaining a stable and cost-competitive supply of oil during the transition to green energy is crucial for the functioning of society. Society remains very reliant on oil for the likes of transport, industry and household use, affecting consumers and businesses alike (Eurostat, 2020).

The recent energy crisis in Europe (and globally) has put further pressure on the oil market, with the price of oil reaching $127 per barrel in March 2022, which was 21% above the earlier peak in 2012 (Bolton, 2022). Increasing energy prices is a wide-reaching issue, which will disproportionately impact smaller business and lower-income households that are less resilient to cost increases. Whilst global geopolitical issues have been the primary cause for the energy crisis, it highlights Europe's dependence on oil and the socioeconomic value in maintaining a stable supply chain and minimizing potential disruptions where possible. In addition, PFAS-containing products addressed in this SEA are critical to the nuclear energy and renewable energy sectors; loss of access to these products would have the potential to disrupt not only oil exploration and production, but also alternative energy sources including nuclear energy and renewable energy.

Semiconductor supply chain disruptions

Microwave / RF assemblies that contain PFAS are used in the measuring and testing of semiconductors. Semiconductors are an essential component within electronic devices, which enable advances in communications, computing, healthcare, military systems, transport, renewable energy (see above section on Energy supply), and numerous other applications. Without semiconductors there would be no vehicles, TVs, smartphones, computers, or many types of advanced medical equipment, and other everyday electronic items. All of these are of high importance for the functioning of the modern economy and society – the "Internet of Things" would be significantly disrupted if PFAS could no longer be used in products covered within this SEA. The recent semiconductor shortage, catalysed by the Covid-19 pandemic, has highlighted the socio-economic impact of semiconductor supply chain delays. For example, the automotive industry, which is reliant on semiconductors for key functions of a vehicle, has been forced to cut production and therefore reduce supply (J.P. Morgan, 2021). This has put increased upwards pressure on the price of vehicles for consumers given the shortage in supply. Vehicle prices have not only increased for new vehicles but they have also increased for used vehicles, since a shortage in supply of new vehicles has driven consumers to the used vehicle market (O'Kane, 2021). Once again, this highlights the impact of a semiconductor supply chain disruption on businesses and consumers.

4.5.2 Wider economic impacts

Sustainability and circular economy

Sustainability and circular economy goals strongly influence the EU economy. A circular economy is an economic model designed to minimise resource input, as well as waste and emission production. Two goals of the European Commission's Circular Economy Action Plan are to normalise sustainable products in the EU and to ensure less waste (European Commission, 2022). Electronic and telecommunications products made without PFAS will not offer the same chemical compatibility, operating temperature range, or cleanliness characteristics which provide high performance and durability against abrasion in many end-use applications. Products of lower quality and/or durability will increase energy use in downstream production processes, as well as being replaced more often, increasing resource use and generating additional waste. Cable coatings containing PFAS are able to extend product lifetime due to their capacity to protect against contaminants. Ceasing the use of PFAS in such products may, thus, negatively impact meeting the EU's sustainability goals. This increased waste will either need to be disposed of via landfill, incineration, or be recycled, which comes at a cost. Furthermore, replacing products more frequently due to using less durable products will also increase resource consumption and greenhouse gas emissions, which conflict the EU's 2050 strategy (EERA, 2022).

Macroeconomic

ECHA's Guidance on Socio-Economic Analysis recommends a consideration of the macroeconomic impacts caused by a restriction, including changes in competition within and outside the EU and changes to international trade (ECHA, 2008). The potential restriction is not expected to affect competition between EU and non-EU actors placing these products on the EU market, as both groups will have to comply with the restriction. However, the use of PFAS enables a high level of efficiency and safety in various electronic and telecommunication processes in the EU, helping industries remain internationally competitive (Wood, 2020). The competitiveness of the EU's downstream user industries may therefore be negatively affected, and there is a risk that non-EU companies (which can continue to use PFAS) will capture a larger share of the market.

Recycling

As noted in a Restriction Task Force note on the approach of DSs and Committees on recycling, a REACH

[redacted]

restriction on use by default also applies to recycled material (ECHA, 2020b). Accordingly, the note calls for DSs to consider how to treat recycled material in a restriction, while balancing the risks associated with continued use and the benefits of recycling (ECHA, 2020b).

Gore does not have specific data on downstream users' recycling of its electronics and telecommunication products. However, as mentioned in Section 2.4.3, (ChemService, 2021) estimated that around 95% of fluoropolymer products are incinerated (85%) or landfilled (10%), i.e., only a small share of the products are potentially recycled. Gore also believes that other factors, such as technical and economic barriers, are the drivers behind the low recycling rate rather than the presence of PFAS. A potential restriction of PFAS is therefore unlikely to significantly affect the recycling rate.

4.5.3 Distributional effects

As explained in Section 4.2.2, there will be a redistribution of sales profits from manufacturers using PFAS (i.e., all manufacturers of products similar to those in **Table 2.1**) to those manufacturing products using non-PFAS materials[19]. This will, however, take some time, as the downstream users will have to adapt their production process to account for the lower performance of the non-PFAS products. Similarly, there will be a decrease in employment from those manufacturers using PFAS and an increase in employment for those companies that make industrial cables without PFAS. Unemployment induced by a restriction of PFAS is thus expected to be temporary. The distributional nature of these impacts has been accounted for in the assessment of economic and social impact, where only the loss resulting from temporary production halts and unemployment have been quantified and monetised. Although, the electronics and telecommunications industries may be somewhat resilient to small-to-moderate changes, the SMEs within the supply chain might still be adversely affected. A risk is that smaller companies do not have the financial means for investments needed to transition to an alternative, nor withstand periods of production halts. The market therefore may become more concentrated among fewer, larger companies.

Without market restrictions, one would expect that the lower performing cables and cable assemblies without PFAS would be cheaper than the products manufactured using PFAS. The difference in price can be viewed as value downstream users put on increasing the quality of the products. Restricting PFAS will temporarily remove high-quality electronic and telecommunications products and increase demand for the lower quality products, allowing the manufacturers of the latter to increase the price of their products although the quality of the product remains the same. A price increase is also expected for products further down the value chain, if cost of substitution and/or adaptation of the production process will be reflected in the price, which means that the end-users would ultimately bear the costs.

A shortage of upstream products may also lead to increasing prices of consumer products. For example, if there is a shortage in supply of semiconductors and computer chips, this will result in higher product prices for computers, TVs, smartphones and other everyday electronic items.

[19] The non-PFAS products (e.g., cables) are not equivalent to products in Table 2.1, but rather products with lower performance

[redacted]

5 Comparison of costs and benefits

5.1 Introduction

This section collates and compares information on impacts from previous chapters. Section 5.2 presents the total quantified costs of restricting the use of PFAS in the products covered within this SEA and compares these with the emissions derived based on information from the DS. Section 5.3 discusses additional costs and benefits that could not be quantified, whilst Section 5.4 combines the results from the quantitative and qualitative analysis to assess and conclude on proportionality of a potential restriction on PFAS.

5.2 Comparison of quantitative impacts

As highlighted throughout Chapter 4, it has only been possible to (partially) quantify a few of the identified impacts, due to data limitations. This also extends to the calculations of emission and emission reductions, detailed in Section 2.5.3. A key aspect to highlight is that a conservative approach has been chosen throughout, in the sense that the monetised costs of a potential restriction have been underestimated and quantified emission reductions have been overestimated. It is not possible to determine the nature of, or monetise, potential impacts associated with a reduction in emissions and exposure to the PFAS used to manufacture products covered within this SEA. The minimum quantified costs of a potential restriction on the use of PFAS covered within this SEA are summarised in **Table 5.1**.

Table 5.1: Minimum quantified costs in the EU of a potential REACH restriction (no derogation)

[redacted]		[redacted]
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

[redacted]

For the comparison of costs and benefits, the minimum costs have been combined with the emission estimates from Section 4.4, to derive 'cost-effectiveness' estimates. Cost-effectiveness is calculated by dividing costs by emissions, then converting the estimates to €/kg which is the preferred unit for cost-effectiveness estimates.

The result, presented in **Table 5.2**, shows that despite taking a highly conservative approach, the cost per kg of PFAS emissions reduced is high – in the range of €10,900 – €29,300 per kg of PFAS emissions reduced.

[redacted]

Furthermore, recognising that PTFE and several other fluoropolymers meet the criteria for a PLC, the low potential risk associated with such emissions should also be taken into account when evaluating proportionality.

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			
[redacted]			

Notes:

1. Monetary values are given in 2022 prices and costs rounded to the nearest € million.
2. Emissions volumes have been rounded to the nearest tonne.
3. Cost-effectiveness is derived as follows: (3,793 x €1,000,000 / (130 x 1,000 kg) = 29,300. The same approach is used for both estimates.
4. Cost-effectiveness has been rounded to the nearest €100/kg.

5.3 Non-quantified impacts

Quantification and monetisation of all impacts associated with regulatory interventions are rarely, if ever, achievable. It has already been highlighted throughout previous chapters that it has only been possible to quantify and/or monetise a few select impacts. It is not always the case that the non-monetised effects are less important or have a smaller effect than the monetised impacts, which means that the conclusions of the analysis may be incorrect or inaccurate if non- monetised impacts are not assessed. To avoid this type of 'numbers' bias', a qualitative analysis of the non- monetised effects must be carried out.

Table 5.3 below sets out the non-monetised impacts and their potential effect on the acceptability of the monetised costs. For example, if a known but non-monetised effect is believed to increase the benefits of the restriction scenario, a higher cost per kg PFAS reduced would be more acceptable. The non-monetised effects are listed in the perceived order of importance and the type of impacts (cost/benefit) is indicated as follows:

- **(+)** indicates an increase in benefits or reduction in costs (of restricting the use of PFAS within this SEA), i.e., higher cost acceptability.
- **(-)** indicates an increase in costs or reduction in benefits, i.e., lower cost acceptability.
- **n/a** indicates that there is no or negligible effects on costs and benefits.

Table 5.3 shows that the vast majority of the identified non-monetised impacts will lead to increased costs, which reflects the conservative approach to cost estimation used throughout the analysis. This means that the estimated €/kg of a restriction would be even higher than those estimated in **Table 5.2**. The assessment of non-monetised impacts thus further strengthens the quantitative results presented in Section 5.2, showing that restricting the use of PFAS in products covered within this SEA will come at very high costs to society.

[redacted]

Table 5.3: Overview of non-monetised impacts in the EU and their overall effect on the cost acceptability

Impact	Description of impacts associated with restricting the use of PFAS in products covered by this SEA	Effect on net benefits/costs
Impacts of PFAS on human health and the environment from reduced exposure to PFAS from products in this SEA	The purpose of implementing a restriction on PFAS is to avoid potential adverse impacts on the environment and human health from exposure to PFAS. Because fluoropolymers are not mobile, bioaccumulative or toxic, it is not clear that a restriction of these substances would create a significant positive impact on human health or the environment.	
Employment	Impacts on employment has only been quantified for Gore and Gore's direct customers, and it was further assumed that only 10% of the jobs at Gore's customers sites are at risk. Considering that Gore only comprises 2% of the EU, the exclusion of downstream user employees for the wider market is believed to significantly underestimate the costs.	**(-)**
Investment costs for downstream users	Since the non-PFAS cables and assemblies will not be identical to the products containing PFAS, minor or fundamental changes in the downstream industrial users' production processes are anticipated, which is expected to induce significant costs. These costs could include altering existing equipment or purchasing new equipment that is suitable to the non-PFAS products being used.	**(-)**
Lost profits for downstream industrial users	In the estimation of lost profits to downstream users (Section 4.3.4) only some downstream industries have been included, and it was conservatively assumed that only 1% of the sales within this industry would be affected and that the profit margins were only 50% of that of Gore and similar manufacturers. It is believed that a larger set of industries would be impacted, and the share sales affected could be significant in many of these. This omission may therefore underestimate the costs of the restriction.	**(-)**
Costs to downstream users of product and process performance testing	When switching to different non-PFAS cables and assemblies, companies will likely need to make sure they acquire product and regulatory approval to use different products. Downstream users will incur costs associated with performance testing of new products and production processes to ensure that the non-PFAS alternatives can operate in the harsh environments in which these products are used.	**(-)**
Maintenance and replacement costs for downstream users	PFAS-containing electronics and telecommunication products are more durable than their non-PFAS counterparts. PFAS-containing products are used in business to business (B2B) capital equipment applications that demand robust materials to avoid premature failure. If these products were not available, downstream manufacturers would be forced to use lower-performing cables and assemblies that would need to be replaced more frequently, resulting in costs (time and money)	**(-)**

[redacted]

Impact	Description of impacts associated with restricting the use of PFAS in products covered by this SEA	Effect on net benefits/costs
	associated with repairs or replacements (e.g., equipment needing to be repaired or replaced more often). As explained in Section 4.3.4, fluoropolymers may provide significant savings for downstream users increasing the product lifetime, which has not been possible to include in the total cost estimates.	
Health and safety fire risks to workers	Fluoropolymers enable improved fire safety, reliability and performance of cables due to their high dielectric properties, high heat resistance and fire resistance (Fluoropolymer Product Group of PlasticsEurope, 2017). The use of lower performing non-PFAS cables in downstream industries could increase the risk of fire hazards and create health and safety risk for workers.	**(-)**
Public health risk from exposure to nuclear waste	Cables containing PFAS support appropriate processing of nuclear waste. Reducing the reliability and performance of nuclear waste processing tools could increase the risk of nuclear waste leaks and consequently increase the public health risk associated with radiation poisoning.	**(-)**
GHG emissions from a reduction in nuclear energy generation	The EU depends on nuclear power for one-quarter of its electricity and half of its low-carbon electricity. Cables containing PFAS support appropriate processing of nuclear waste. Processing this waste safely is crucial in public acceptance of nuclear energy generation and in reducing the investment risk associated with developing a nuclear power plant. Both aspects, namely public acceptance and financial investment are crucial in ensuring that nuclear power plants continue to be developed or are not decommissioned prematurely in the EU and continue to provide the EU with a source of zero emission energy.	**(-)**
Worst-case sensitivity emissions assumptions	The worst-case sensitivity emissions are, in addition to being based on upper bound emission factors, based on an extreme assumption that all products being placed on the EU market will also be manufactured in the EU. This is clearly an unrealistic assumption, which is why the resulting emissions are considered a worst-case sensitivity. This does, however, not affect the realistic worst-case emissions.	**(-)**
Emission factors covering a broader set of products	As explained in Section 2.5.3, emissions estimated at the EU level has been carried out using emission factors for a broader set of products that are not fully representative for the products within this SEA. Gore upholds that there are negligible emissions from their products throughout the product life cycle and believes therefore the same should hold for similar products placed on the market. This means that using the emissions factors for the broader product group will likely significantly overestimate the emissions.	**(-)**
Temporary production halt of downstream user products	If downstream users are not able to redesign and change their production processes to fit the lower performing electronics and telecommunication products by the end of the transition period, there is a risk of temporary production halt for products relying on PFAS-containing cables and assemblies. The EU industrial base, such as the chemical industry, mining	**(-)**

[redacted]

Impact	Description of impacts associated with restricting the use of PFAS in products covered by this SEA	Effect on net benefits/costs
	industry and electronics sector, would then be faced with disruptions, the duration of which is difficult to predict.	
Temporary shortage of supply of cables and assemblies	Due to the unique properties of PFAS, it is believed that the majority of high-performing cables and assemblies included in this assessment contain PFAS. Therefore, it is likely that there will be a temporary shortage of non-PFAS cables and assemblies in the EU, until the production capacity for non-PFAS products is able to meet the market demand. This would impact the products manufactured by downstream industrial users of such as the chemical industry, mining industry and electronics sector, and could lead to a temporary shortage of the products manufactured by these industries within the EU or could lead to the import of such products at an elevated cost.	**(-)**
Habitat and biodiversity impacts from nuclear waste leaks	Cables containing PFAS support appropriate processing of nuclear waste. Reducing the reliability and performance of nuclear waste processing tools could increase the risk of nuclear waste leaks. A nuclear waste leak would have a damaging impact on animal and plant life, including causing cancerous growths and genetic problems for multiple generations.	**(-)**
Resource consumption of raw materials and waste	If cables and assemblies without PFAS are less durable, this will result in more resources being used to manufacture replacements (parts). This is an inefficient use of resources as well as contributing to increased energy and emissions from increased production. Higher consumption of cables and cable assemblies would consequently increase the amount of waste generated during product manufacturing and at product end-of-life, which will have to be managed via, for example, either incineration or landfill. Landfill sites may generate emissions and may also impact the surrounding environment and biodiversity. The EU has introduced the WEEE Directive and the RoHS Directive to tackle the issue of the growing amount of WEEE. One of the primary priorities of these Directives is to prevent the creation of WEEE (European Commission, n.d.). This is achieved by extending product use life.	**(-)**
Semiconductor supply chain disruptions	Microwave / RF assemblies that contain PFAS are used in the measuring and testing of semiconductors. Semiconductors are an essential component within electronic devices, which enable advances in communications, computing, healthcare, military systems, transport, renewable energy, and numerous other applications. As has been demonstrated in the recent semiconductor shortage, a supply chain disruption can have negative socioeconomic impacts on businesses and consumers, creating delays and increasing consumer prices.	**(-)**
Further increased profits for manufacturers of inferior alternatives	The increased profits of manufacturers of inferior alternatives are already included in the approach set out in the SEAC guidance on assessing changes in consumer surplus loss (SEAC, 2021). However, if downstream users are able to transition to alternatives earlier than 4 years, the increased profits for manufacturers of such alternatives may be higher.	**(+)**

[redacted]

Impact	Description of impacts associated with restricting the use of PFAS in products covered by this SEA	Effect on net benefits/costs
Exclusion of manufacture in reasonable worst-case emissions	The reasonable worst-case emissions were derived using the DSs' emission factors for service life and EoL but excludes potential emissions from manufacture of products. According to Gore, who has first-hand knowledge of the manufacturing process and emission from the specific group of products contained in this SEA, the emissions from manufacture of these types of products are negligible, and the overestimation of emissions from service life and EoL will by far outweigh the omission of emissions from manufacture. This will not affect the worst-case sensitivity emissions, as these are derived by assuming that all manufacture and potential emissions will occur in the EU.	**(-)**
Exclusion of PFAS imported through indirect sales	As explained in Section 2.3.1, some customers of manufacturers of products covered within SEA (that contain PFAS) that are located outside the EU may in some instances import the products to the EU market (e.g. if the customers are distributors). This will lead to a higher volume of PFAS ending up on the EU market that is not captured through direct sales to EU customers. Gore sells their products directly to OEMs (which use rather than sell the products in question) and there are no indications that products sold to OEMs outside the EU will enter the EU market. It is therefore considered unlikely that significant volumes of PFAS enters the EU market through indirect sales.	**(+)**
Costs for suppliers	If some PFAS suppliers are able to start manufacturing or supplying alternative substances or materials, this will involve R&D, investments and/or operational modifications. New equipment or production plants may be needed, whilst for importers it is likely that they will have to find new suppliers. The prices of the alternative substances or materials will likely be inflated (i.e., more costly), as new production capacity will be needed in order to meet the new demand.	**(-)**
Increase in product and regulatory costs	Downstream industrial sectors affected (e.g., nuclear waste processing) will need to ensure continued compliance with regulatory requirements and meet industry standards. New regulatory approvals will likely be needed if products or production processes change.	**(-)**
Security of energy supply	Cable coatings containing PFAS protect products against harsh chemicals, which allows these cables to reliably function in harsh environments such as during the exploration and extraction of oil. Although there is a need to transition to renewable energy sources, oil remains an important part of the EU's energy mix making up approximately 35% of energy consumption in 2020 (Eurostat, 2020). Maintaining a stable and cost-competitive supply of oil during the transition to green energy is important to the functioning of society, as has been highlighted with the recent energy crisis in Europe. A disruption in the supply chain for cables used in oil exploration and extraction could therefore have negative socioeconomic impacts.	**(-)**

[redacted]

Impact	Description of impacts associated with restricting the use of PFAS in products covered by this SEA	Effect on net benefits/costs
Change in environmental service costs, such as waste treatment and disposal services	If industrial cables and assemblies without PFAS are less durable, this will also result in more waste being produced at the end-of-life stage (volume basis). This increased waste will either need to be disposed of via landfill, incineration, or be recycled, which comes with waste management treatment costs to downstream industrial users.	**(-)**
Macroeconomic impacts and changes in EU competition	The use of PFAS enables a high level of efficiency and safety in various electronics and telecommunication manufacturing processes in the EU, helping industries remain internationally competitive (Wood, 2020). The competitiveness of EU's downstream user industries may therefore be negatively affected, and there is a risk that non-EU companies (which can continue to use PFAS) will capture a larger share of the market.	**(-)**
Ecological and biodiversity impacts from increased waste.	If cables and cable assemblies without PFAS are less durable, this will also result in more waste being produced at the end-of-life stage, therefore increasing the amount of waste disposed of in landfill. Landfill sites may not only generate emissions and increase air pollution (covered above) but also impact the surrounding environment and biodiversity. However, this impact is expected to be small compared to other non-quantified impacts.	**n/a**
Recycling	It is believed that the low recycling rate for fluoropolymer products (<5%) is driven by technical and economic barriers rather than the presence of PFAS. It is therefore considered unlikely that a restriction on PFAS will significantly affect the recycling rate	**n/a**

5.4 Proportionality assessment

The socio-economic analysis clearly shows that restricting (and not granting a derogation for) the use of PFAS in products similar to those in **Table 2.1** will have large and wide-reaching impacts on the EU. The adverse impacts induced by a potential restriction includes significant economic impacts throughout the value chain, impacts on employment (lost jobs) as well as adverse impacts on human health and the environment.

The estimated reasonable worst-case emissions are ~130 tonnes/year. The types of PFAS used by Gore meet the Polymer of Low Concern (PLC) criteria and PFAS used in similar products manufactured by other companies are also believed to meet the PLC criteria. It is therefore not clear that a restriction would create a significant positive impact on human health or the environment.

The cost-effectiveness (CE) estimates, based on reasonable worst-case and worst-case sensitivity emissions combined with minimum costs, are estimated at €10,900 - €29,300 per kg of PFAS emissions reduced. This means that the benefits of a potential restriction would need to be high to outweigh the costs.

A CE estimate does not, in itself, indicate whether benefits (costs) of a restriction outweigh the costs (benefits). For cases where risks and impacts of reducing exposure to a substance are unknown, it is common to compare the cost-effectiveness estimates with some type of benchmark. A study by Oosterhuis et al., (2017) found that for PBTs, vPvBs and substances with similar properties (e.g. lead) emission reduction measures with a cost-effectiveness below €1,100[20] per kg emission reduced were generally not rejected due to costs i.e., the costs were found to be proportionate. Measures with costs above €56,400[21] per kg, on the other hand, were more likely to be rejected, i.e., costs at this level were found to be disproportionate. Costs in between could be either proportionate or disproportionate – a so called 'grey zone' (Oosterhuis et al., 2017).

The Oosterhuis benchmarks (BMs) have been used for the assessment of a number of regulations of PBTs and vPvBs, which are substances of very high concern (SVHCs). These BMs are, however, not necessarily applicable to substances of low concern such as PTFE and other PLCs. The reasoning behind this is that the implied willingness to pay (acceptability of costs) would be higher, the higher the perceived risk of a specific substance.

If the Oosterhuis BMs are to be used for substances of low concerns, it is reasonable to make some indicative, quantitative or qualitative, adjustments. For example, if the 'grey zone' for a PBT ranges from €1,100 – €56,000 per kg PBT emission reduced, it is reasonable to assume that the upper bound (and likely also the lower bound) would be significantly lower for substances of low concern. For the purpose of this SEA, a grey zone of €1,000 – €10,000 per kg emissions reduced will thus be used for illustrative purposes, alongside the original BMs.

[20] €1,000 in original study, uplifted to 2022 prices
[21] €50,000 in original study, uplifted to 2022 prices

[redacted]

Table 5.4 shows the comparison between the midpoint[22] CE estimate derived for a restriction on the use of PFAS in the products within this SEA and the Oosterhius and (illustrative) adjusted BMs. The midpoint cost-effectiveness is over 18 times higher than both lower bound BMs, i.e., is unlikely that these costs would be deemed proportionate. The costs are also twice the size of the upper bound adjusted benchmark, whilst it is lower (comprising around 40%) than the upper bound Oosterhuis BM. As emphasised above, it is not realistic to believe that the upper bound Oosterhuis BM is appropriate to use for PLCs, as it was intended to reflect society's willingness to pay to remove SVHCs. It should also be highlighted that it is believed that the costs (in particular employment impacts) are significantly underestimated, and the emissions (average of the realistic worst-case emissions and the worst-case sensitivity) is very conservative. It is therefore deemed likely that not derogating the products within this assessment would lead to disproportionate costs.

Table 5.4: Cost-effectiveness in the EU and benchmark comparison

Upper bound BM (€/kg)	Lower bound BM (€/kg)	Upper bound BM (€/kg)	Midpoint cost-effectiveness (€/kg) used for comparison	How many times higher is the CE compared to lower bound BMs	How many times higher is the CE compared to upper bound BMs
Oosterhuis et al.	1,100	56,400	20,100	18	0.4
Illustrative adjusted benchmarks	1,000	10,000		20	2

Notes: Monetary values are given in 2022 prices and rounded to the nearest €100/kg.

There are uncertainties associated with all parts of the analysis and a multitude of impacts could not all be quantified and/or monetised. However, due to the consistent conservative approach taken it is believed that the most significant non-quantified impacts, described in detail in **Table 5.3**, are costs of a possible REACH restriction and would further strengthen the conclusions from the quantitative analysis. Therefore, it is concluded that restricting the use of PFAS in products covered within this SEA (i.e. no derogation) will result in disproportionate societal costs for EU.

[22] The midpoint cost-effectiveness (€20,100/kg) was derived by taking the midpoint between cost-effectiveness derived using the reasonable-worst case emission estimate (€29,300/kg) and the worst-case sensitivity estimate (€10,900/kg).

6 Conclusions and recommendations

PFAS-containing cables and cable assembly products support a multitude of electronic and telecommunication end use applications, where small and flexible cable assemblies can transmit increasing amounts of data and power in harsh environments exposed to low pressures, broad temperature ranges, continuous rapid flexing, and harsh chemicals.

There are currently no non-PFAS alternatives on the EU market with comparable performance to these products. While Gore and semiconductor equipment companies have performed trade studies and invested in non-PFAS alternatives, Gore upholds that no suitable alternatives are likely to be found in the foreseeable future. If PFAS-containing cables and cable assembly products become unavailable as a result of a restriction of PFAS, downstream users will need to modify their processes and products to compensate for reduced performance such as changes in cleanliness, flexibility, performance, and durability of cables made without PFAS. Furthermore, they will need to acquire product and regulatory approval to use different products until non-PFAS products have been found. This will induce costs of R&D, investments, testing, and regulatory approvals, to mention a few, resulting in significant costs for these downstream users. If downstream users are not able to redesign and change their production processes to fit the lower performing electronics and telecommunication products, there is a risk of temporary production halts for products relying on PFAS-containing cables and assemblies. The EU industrial base, such as the chemical industry, mining industry and electronics sector, would then be faced with significant disruptions, the duration of which is difficult to predict.

The cost-effectiveness of a potential restriction for the use of PFAS within the products covered by this assessment is believed to be at least €10,900 - €29,300 per kg of PFAS emissions reduced, which means that the benefits of a potential restriction would need to be high to outweigh the costs. The substances involved are not mobile in the environment, are demonstrated to be non-toxic and extremely stable, and are also identified as PLCs. This, combined with the conservative approach taken throughout the analysis, indicates that the costs of restricting the use of PFAS within the products covered by this assessment will likely outweigh any benefits.

There are uncertainties associated with all parts of the analysis and a multitude of impacts could not all be quantified and/or monetised. However, due to the consistent conservative approach taken it is believed that the non-quantified impacts lead to net additional costs of a possible REACH restriction and would, therefore, further strengthen the conclusions from the quantitative analysis.

Considering the lack of any suitable alternative to PFAS, combined with the significant economic and social costs as well as adverse impacts to human health and the environment of using inferior alternatives, it is believed that a derogation is justified for the products covered within this SEA.

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Appendix 1 PFAS volumes and emissions across multiple sectors

The DSs published a series of "*investigation report summaries*" in 2021 (National Institute for Public Health and the Environment (RIVM) et al., 2021), where they presented currently available information on the use of PFAS within different sectors which was gathered through a Call for Evidence in 2020 and supplemented with desk-based research. This information has been summarised in:

- Section A1.1: PFAS manufacture
- Section A1.2: Use of PFAS Use of PFAS
- Section A1.3: End-of-life of products containing PFAS; End-of-life of products containing PFAS
- Section A1.4: Emissions of PFAS

Disclaimer

The information summarised below is solely based on information published by the DS in their "investigation report summaries" (National Institute for Public Health and the Environment (RIVM) et al., 2021). The below text includes information presented in all the "investigation summaries", with varying applicability to this SEA. Where the information has been used, this is clearly stated in the main text of the report.

This summary is not an endorsement of the validity nor applicability of the information gathered by the DS, but it is included for completeness and transparency reasons.

A1.1 PFAS manufacture

The production of PFAS is the first stage in the lifecycle of PFAS where PFAS is produced (see **Figure 2.3**). **Appendix Table 1** details the estimated volume of PFAS produced in the EEA annually according to each PFAS group. Responses to the Call for Evidence survey elicited a wide range of tonnage data, and hence a literature review was used to corroborate the average tonnages of each PFAS manufactured and processed in the EEA.

Appendix Table 1 PFAS and PFAS polymer production in the EEA

PFAS Group	PFAS manufactured/processed in the EEA (tonnes/year)		
	Minimum (Consultation)	Realistic estimate (literature review)	Maximum (Consultation)
Fluoropolymers	49,458	51,000	101,763
Remaining PFAS	53,902	85,977	118,051
Total	**103,360**	**136,977**	**219,814**

Source: National Institute for Public Health and the Environment (RIVM) et al. (2021)

Notes

1. The minimum and maximum estimates were based on companies' responses to a survey sent by the DSs. Some companies reported exact figures, while others reported ranges. The lower and upper estimates reflect the lower and upper ranges. In

some cases, companies reported tonnage data as "greater than x", with no upper bound included (e.g., "> 1,000 tonnes"). Therefore, the "upper estimate" column is not a true maximum value.

2. It should be noted that the volume of F-gases, including hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), manufactured in the EEA were estimated in the 'PFAS and PFAS polymer production' report published by the DSs (National Institute for Public Health and the Environment (RIVM) et al., 2021). F-gases have not been included in the production tonnages reported in this table as the registry of restriction intentions for PFAS has been amended to exclude F-gases.

Fluoropolymers make up the second largest proportion of PFAS produced in the EEA. The main fluoropolymers produced for commercial and industrial use are polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF), as well as fluoroethylene propylene (FEP). Ethylene-tetrafluoroethylene (ETFE), perfluoroalkoxy (PFA) and polyvinylfluoride (PVF) follow in terms of volume, whilst perfluoropolyether (PFPE) is a minor use, used mainly for lubrication.

The 'remaining PFAS' category, are defined as PFAS that is neither a fluoropolymer nor an F-gas[23]. This represents the largest category of PFAS produced in the EEA. This group includes perfluoroether non-polymers with unsaturated bonds. These are the monomers that form the fluoropolymers found in the fluoropolymer group mentioned above. Another group of substances included in this group are perfluoroether non-polymers with only saturated carbon bonds. Information on this PFAS category has been included for completeness but is not relevant to this SEA.

A1.2 Use of PFAS

The "*investigation report summaries*" published by the DSs estimated the volumes of PFAS used in products manufactured for a number of different sectors, which are summarised in **Appendix Table 2**. The total use of PFAS across all sectors have been calculated as part of this SEA. It has been highlighted that the volumes are likely underestimated as the DS did not have access to a complete dataset for volumes of PFAS used in the EEA/EU.

The estimates show that the 'transportation' sector uses the highest volume of PFAS in the EEA. This sector includes the automotive, shipping, aviation and railway sectors and the use of PFAS in these sectors range from sealing applications to lubricants, fire prevention and protection and HVCAR-systems (including F-gases). A large number of PFAS-containing products in the transportation sector are products which are subjected to harsh conditions like exposure to seawater, heat, UV-radiation or aggressive chemicals. In other cases, PFAS in products are necessary for a defined performance like in firefighting foams or as part of fuels and lubricants (National Institute for Public Health and the Environment (RIVM) et al., 2021). The transportation sector therefore encapsulates a broad range of sub-sectors which require the use of PFAS given the harsh conditions in which the products are used.

[23] Data on the volume of F-gases manufactured in the EEA were also published by the dossier submitters but these volumes have not been reported in this SEA based on a change in the registry of restriction intentions for PFAS which now excludes F-gases (ECHA, 2022).

[redacted]

Appendix Table 2 Estimated volume of PFAS used per sector in the EEA

Sector covered by RMOA		Volume of PFAS (tonnes/year)			Proportion of total volume (%)
		Low	High	Midpoint or average	
Cleaning agents, polishes, and waxes (non-industrial uses)		No volume data reported			
Construction products		4,203	9,197	6,698	<1%
Cosmetics		No volume data reported			
Electronics and energy		2,600	6,200	4,300	<1%
Food contact materials and packaging		7,327	11,462	9,395	<2%
Lubricants		4,820	4,820	4,820	<1%
Medical Devices		1,500	14,000	8,900	<2%
Medicinal products (active pharmaceutical ingredients, diagnostics, anaesthetics, and intermediates)	ECHA[4]	26,000	57,000	42,000	<9%
	Call for evidence	5,000	17,000	11,000	-
Metal plating and manufacturing of metal products		960	960	960	<0%
Petroleum and mining		3,671	7,671	5,671	<1%
Ski treatment		No volume data reported			
Textiles, Upholstery, Leather, Apparel and Carpets (TULAC)		41,183	142,694	91,939	<20%
Transportation [5]		295,234	295,234	295,234	<63%
Total volume used across all sectors		**>387,498**	**>549,238**	**>469,916**	

Source: National Institute for Public Health and the Environment (RIVM) et al. (2021)

Notes:

1. The "Midpoint or average" column lists the midpoint values provided in the '*investigation report summaries*' and, where no midpoint was reported the average volume estimated from the high and low volumes.
2. For sectors where only a single value for PFAS volumes was provided, this was used for the low, high and average volumes of PFAS.
3. The ECHA figure for the volume of PFAS in medicinal products was used in estimating the total, as opposed to the call for evidence figure.
4. The ECHA estimate for the volume of PFAS used in medicinal products is assumed to be higher than the volume estimated via the call for evidence (CfE) because only a selection of companies responded to the CfE, and companies may not have recognised their use of PFAS as medicinal.
5. PFAS volumes used in Transportation are given for the EU as opposed to the EEA.
6. These PFAS volumes include all types of PFAS, beyond those relevant to this SEA.

The end-use industries for which the Gore products detailed in this SEA (i.e. those listed in **Table 2.1**) are used include chemical manufacturing, defence, electronics, electrical equipment, mining and quarrying, and semiconductors, and telecommunications equipment (as detailed in Section 2.2.2). These are broadly related to the construction products, electronics and energy, metal plating and manufacturing of metal products and petroleum and mining sectors included in **Appendix Table 2**. The volume of fluoropolymers used in the petroleum and mining sector "investigation report summaries" have been extrapolated and applied in Section 2.5.3.

A1.3 End-of-life of products containing PFAS

The DSs also collected and published data on the fate of PFAS in several selected waste streams. The most relevant waste streams for PFAS were selected according to a set of criteria that identified the waste streams likely to have high volumes of PFAS and significant emission risks during waste treatment and/or recycling. This led to the following wastes being chosen for further analysis:

- Textiles
- Food contact material (paper and board)
- End-of-life-vehicles (ELV)
- Electrical and electronical equipment and
- Sewage sludge

Appendix Table 3 details the volumes of PFAS found at the end-of-life of end-use products, whether disposed and recovered, in each waste stream. These volumes have been estimated and reported by the DS. The "*investigation report summaries*" reported estimating the amount of PFAS in each waste stream according to the concentration of PFAS in that waste stream and the amount of waste generated in that stream.

Appendix Table 3 Total amount of PFAS ending up in waste annually in the EEA per use category

Selected waste	**Relevant waste stream**	**Total amount of PFAS (tonnes/year)**	
		Disposal (i.e. landfill, incineration, etc.)	Recovery (i.e. recycling, energy recovery, backfilling, etc.)
Textiles[1]	Textile waste	783	7,310
	Household and similar waste	4,949	9,348
	Healthcare and biological waste (medical textiles)	176	133
Food contact material (paper and board)	Paper and cardboard wastes	1	2,230
	Household and similar waste excluding bulky waste in EEA	470	817
End-of-life-vehicles (ELV)	Shredder light fraction (SLF)	7	1
	Shredder heavy fraction (SHF)	0	0.8
Waste electrical and electronic equipment	WEE	Unknown	
Sewage sludge	Sewage sludge from urban	0.2	0.2 [2]

[redacted]

Selected waste	Relevant waste stream	Total amount of PFAS (tonnes/year)	
		Disposal (i.e. landfill, incineration, etc.)	Recovery (i.e. recycling, energy recovery, backfilling, etc.)
	wastewater treatment		
Total emission from waste across the specified use categories		**6,387**	**19,853**

Source: National Institute for Public Health and the Environment (RIVM) et al. (2021)

Notes

1. Not all TULAC (textiles, upholstery, leather, apparel and carpets) could be considered within this analysis, as no information on treatment of technical textiles and "other" is available.
2. Recovery for sewage sludge includes agricultural use and compost and other uses.

Discarded textiles, whether disposed or recovered, have the highest volume of PFAS found in waste streams of all the product categories assessed by the DSs. Within the textiles waste stream, household and similar wastes (which includes home textiles, consumer apparel and professional apparel) make up the largest volume of PFAS found in textile waste. This is in line with volume of textiles discarded on an annual basis. For example, the average consumer today buys 60 percent more clothing than 15 years ago, but individual items are kept only half as long (United Nations Environment Programme (UNEP), 2019).

Waste Electrical and Electronic Equipment (WEEE) represents the fastest-growing waste stream in the world (World Economic Forum, 2019), but data on the volumes and concentration of PFAS in (WEEE) waste stream is unavailable.

A1.4 Emissions of PFAS

Section A1.1 to Section A1.3 detailed the volumes of PFAS used at different stages of the PFAS life cycle and across different sectors in the EEA. The "*investigation report summaries*" published by the DSs in 2021 (National Institute for Public Health and the Environment (RIVM) et al., 2021), also include information on the PFAS emitted at each stage of the life cycle. These emissions and emission factors have been summarised in this section.

Caveat: *It should be noted that whilst the data presented in this Section highlights general PFAS emissions and the effectiveness of different waste treatment methods in removing PFAS, these are <u>not</u> representative for the products included in this SEA. Even though these emissions are significantly higher than the emissions reported by Gore, they are – following a conservative approach – used as basis for this SEA.*

A1.4.1 PFAS emissions from PFAS manufacture

The emission factors to air and water from the manufacture of PFAS in the EEA were estimated by the DSs and are provided in **Appendix Table 44**. These emission factors were derived based on information on emission to air and water from survey respondents, which included some of the biggest producers and processors of PFAS in the EEA. We then extrapolated these emission factors for this SEA and multiplied the total volume of PFAS produced and processed per year (estimated by the DSs and detailed in **Appendix Table 1**) by the emission factors provided in **Appendix Table 44**. The emission factors represent the percentage of PFAS which is released to the environment when a certain amount of PFAS is being manufactured or processed (National Institute for Public Health and the Environment (RIVM) et al., 2021). The DSs did not consider direct emissions to soils relevant for industrial settings.

As can be seen in **Appendix Table 44** emissions during PFAS production make up a very small proportion of the total amount of PFAS produced. For the uses in this assessment, Gore purchases fluoropolymer resins from suppliers, therefore PFAS production is not covered. The information on PFAS production published by the DSs has been reported for completeness.

Appendix Table 44 Average emission factors and average emissions to water and air from PFAS production for each PFAS group in the EEA

PFAS Group	Average emission factors (%)		Total emissions from PFAS production in the EEA (tonnes/year)	
	Emissions factor to water	Emissions factor to air	Emissions to water (estimated)	Emissions to air (estimated)
Fluoropolymers	0.01%	0.02%	5	10
Remaining PFAS	0.04%	0.06%	34	52
Total			**39**	**62**

Source: *National Institute for Public Health and the Environment (RIVM) et al. (2021)*

Notes:

1. The total emissions from PFAS production have been estimated by multiplying the total volume of PFAS produced (average value used) in the EEA by the emission factors.
2. The "investigation report summaries" do not provide any information on the use of emission control technologies and hence it is unknown whether the emission factors reported by the DSs include the use of emission abating technologies.

A1.4.2 PFAS emissions from product manufacture and use

PFAS emissions during the manufacture and use of PFAS-containing products varies between sectors. These emissions have been estimated and reported in the "*investigation report summaries*" published by the DSs for several different sectors (National Institute for Public Health and the Environment (RIVM) et al., 2021) and are summarised in **Appendix Table** 55. The emissions reported in in **Appendix Table** 55 include emissions from all types of PFAS and are therefore not reflective of the fluoropolymer emissions covered in this SEA.

Appendix Table 55 PFAS emissions from product manufacturing and product use per sector in the EEA

Sector covered by RMOA	PFAS emissions (tonnes/year)			Proportion of total emissions across product manufacturing and use (%)
	Product manufacturing	Product use (service life)	Product manufacturing and use	
Cleaning agents, polishes, and waxes (non-industrial uses)	Unknown			
Construction products	608	796	1,404	5%

[redacted]

Cosmetics	-	12	12	0%
Electronics and energy	740	21	761	3%
Food contact materials and packaging	8,293	72	8,365	28%
Lubricants	50	170	220	1%
Medical devices [3]	4,290	1,300	5,590	19%
Medicinal products (active pharmaceutical ingredients, diagnostics, anaesthetics and intermediates) [3]				
Metal plating and manufacturing of metal products	Unknown			
Petroleum and mining	732	879	1,610	5%
Ski treatment	0.0	0.9	0.9	0%
Textiles, Upholstery, Leather, Apparel and Carpets (TULAC)	7,520	3,998	11,518	39%
Transportation	Unknown			
Total	**>68,243**	**>7,278**	**>75,521**	**100%**

Source: National Institute for Public Health and the Environment (RIVM) et al. (2021)

Notes

1. The petroleum and mining sector and the TULAC sector provided emissions as a range (low and high estimates). The emissions reported in this table are an estimated average (midpoint) between these low and high emission estimates.
2. Emissions from the manufacture and use of medical devices and medicinal products were provided in a combined table in the "*investigation report summaries*".
3. 'Medicinal products' comprise active pharmaceutical ingredients, diagnostics, anaesthetics and intermediates. The data provided on PFAS emissions from manufacturing and use of medical devices and medicinal products was unclear and therefore has an additional layer of uncertainty. These emissions have however been reported in good faith.
4. The emissions reported include emissions from all PFAS types as opposed to the types of PFAS relevant to the products covered by this SEA. These emissions are therefore not reflective of the emissions covered in this SEA but have been reported for completeness.
5. The emissions reported are emissions to air and water. The emissions from waste are reported in Section A1.4.3.

As shown in **Appendix Table** 55, the textiles sector has the highest PFAS emissions (of the sectors that data is available for) at both the product manufacturing and use stages. This is expected given that the sector is the second-highest user of PFAS by volume, behind the transportation sector, for which emissions data is not currently available.

In Section 2.5.3 the volumes and emissions from the manufacture and use of fluoropolymer products in the electronics and energy "*investigation report summaries*" were used to estimate an upper bound emission factor for the products covered in this SEA. The emissions reported in **Appendix Table** 55 include the emissions from all types of PFAS and hence does not distinguish between the emissions from each type of PFAS, which vary greatly. The emissions in **Appendix Table** 55 have therefore been reported for completeness but are not reflective of the emissions associated with the products in this SEA.

Across most sectors, the majority of PFAS emissions occur during product manufacturing (i.e. when PFAS is used to make products). Overall, only 25% of the total emissions across these two stages of the life cycle occur during product use (i.e. service life). It can be observed that the products that are fully consumed, such as lubricants and ski treatment, generate the majority of their emissions during the use stage. For example, within the ski treatment sector, most emissions are likely to occur during the application of ski-wax and skiing (i.e. use stage) where the DSs assume that 100% of the wax applied is lost to the environment through erosion of the wax (National Institute for Public Health and the Environment (RIVM) et al., 2021).

A1.4.3 PFAS emissions from product end-of-life

The DS also estimated total PFAS emissions to air, water, and soil from three waste streams, namely landfill, incineration, and wastewater treatment in the EEA (National Institute for Public Health and the Environment (RIVM) et al., 2021).

For products disposed of via **landfill** the DS assumes that, over time, 100% of PFAS will eventually end up in the environment. This is based on an assumption that contaminants are not destroyed by the storage on a landfill site and will over time be washed out via rain or desorption processes. This assumption does not reflect the landfill emissions associated with PTFE, which is the type of PFAS covered in this SEA. As detailed in Section 2.5.3, landfilling of PTFE products are not expected to contribute to emissions associated with landfill leachate since PTFE is not water soluble.

For **wastewater treatment** plants (WWTP), the literature analysed by the DSs concludes that currently WWTPs are not effective in destroying or removing PFAS. The median removal efficiency of the European WWTP calculated in the "*investigation report summaries*" is 42%, which means that roughly 58% of the PFAS contained in influent would be emitted into the European surface waters (through effluent) or be found in the sludge, which in some cases is spread on land as fertilisers. The products covered in this SEA are not disposed of via wastewater treatment plants at any stage of the product lifecycle. The emissions from wastewater treatment are therefore not reflective of the emissions from waste associated with the products covered in this SEA.

The incineration of PFAS containing waste is currently seen as the most effective treatment option for destroying PFAS, however, the remaining bottom and fly ash are typically landfilled in Europe, with smaller proportion being recycled as aggregates for use in example pavements and highway foundations (National Institute for Public Health and the Environment (RIVM) et al., 2021).

Caveats have been included where emissions have not been estimated for each environmental compartment. The volume and share of PFAS emissions estimated by the DSs are detailed in **Appendix Table** 6.

Appendix Table 6 Amount and proportion of PFAS emissions in each waste stream in the EEA

Waste treatment	Amount of PFAS emissions per waste stream (kg/year)			Share of total emissions from waste (%)	
	Low	High	Median	Low	High
WWTP effluent and sludge	-	-	9,884	94%	77%

[redacted]

Landfill	597	2,983	-	6%	23%
Incineration [2]	-	-	49	<0.5%	<0.4%
Total	**10,530**	**12,916**	**-**	**100%**	

Source: National Institute for Public Health and the Environment (RIVM) et al. (2021)

Notes:

1. The low and high estimates for the contribution of each waste treatment to the total amount of PFAS include the median amount of PFAS found in incineration and WWTP effluent and sludge given that the source data does not provide low and high estimated for these waste treatments.
2. Emissions to air not accounted.

As shown in **Appendix Table** 6 WWTP effluent and sludge has the highest contribution to PFAS emissions into the environment followed by landfill. This is expected given that WWTP effluent represents a direct PFAS emission into the environment and given that some of the landfill leachate is treated in WWTPs and hence is included in the WWTP emissions.

The contribution of incineration to the total PFAS emissions comes via incinerator bottom ash. The share of emissions from incineration are below 0.5% of total emissions across waste treatment options, indicating that this is the best treatment option for the destruction of PFAS.

The emissions reported in **Appendix Table** 6 are based on the overall volume of waste in each waste stream, which therefore could not be extrapolated and applied to the emissions from the end-of-life of products covered in this SEA. These emissions published by the DS have therefore been detailed here for completeness.

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