ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

PROVIDED AS COMMENTS TO THE PUBLIC CONSULTATION ON THE REACH RESTRICTION PROPOSAL ON PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

Public version

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Industrial PVDF-based ultrafiltration membranes required to be installed into (a) new water or wastewater treatment plants designed after EiF (including extensions of/changes to existing plants) subject to special conditions (low spatial requirements) for high quality purification of industrial and urban wastewater, process water and drinking water and (b) existing water or wastewater treatment plants ensuring possibility for maintenance and replacement during the operational life of the plant, both (a) and (b) until at least 15.5 years after EiF.

[1] Countries of sales and service: [redacted]

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACC	American Chemical Council
AoA	Analysis of Alternatives
BOD	Biological Oxygen Demand
BTEX	Benzene, Toluene, Ethylene and Xylenes
BWD	Bathing Water Directive
CAPEX	Capital Expenditure
CAS	Chemical Abstracts Service
CAS no	Chemical Abstracts Service number
[redacted]	[redacted]
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
CSR	Chemical Safety Report
CPE	Chlorinated poly ether
DEST	Scientific & Technological Expertise Department
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
DU	Downstream User
DWD	Drinking Water Directive
E	Exponent (scientific notation)
e.g.	for example
EBIT	Earnings Before Interest and Taxes
EC	European Commission
EC no	European Community number
ECHA	European Chemicals Agency
ED	Endocrine Disruptor
EEA	European Economic Area
EGL	European Green Deal
EiF	Entry into Force
EN	European Norm
EOL	End Of Life
etc.	et cetera
EU	European Union
EU-27	European Union with 27 Member States from 01 February 2020 on
EU-28	European Union with 28 Member States (01 July 2013 to 31 January 2020)
EUR	Euro
Eurostat	Statistical Office of the European Union
F	Fatality rate parameter
FTE	Full Time Equivalent
GWD	Groundwater Directive
H	Hour
I	Discount rate parameter / Index for worker contribution scenarios
i.e.	id est (that is)
ID	Identification number
IED	Industrial Emissions Directive
incl.	Including

Kg	Kilogram
LCI	Labour Cost Index
M	Metre
m^3	Cubic meter
m^3/h	Cubic meter per hour
Max.	Maximum
MBR	Membrane Bioreactor
MLD	Million Litres per Day
MTBE	Methyl Tertiary Butyl Ether
n/a	not applicable
NaOCl	Sodium hypochlorite
NMP	N-Methyl-2-pyrrolidone
No	Number
NPV	Net Present Value
OC	Operational conditions
OECD	Organization for Economic Co-operation and Development
OPEX	Operational Expenditure
PAC	Powdered Activated Carbon
PAN	Poly acetonitrile
PCP	Personal Care Product
p.e.	People equivalent
PES	Poly Ether Sulfone
PFAS	Polyfluorinated Alkyl Substances
p.	Page
ppm-h	Parts per million – hours
PVC	Poly Vinyl Chloride
PVDF	Polyvinylidene fluoride
R&D	Research and Development
RAC	Risk Assessment Committee
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
Rev.	Revision
RO	Reverse Osmosis
RMM	Risk Management Measures
SEA	Socio-Economic Analysis
SEAC	Committee for Socio-Economic Analysis
SVHC	Substance of Very High Concern
TSS	Total Suspended Solids
t/y	Tonnes per year
UF	Ultrafiltration
UK	United Kingdom
USA	United States of America
USD	US-dollar
UWWTD	Urban Wastewater Treatment Directive
[redacted]	[redacted]
WFD	Water Framework Directive
WRR	Water Reuse Regulation

WWTP	Wastewater Treatment Plant
[redacted]	[redacted]

GLOSSARY

Term	Definition
Alternative	An alternative technology or a membrane material to PVDF, considered and assessed for its suitability to substitute the use of PVDF-based UF membranes.
Coagulation and Flocculation	Coagulation and flocculation are conventional process uses for both drinking water and wastewater treatment and involve adding chemicals to the media to cause suspended particles to clump together to allow easy removal in later stages.
Drinking water	Drinking water shall mean "water intended for human consumption" as defined in Article 2(1)(a) and (b) of Directive (EU) 2020/2184 on the quality of water intended for human consumption. Drinking water is covered by Application 2 below.
Eutrophication	Eutrophication is a process of increasing biomass generation in a water body caused by increasing concentrations of plant nutrients, most commonly phosphate and nitrate. Increasing nutrient concentrations leads to increasing growth of aquatic plants, both macrophytes and phytoplankton.
High quality purification	Meeting or exceeding the most stringent regulatory requirements for removal of contaminants including turbidity (to less than 0.1 NTU), pathogens (e.g., + 99.9999 % removal of parasites and bacteria, + 99.99 % removal of viruses) and microplastics (to not detectable levels). For MBR, additionally BOD (to less than 2 mg/L and nutrients – total nitrogen (to less than 1 mg/L) and total phosphorus (to less than 0.05 mg/L). + 90 % removal of micropollutants. For industrial applications where pre-treatment is required for reverse osmosis (RO), a silt density index (SDI) <1.0 reduces fouling and extends the life of the RO system.
Key performance functionalities	Key performance functionalities of the PVDF-based UF membranes shared by all four Applications: 1. Low spatial requirements (small footprint of treatment plant, 'footprint' meaning the area required for building a treatment plant) 2. Chemical stability 3. Fouling resistance 4. Mechanical properties 5. Separation and removal capacity 6. Low use of treatment chemicals *(Specific definitions for each key performance functionality are set out in chapter 5.4 below)*
(Semipermeable) Membrane	Semipermeable membrane is a type of filter that allows the passage of water (when applied for water and wastewater treatment) and blocks the passage of certain solutes or contaminants. The rate of passage depends on the pressure, concentration, and temperature of the molecules or solutes on either side, as well as the permeability of the membrane to each solute. Depending on the membrane and the solute, permeability may depend on solute size, solubility, properties, or chemistry. How the membrane is constructed to be selective in its permeability will determine the rate and the permeability.
Microfiltration	Microfiltration (MF) is defined as filtration that retains particles larger than 0.1-10 micrometers in diameter. It is a low-pressure filtration through a semipermeable membrane in which colloidal particles are retained while the small sized solutes and the solvent are forced to move across the membrane by hydrostatic pressure forces. Microfiltration is a technique for separating elements contained in a liquid. It uses semi-permeable membranes with a pore diameter between 0.1 and 10 micrometers.
People equivalent	People equivalent (p.e.) is a unit of measure for an amount of sewage treated by a wastewater plant corresponding to 60 grams of BOD. For calculation purpose, an assumed volume of 200 L per one people equivalent was considered.

Production of Industrial Process Water application ("Application 1")	Process water application covers the production of water for a wide range of industries: food processing, cosmetic fabrication, chemical, fuel and energy production, steel manufacturing, etc. The water quality objectives are industry specific and vary depending on the industry needs: turbidity, solids content, organic content, metals content, pathogens removal. Plant capacity varies also depending on industry needs, from small size to medium size production (hundreds to tens of thousands m³ per day). Like for drinking water application, raw water for the production of process water has two sources: surface water or groundwater with respective impacts on the raw water quality and treatment process line. To minimize water intake, industries rely on internal recycling loop, bringing back the used water as a source for process water. Here apply two sub-categories based on the suspended solids content: groundwater / easy to treat surface water / internal loop (below ~50 ppm suspended solids) – considered as low loaded water and tough to treat surface water / internal loop (above ~ 50 mg/l suspended solids) – considered as high loaded water. Process water plants are designed and built for decades of operation. During their lifespan, the plants will face evolving challenges like extension capacity, new water quality to meet industry demand and potentially raw water contaminants modifications.
Production of Municipal Drinking Water application ("Application 2")	Municipal drinking water application covers the production of drinking water for public communities with strict water quality objectives: turbidity, organic content, metals content, pathogens removal, etc. Drinking water plant capacity varies significantly depending on the size of the community served, ranging from hundreds to hundreds of thousands m³ per day (= population ranging from few hundred inhabitants up to above one million). Raw water to produce drinking water has two sources: surface water (lake, river) or ground water with larger communities relying on surface water. Ground waters are usually stable in terms of physico-chemical characteristics and low loaded in terms of contamination (low solids content, low organic content). Surface waters are subject to variations following seasonal changes: temperature, impact of rain events, algae blooms, etc. and typically present higher contamination compared to ground waters: solids content, organic content, pathogens content, etc.). The level of contamination of the raw water will have a direct impact on the water treatment process line. More specifically for membrane solutions, two subcategories can be defined depending on the quantity of solids (natural solids and/or from chemical precipitants) reaching the membrane treatment step: ground water / easy to treat surface water (below ~50 mg/l suspended solids) – considered as low loaded water and tough to treat surface water (above ~ 50 mg/l suspended solids)- considered as high loaded water. The membrane's operating conditions in these two sub-categories will be different and significantly more challenging for tough to treat surface water to prevent membrane clogging. Municipal drinking water plants are designed and built for decades of operation. During their lifespan, these infrastructures will go through evolutions like extension capacity, meeting new drinking water targets and potentially facing new raw water contaminations.
Treatment of Industrial Wastewater application ("Application 3")	Industrial wastewater application covers the treatment of wastewater from industrial activities: food processing, cosmetic fabrication, chemical, fuel and energy production, steel manufacturing, etc. The discharge parameters are defined by local regulation addressing the specificities of the receiving water bodies and those of the industrial activity. In case of water reuse, the treated water would have to meet specific requirements. The latest is a clear trend due to water scarcity and industries growing sustainability goals. Plant capacity varies depending on industry needs from small size to medium size capacity (from few hundreds to tens of thousands m³ per day). The wastewater collected from diverse sources is industry specific: it can be loaded with solids, grease, fibers, carbon / nitrogen contents, industry specific compounds,

	etc. and must go through several treatment steps combining physicochemical and biological treatments prior to discharge. Industrial wastewater plants are designed and built for decades of operation. During their lifespan, the plants will face evolving challenges like expansion capacity, new discharge water quality and implementation/increase of wastewater reuse.
Treatment of Urban Wastewater application ("Application 4")	Urban wastewater application covers the treatment of domestic wastewater (flushing toilets, showers, dish washing, etc.) from people living in communities and related commercial activities or the mixture of domestic wastewater with industrial wastewater and/or run-off rainwater prior to discharge in surface water bodies. The discharge parameters and values are defined by national and EU legislation. They are also based on the sensitivity and usage of the discharge body, the size of the wastewater treatment plant and the potential presence of specific upstream pollution. In case of wastewater reuse, the treated water would have to meet specific requirements. Plant capacity varies significantly from small communities to large cities ranging from hundreds to hundreds of thousands m^3 per day (also expressed in people equivalent). The wastewater coming from the sewer network is loaded with solids, grease, fibers, carbon / nitrogen / phosphorus content, pathogens, micropollutants (pesticides, pharmaceuticals, personal care products) and must go through several physicochemical and biological treatment steps prior to discharge: primary / secondary / tertiary / quaternary treatment depending on treatment objectives. Urban wastewater plants are designed and built for decades of operation. During their lifespan, the plants will face new objectives like expansion capacity, new discharge parameters and potentially raw water contaminants modifications.
Ultrafiltration	Ultrafiltration (UF) is defined as *filtration that retains particles larger than 10-50 nanometers in diameter*. It is a low-pressure filtration through a semipermeable membrane in which colloidal particles are retained while the small sized solutes and the solvent are forced to move across the membrane by hydrostatic pressure forces. Ultrafiltration is a technique for separating elements contained in a liquid. It uses semi-permeable membranes with a pore diameter between 10 and 50 nanometers.
Supported / unsupported membranes	Supported membranes: they consist of a supporting structure, i.e., the so-called braid, which provides the necessary stability and overall tensile strength to the hollow fiber membrane. The braid is a textile structure consisting of multifilament polyester yarns. No PVDF is used for the support structure. In a proprietary process, PVDF is coated as an outside layer onto the supporting structure. The membrane itself must still possess special mechanical properties (i.e., high level of flexibility) to prevent cracking and delamination from the support. Unsupported membranes: these are membranes made from PVDF without the supporting structure.

DECLARATION

We, [redacted] ("[redacted]"), are aware of the fact that further evidence might be requested by ECHA to support the information provided in this document.

Also, we request that the information blanked out in the "public version" of the Analysis of Alternatives and Socio-economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today (June 29, 2023) the information is not publicly available, and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature:

[redacted]

General Counsel [redacted]

Date, Place:

[redacted]

1. INTRODUCTORY STATEMENT, INCLUDING ON FLUOROPOLYMERS AND RELATED HAZARD & RISK

[redacted] uses the fluoropolymer poly vinylidene fluoride ("**PVDF**" – EC No: 607-458-6; CAS No: 249370-79-9) to produce ultrafiltration ("**UF**") membranes for water treatment. Fluoropolymers are high value chemicals that provide a wide variety of properties in key industrial sectors. In comparison to their benefit for society, their hazard potential is very low. Fluoropolymers are not expected to degrade under intended conditions of use or at their end of life. At this point in time, no scientific evidence is available proving that fluoropolymers pose any risk to humans or the environment. Due to their chemical properties, such as high molecular weight and negligible solubility in water, fluoropolymers cannot enter or accumulate in the human tissue. They do not degrade into other PFAS under intended conditions of use or under ambient environmental conditions.

Fluoropolymers are part of the PFAS group by OECD definition and thus are included in the scope of the restriction proposal published on March 22, 2023. Because of their different chemical structure and properties, they need to be considered as a separate family within the broad PFAS group and clearly distinct from the non-polymeric PFAS. These differences are relevant for grouping but more importantly for considering risks for human health and the environment that will be derived from their manufacture, use and disposal.

The main differences between fluoropolymers and the other members of the broader PFAS group are the following (Korzeniowski, 2022):

- Structural differences which render them a unique and clearly differentiated family of chemicals to be separated from the broad PFAS group.
- Safety and environmental considerations due to their high molecular weight and negligible solubility in water. Thus, they cannot be toxic, bioavailable, bio-accumulative, mobile, and have insignificant human health or environmental impacts.
- Low potential to degrade into smaller PFAS molecules (possessing the identified hazards & risks for PFAS) during the intended conditions of use or under ambient conditions in the natural environment.
- Unique combination of properties, frequently related to the enhancement of safety of workers, population, and the environment, as well as to the development of green energy solutions and high technological applications. This makes fluoropolymers extremely valuable and irreplaceable in extremely demanding uses in a wide variety of industrial sectors.

[redacted] fully supports the information provided above and based on that is generally of the opinion that the use of fluoropolymers should be completely exempted from the PFAS restriction proposal. This is also in line with what we understand is the position that the European fluoropolymer industry, including [redacted] PVDF suppliers, presented during the current public consultation.

Therefore, the present submission is made in case and to the extent that the position of the European fluoropolymer industry would not be accepted by the Dossier Submitters, RAC, SEAC and the European Commission. Specifically, [redacted] has prepared a detailed analysis of alternatives ("**AoA**"), socio-economic analysis ("**SEA**") and a Chemical Safety Report ("**CSR**") for its use of PVDF to justify a time-limited derogation of at least 15.5 years (calculated from the expected Entry into Force ("**EiF**") in Q2 2025) for both new and existing plants.

2. SUMMARY

[redacted] uses PVDF to produce UF membranes at its [redacted] site located in [redacted]. Importantly, no polymerization process is carried out at the site because [redacted] purchases the PVDF polymer from an EU-based supplier. The [redacted] UF membranes manufactured in the plant in [redacted] are sold within the EEA and the rest of the world.

[redacted]'s UF membranes are critical components to industrial-scale water and wastewater treatment plants owned by municipalities, water companies and industrial companies in the European Union ("**EU**") and all over the world. UF removes particles, pathogens (parasites, bacteria, and viruses), microplastics, and combined with adsorption removes micropollutants (such as pesticides, pharmaceuticals, personal care products ("**PCPs**"), endocrine disruptors ("**EDs**")) from liquid media (water). Through this PVDF-based UF, the membranes achieve high quality of water purification in the following applications:

- Application 1: Production of Industrial Process Water;
- Application 2: Production of Municipal Drinking Water;
- Application 3: Treatment of Industrial Wastewater;
- Application 4: Treatment of Urban Wastewater.

The key performance functionalities of PVDF-based UF membranes that are required for all four water & wastewater applications in scope of the AoA are:

- Low spatial requirements (small footprint of treatment plant);
- Chemical stability;
- Fouling resistance;
- Mechanical properties;
- Separation and removal capacity;
- Low use of treatment chemicals.

[redacted] manufactures the following types of PVDF membranes: [redacted]. Please refer to chapter 5.3 for more details. The Product Data Sheets to the three products are attached in the Annex.

<u>PVDF-based UF membranes play a key role in the EU's strategy for safe drinking water and wastewater discharge (see further below in section 5.1).</u> Surface waters and groundwaters are protected and managed in a sustainable manner as a source for drinking water. It needs to be ensured that all drinking water is safe for human consumption and that levels for contaminants are kept under applicable EU and national statutory thresholds. All wastewater resulting from human consumption and use needs to be purified in the highest possible quality to guarantee safe discharge to feed the EU/global water circle. Due to their performance and their market integration PVDF UF membranes offer decisive advantages for water/wastewater treatment compared to other membrane materials like polyethersulfone ("**PES**"), chlorinated poly ethers ("**CPE**"), poly acetonitrile ("**PAN**") and ceramics and conventional technologies like physico-chemical clarification, sand filtration, etc.). Please refer to chapter 5.6.5 for details.

In this regard, the upcoming PFAS restriction is highly critical for EU citizens, considering the non-availability of a one-to-one replacement for PVDF-based UF membranes. According to [redacted]'s substitution plan at least 17.5 years[2] are required to develop a suitable one-to-one replacement. This means that from the expected EiF of the PFAS restriction in Q2 2025, a derogation of at least 15.5 years is required for [redacted] to substitute PVDF-based UF membranes while ensuring supply with critical components to EU water and wastewater treatment plants.

Importantly, the substitution timeline is developed for the scenario of replacing the PVDF-based UF membranes one-to-one with an alternative-based UF membrane. The substitution timeline does not consider a switch to a completely different treatment technology. This is because PVDF-based UF membranes currently offer the only available option for providing high quality treated water (meeting current and future EU legal requirements) in the small footprint required by relevant municipal and industrial downstream users ("**DUs**") (see section 5.1).

In addition, for existing DUs, once a specific plant setup is decided and constructed little to no adaptations are possible regarding the core treatment unit. In other words, a plant designed for water/wastewater treatment via UF membranes will always rely on the use of UF membranes and cannot simply switch to a completely different treatment technology. More specifically, in case a PVDF UF membrane is chosen, customers need to be able to replace the membranes with PVDF UF membranes when their end-of-life (10-20 years) is reached. Otherwise, critical parameters like plant capacity and water quality cannot be met. Notably, these parameters are pre-defined during plant design and need to be guaranteed throughout a plant's service life (40-50 years). Besides technical arguments, investment costs play another important factor for DUs. PVDF UF membranes have the best price-to-lifetime ratio available on the market.

[redacted] is also committed to increase the sustainability of the manufacture, application, and disposal of their PVDF-based UF membranes. For this purpose, the company developed a sustainability commitment that will fully apply during the required 15.5-year derogation.

With this information submitted as comments to the public consultation on the PFAS restriction proposal, [redacted] aims to achieve at least a derogation of 15.5 years (from EiF) for the manufacturing and placing on the market of PVDF-based UF membranes. By obtaining a time-bound derogation from the upcoming PFAS restriction, [redacted] ensures supply for the growing need (urbanization and related population growth, stricter water quality parameters, climate change, sustainable industry, etc.) of this advanced water and wastewater treatment technology across Europe and the rest of the world (see section 5.1).

[redacted] considers that its PVDF use is not fully covered by any of the currently proposed derogations in the PFAS Annex XV REACH Report. Therefore, [redacted] requests a specific derogation.

Restriction scenario and evaluation of impacts

The absence of suitable alternatives will result in partial business closure for [redacted] in the EEA. The closure of the [redacted] line for [redacted] would result in massive producer surplus losses and social cost of unemployment in the EEA. Section 6.4.2 explains that the reconstruction of industrial and municipal water and industrial and urban wastewater treatment plants in the restriction scenario would imply high capital (one-off) and operating costs. While in some cases an expansion may be needed, others may require completely new infrastructures. For end users or EEA society, welfare losses due to significant costs for DUs and compromised water quality

[2] Calculated from Q2 2023 - the timepoint of submitting the comment to the public consultation.

and quantity are evaluated in terms of welfare losses due to reduced economic value of reclaimed wastewater and consequent increase in water tariffs.

Based on the impact assessment, a restriction of PVDF membranes would result in socio-economic impacts valued at EUR [redacted] million in 2025 or EUR [redacted] million per year for 15.5 years (see Appendix 2: Explanation on NPV calculations) for the EEA society whilst any releases to the environment across all life cycle stages are precluded. It must be emphasized that these impacts only present a partial picture of the overall impacts of a restriction. The impacts are only quantified for [redacted] and its DUs. The overall impacts of a restriction on the EEA society are expected to be much higher.

3. SCOPE AND AIMS

The objective of the present submission is to provide comments to the public consultation on the PFAS Annex XV REACH Report ("**Restriction Proposal**") launched by the European Chemicals Agency ("**ECHA**") on March 22, 2023. Specifically, [redacted] considers that its PFAS use is not fully covered by any of the currently proposed derogations in the PFAS Restriction Proposal. Therefore, [redacted] requests the following derogation:

"Industrial PVDF-based ultrafiltration membranes required to be installed into (a) new water or wastewater treatment plants designed after EiF (including extensions of/changes to existing plants) subject to special conditions (low spatial requirements) for high quality purification of industrial and urban wastewater, process water and drinking water and (b) existing water or wastewater treatment plants ensuring possibility for maintenance and replacement during the operational life of the plant, both (a) and (b) until at least 15.5 years after EiF.[3]

[redacted] hereby presents a detailed AoA, SEA and a CSR to fully justify the company's request for the 15.5-year derogation. The concrete aims of the three dossier parts are:

1) From an AoA perspective, to provide information on the technical importance of PVDF-based UF membranes for industrial-scale water and wastewater treatment applications and thus for the European society and a sustainable industry. Furthermore, to describe the technical disadvantages and limitations of potential alternative technologies and membrane materials by direct performance comparison to PVDF membranes. As part of the assessment of alternatives, the economic feasibility of substitution is discussed. Finally, [redacted]'s R&D efforts to reduce and substitute PVDF usage are presented. Based on this a best-case estimated timeline for substitution of PVDF-based membranes is derived.
2) From a SEA perspective, to analyze the relevant market for PVDF membranes and introduce its main players. Furthermore, to describe actors that play a crucial role along the value chain and underline the significance of PVDF membranes for different applications. Finally, the SEA aims to demonstrate that the socio-economic benefits associated with the continued use of PVDF outweigh the remaining risks to the environment which, as it is shown in chapter 6.2 are minimal. The period covered by the SEA runs from EiF (Q2 2025) to 2040 (taking 2025 as a base year for calculation).
3) From a CSR perspective, to provide information on the substance identity, its composition, stability, and degradation mechanisms (Chapter 2). Most importantly, this document shall provide information on Risk Management Measures ("**RMMs**") and Operational Conditions ("**OCs"**) of the manufacture, use and disposal of membranes during their life cycle (Chapter 3). Potential emissions during the life-cycle stages are outlined. Measurement results and laboratory studies on degradability are used to support the hypothesis that environmental emissions from the manufacture and use stages of membranes made of PVDF are minimal (Chapter 4). [redacted] is aware of the

[3] [redacted] is aware that derogation 6a under the PFAS Restriction Proposal (i.e. *"fluoropolymers for use in food contact materials for the purpose of industrial and professional food and feed production until 6.5 years after EiF"*) covers filters to capture contaminants […] (see paragraph 6 on p.11 of the Restriction Proposal). However, this derogation cannot entirely support [redacted]'s PVDF use as: (i) it only captures one of the four applications (i.e Application 2: the production of municipal drinking water), and (ii) in accordance with the Substitution Plan (see chapter 6.1.1) the length of the derogation is not sufficient to substitute the PVDF in this application.

concerns raised over certain PFAS compounds. For this reason, it is important for the company to provide information on the upstream polymerization process (only qualitatively), the membrane manufacturing process (incl. OCs and RMMs), the application process at DUs (water/wastewater treatment plants) and the membrane disposal in a CSR. At all stages, the focus is on potential PFAS emissions and the corresponding environmental impact.

In general, [redacted] is committed to further reduce the overall environmental impact caused by membrane manufacturing, application and disposal which is already considered minimal. For this purpose, the company decided on a multistep approach for further sustainability. [redacted]'s commitment is described in Section 4 of this AoA/SEA.

4. [redacted]'s COMMITMENT TO REDUCTION OF PVDF USE AND GENERAL ENVIRONMENTAL IMPACT

[redacted] is committed to reduce the environmental impact caused by the manufacture, application, and disposal of its PVDF-based UF membranes. For this purpose, the company developed a commitment that will fully apply during the 15.5-year derogation that is required to substitute the use of PVDF-based UF membranes. For this commitment [redacted] considered the entire lifecycle of its membranes starting from membrane manufacture through disposal at end-of-life (EOL). (It should be noted that 80 % of the produced membranes are exported outside the EU.)

Note: the upstream polymerization process for production of the PVDF raw material is out of scope since it cannot be monitored by [redacted]. We understand that PVDF suppliers will address PVDF emissions during Public Consultation. Also, as part of its Sustainable Purchase Strategy, [redacted] will keep influencing PVDF suppliers to reduce the impact of their production.

5. ANALYSIS OF ALTERNATIVES

5.1. Use of PVDF UF membranes, its importance for society and applicable EU water legislation

General overview

Today, membrane-based technologies are clearly recognized as the state-of-the-art in water and wastewater treatment. A very large number of public (e.g. municipalities) and private (e.g. manufacturing sites) installations have been developed since the early 1990's. More specifically, membrane-based technologies have supported, due to their universality and advanced performance, the implementation of EU water protection and management frameworks and related legislation.

UF membranes fabricated from PVDF are used in the production of industrial process water, municipal drinking water as well as in the treatment of industrial and urban wastewater. The functional principle of these hollow-fiber membranes is based on the vacuum-or pressure-driven removal of particles, pathogens (parasites, bacteria, and viruses), micropollutants (such as pesticides, pharmaceuticals, PCPs, EDs) and microplastics from the water based on a combination of adsorption and size exclusion.

PVDF UF membranes are a highly effective and efficient method of water and wastewater treatment. They offer decisive combined advantages for water/wastewater treatment compared to other membrane materials like PES, CPE, PAN and ceramics and conventional technologies like physico-chemical clarification, sand filtration, etc.:

- **Low spatial requirements** ensure high quality water treatment in applications with reduced spaces (e.g. urban areas, industrial sites, etc.). PVDF-based UF membrane modules (and cassettes) (see chapter 5.3) are designed with high packing density and for small footprint due to the mechanical properties (unique combination of strength, flexibility and wear resistance) of the PVDF membranes.
- **High chemical stability** enables usage in applications with aggressive media (e.g. presence of biomass, chemicals, cleaning agents, etc.). Importantly, high chemical stability results in long membrane lifetimes of 10 - 20 years which increases sustainability (less raw material consumption / less waste) and lowers costs for membranes at DUs. In addition, the inertness of PVDF-based membranes makes them suitable for use in drinking water applications. [redacted]'s membrane were granted the drinking water certification in various EU Member States like Germany (Kunststoff-Trinkwasser), Italy (ICIM), Hungary (ANTSZ), Poland (PZH) and non-EU countries like the Unites States of America (NSF-61 and NSF-419), United Kingdom (Drinking Water Inspectorate), Korea (Koran Water and Wastewater Association), China (Ministry of Health of the People's Republic of China).
- **Fouling resistance** allows to maintain filtration performance in a wide range of operating conditions.
- **Mechanical properties** guarantee the durability of the membrane in all operating conditions
- **Separation and removal capacity** PVDF UF membranes are perfectly suitable to simultaneously remove particles, bacteria, giardia, Cryptosporidium, viruses, particles,

colour, other small organic compounds and microplastics with pores size in the range of 10 to 50 nanometers.

- **Low use of treatment chemicals** eliminate or significantly reduce the need of chemicals which are typically required for conventional physico-chemical treatments

At this point, it is important to understand that when UF membranes are selected for a water / wastewater treatment plant due to their critical functionality, the UF membranes become the core technology for the treatment and the rest of the equipment and infrastructure are built around it. Once a specific plant configuration is established and constructed, little to no adaptations are possible without significant economic efforts (order of magnitude: tens of millions to hundreds of millions EUR for one treatment plant). The lifetime of water/wastewater treatment plants range from 30 to 50 years. In other words, a plant designed for water/wastewater treatment via UF membranes will always rely on the use of UF membranes and cannot simply switch to a membrane technology with a larger footprint or a completely different treatment technology (conventional technologies). More specifically, in case a PVDF UF membrane is chosen as the best technical and economical solution, for the very vast majority of sites, customers need to be able to replace the membranes with PVDF UF membranes after the end-of-life (10 - 20 years) is reached. Otherwise, critical parameters like plant capacity (water volume treated per day) and water quality cannot be met. As stated above, PVDF-based UF membrane modules (and cassettes) (see chapter 5.3) are designed for high packing density and small footprint due to the mechanical properties (unique combination of strength, flexibility and wear resistance) of the PVDF membranes. Membranes made from other materials (PES, CPE, PAN and ceramics) are up to five times less efficient in terms of footprint.

Therefore, there are currently no existing one-to-one replacements to PVDF-based UF membranes.

Importance of PVDF UF membranes for society and regulatory landscape

Water is a limited resource that needs to be protected and used in a sustainable way[4]. It is, however, under pressure from many different uses from a variety of sectors, such as agriculture, industry, tourism, transport, and energy. In 2012, the EU Commission launched the Blueprint to Safeguard Europe's Water Resources (the "**Blueprint**") [5], a long-term strategy that aims to ensure the availability of a sufficient level of good quality water for all legitimate uses by better implementing current EU water policy, integrating water policy objectives into other policy areas and filling gaps in the current framework. As described in the Blueprint, water is essential for human life, nature, and the economy. It is permanently renewed but it is also finite and cannot be made or replaced with other resources. Freshwater constitutes only about 2 % of the water on the planet and competing demands may lead to an estimated 40 % global water supply shortage by 2030[6].

The key pieces of EU legislation that govern the treatment and management of water and wastewater in the EU are provided below. The EU continues to review and update its legislation to ensure that it remains relevant and effective in protecting water resources and ensuring that they are managed in a sustainable manner.

[4] https://watercommission.org/

[5] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2012:0673:FIN

[6] Charting our water future, a report of the 2030 Water Resources Group, http://www.mckinsey.com/client_service/sustainability/latest_thinking/charting_our_water_future

- Water Framework Directive 2000/60/EC ("**WFD**")[7]: This Directive sets the legal framework for the protection and management of EU's water resources, with the aim of ensuring that all surface waters and groundwater are protected and managed in a sustainable manner. The WFD requires all EU Member States to establish and implement programs of measures to achieve good ecological and chemical status of their water resources.
- Groundwater Directive 2006/118/EC ("**GWD**")[8]: This Directive sets standards for the protection and management of groundwater in the EU. The GWD requires all Member States to ensure that groundwater is protected against pollution and to prevent the abstraction of water in excess of the long-term sustainable yield of the resource.
- Drinking Water Directive (EU) 2020/2184 ("**DWD**")[9]: This Directive sets the quality standards for drinking water in the EU and requires all Member States to ensure that all drinking water is safe for human consumption. The DWD sets maximum levels for a range of contaminants, including heavy metals, pesticides, and microorganisms. Minimum requirements for "Total PFAS" and "Sum of PFAS" as described in the Directive, are respectively 0,50 µg/l and 0,10 µg/l. It is important to understand that PFAS which may be measured in the water have no relation with the technology used to treat the water and here more specifically with PVDF UF membrane.
- Urban Wastewater Treatment Directive 91/271/EEC ("**UWWTD**")[10]: This Directive sets standards for the treatment of urban wastewater to protect the environment and public health. The UWWTD requires all EU Member States to provide adequate treatment for all urban wastewater and to ensure that it is disposed of safely. The EU authorities are currently working on the revision of this Directive (Urban Wastewater Recast) which will come up with broader wastewater collection and tighter discharge limits. Among other, the following main measures will be progressively applied until 2040:
    - Nutrient releases will be further reduced with more stringent discharge limits values for nitrogen and phosphorus. These new standards will be systematically applied to all larger facilities above 100,000 p.e. (~ 20 million litres per day) but also in all facilities above 10,000 p.e. (~ 2 million litres per day) located in areas where eutrophication remains an issue (vast majority of inland discharge).
    - New limit values will be established for micro-pollutants that require additional treatment. This would apply first for all large facilities and then for facilities above 10,000 p.e. (~2 million litres per day) where there is a risk to the environment or public health on the basis of clear and simple criteria. (based on monitoring results in discharge area).

      To meet these new limits, the Directive Recast requires the implementation of tertiary treatment for nitrogen and phosphorus objectives and quaternary treatment for micro-pollutants objectives.
    - In addition, Member States shall systematically promote the reuse of treated wastewater from all urban wastewater treatment plants. The implementation of Water

[7] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A02000L0060-20141120

[8] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A02006L0118-20140711

[9] Available at: https://eur-lex.europa.eu/eli/dir/2020/2184/oj

[10] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A01991L0271-20140101

Reuse is supporting European Green Deal (EGD) objectives and EU ability to respond to the increasing pressure on water resources.

- Regulation (EU) 2020/741 on minimum requirement for water reuse ("**Water Reuse Regulation/"WRR"**)[11]: This Regulation lays down minimum requirements for water quality and monitoring and provisions on risk management, for the safe use of reclaimed water in the context of integrated water management. The purpose of the WRR is to guarantee that reclaimed water is safe for agricultural irrigation, thereby ensuring a high level of protection of the environment and of human and animal health, promoting the circular economy, supporting adaptation to climate change, and contributing to the objectives of the WFD by addressing water scarcity and the resulting pressure on water resources, in a coordinated way throughout the Union, thus also contributing to the efficient functioning of the internal market.
- Bathing Water Directive 2006/7/CE ("**BWD**")[12]: The purpose of this Directive is to preserve, protect and improve the quality of the environment and to protect human health by complementing the WFD and is applicable to any element of surface water where the competent authority expects a large number of people to bathe and has not imposed a permanent bathing prohibition, or issued permanent advice against bathing (hereinafter bathing water).
- Industrial Emissions Directive 2010/75/EU ("**IED**")[13]: This Directive requires all EU Member States to ensure that industrial activities are subject to integrated pollution prevention and control, with the aim of preventing and reducing pollution and protecting the environment.

Water and wastewater treatment plants using PVDF UF membranes play a key role in the EU's strategy and in the implementation of the above Directives/Regulations in order to ensure the availability of a sufficient level of good quality water for all legitimate uses. As such, PVDF UF membranes participate to provide EU citizens with an essential service. Their need is expected to increase in the future, particularly in the EU, due to several factors[14] including:

- The need for cleaner and safer water is increasing. PVDF-based UF membranes achieve the highest level of water purification including eliminating particles, pathogens (parasites, bacteria, and viruses), microplastics and combined with adsorption removes micropollutants (such as pesticides, pharmaceuticals, PCPs, EDs) and microplastics. These membranes ensure removal of all solids with a diameter larger than in the range of 10 nanometers.
- As populations continue to grow and urbanize, suitable water and wastewater treatment infrastructures need to be in place for ensuring that communities in urban areas have access to clean water and surrounding water bodies remain safe and protected. In this regard, the generally low space availability and zero net artificialization (the aim to suspend any net increase in the total amount of artificial surfaces) of urbanized areas present important aspects to be considered. PVDF-based UF membranes enable construction of treatment plants with lowest possible spatial requirements (= low

[11] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A32020R0741

[12] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A02006L0007-20140101

[13] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A02010L0075-20110106

[14] https://apps.who.int/gb/ebwha/pdf_files/WHA72/A72_R7-en.pdf

footprint) while delivering high quality water. This ensures lower environmental impact of treatment plants and thus improved land use in dense/urban areas.

- Climate change is expected to have a significant impact on water resources in the future, leading to changes in water quality and availability. The versatility of PVDF-based UF membranes allow municipal and industrial DUs to cope with variability of water qualities and are recognized as a leading technology for water reuse.
- For municipalities, the more stringent limits for nutrients and micro-pollutants in wastewater are critical in terms of treatment technology selection. To reach these objectives, a separation step acting as tertiary treatment – see chapter 5.3 -must be implemented to block particulate pollution. PVDF-based membrane bioreactor ("**MBR**") combines secondary and tertiary treatment in one simple process step. PVDF-based UF membranes remain today the most effective way to block particulate pollution. Concerning micro-pollutants, here as well PVDF-based UF membranes play a critical role either by addition of absorptive media (e.g. powdered activated carbon) as part of the MBR to remove micro-pollutants directly or as a highly effective means to remove all particulate pollution to eliminate interferences to effective quaternary treatment (e.g., reverse osmosis, granular activated carbon).
- For industry, wastewater treatment for reuse is among the key topics to ensure sustainable manufacturing and to compensate for the projected future water shortage. Here as well, the versatility of the PVDF-based UF membrane allows to cope with a very wide range of industrial water qualities and is recognized as a leading technology for water reuse. Logically, industrial water use is interlinked with the water supply for other users.
- As a leading technology for implementation of water reuse in both municipal and industrial sectors, PVDF-based UF membrane contributes to reducing the impact of climate change (addressing water shortage) and supporting the advancement of the circular economy.

The huge benefit of PVDF UF membranes is that they provide a unique combination of performance (removal of a broad range of contaminants) and cost-efficiency (long lifetime, low footprint/spatial requirements, cost competitiveness). Therefore, their use is key to counteract the above-mentioned factors which will not only become relevant in the future but are already fully applicable now.

5.2. The value chain of PVDF UF membranes

In accordance with the economic forecasts and the societal need (see section 5.1), membrane manufacturing is one of the fastest growing segments in the global water industry. In 2022, the global market for microfiltration ("**MF**") and UF membranes used in water and wastewater treatment was estimated at EUR 1.5 billion[15] and is expected to annually grow by 6 % until 2027. The corresponding market in the EEA is estimated to be approximately EUR 170 million with an annual growth rate of 4 % (Global Water Intelligence Data (GWI), 2023).

Polymeric membranes represent around 90 % of this market value, whereas ceramic membrane solutions only make up less than 10 %. Among the polymeric membranes, 70 – 80 % are PVDF

[15] Note: Exchange rate of USD 1 = EUR 0.916911, as of April 10, 2023.

membranes. Additionally, the vast majority of MBR used in the treatment of wastewater are made of PVDF (Global Water Intelligence Data (GWI), 2023).

The market sizes mentioned above only include the sales of individual membranes themselves. Typically, suppliers of PVDF membranes (including [redacted]) deliver complete membrane systems comprising of membranes, mechanical and electronic components (i.e. pipes, pumps and skids), and instrument control components (i.e. meters). The market size of complete membrane systems is thus estimated to be three times the membrane market, valued at approximately EUR 510 million annually in the EEA (Global Water Intelligence Data (GWI), 2023).

Strong know-how, manufacturing skills and integrator networks in Europe contribute to [redacted] leading role in the industry for PVDF UF membranes.

5.2.1. Key actors within the value chain of PVDF UF membranes

The value chain of the PVDF UF membranes constitutes the following stakeholders:

Direct and indirect suppliers of input material for the assembly of the membranes form an integral part of the supply chain. [redacted], for instance has a total of [redacted] direct and [redacted] indirect suppliers in the EEA, amounting to a total annual spend of approximately EUR [redacted] million[16] on these suppliers.

Original equipment manufacturers ("OEMs") (such as [redacted] and its [redacted] product line) that design, manufacture and sell PVDF UF membranes to be used by customers for water and wastewater treatment applications. To assess if this water filtration technology applies to the needs of the respective customer, the support of consultants, engineering firms and internal resources is required. [redacted] has application specialists to support customers in the design and integration of the membranes into an overall treatment solution. Additionally, [redacted] offers engineering services to support customers with detailed process design, project management, and mechanical and electrical engineering. [redacted] services team provides support for installation and commissioning of the membranes and ancillary equipment, as well as ongoing servicing during the operating life of the plant.

Next, the **DUs** purchase PVDF UF membranes for different uses, which broadly fall under the four Applications, introduced in chapter 2. [redacted] can deliver either individual membranes or complete systems that include a range of other key components.

DUs that use PVDF UF membranes comprise an array of sectors. For instance, Figure 1 presents the share (in %) of all customer segments in [redacted]'s total PVDF-dependent sales revenue in the EEA. The most dominant customer segment is clearly the treatment of urban wastewater ([redacted] %). This is followed by customers from the general industry ([redacted] %), chemicals & pharma ([redacted] %), and oil & gas ([redacted] %) where the treated wastewater is reused for industrial processes. Additionally, municipal drinking water constitutes [redacted] % of [redacted]'s revenue share. Other customer segments include the food & beverage, pulp & paper, microelectronics and power industry for industrial process water.

[16] Note: Exchange rate of USD 1 = EUR 0.912507, as of May 9, 2023.

[redacted]

[redacted]

End-users constitute citizens, municipalities and industries that rely on the treatment of water and wastewater applicable for the customer segments described in Figure 1. As emphasized before, the two largest customer segments are the treatment of Urban Wastewater (Application 4) and Industrial Wastewater (Application 3)[17].

The main source of urban wastewater is domestic use, which is treated in WWTPs before being discharged in surface water bodies. Additionally, wastewater is produced during industrial activities. For reuse of industrial wastewater, strict specifications apply. This reused water is commonly called reclaimed water. Reclaimed water in the industrial context has several benefits, such as reducing the need of and thus also the costs of fresh water, lowering the environmental impact and meeting regulatory standards by reducing discharges. Moreover, reclaimed water can also be used for environmental enhancement, namely, to maintain river flows during hot periods or to supplement water in lakes and wetlands as a measure to preserve biodiversity (EIB, 2022).

In a global context, the largest part of reclaimed water is used for agricultural irrigation (32 %) (EIB, 2022). Especially, in times of increasing water scarcity and changing climatic conditions, this reuse is becoming steadily relevant. Another common reuse is for the irrigation of urban landscapes (20 %), such as parks, gardens and sports fields, as well as for the cleaning of streets. This is closely followed by using reclaimed water for industrial purposes (19 %), as for example in the manufacturing of textile, the production of paper, and heating or cooling processes (EIB, 2022).

Besides the use of reclaimed water, industries need to produce process water for the performance of industrial activities and in certain sectors, such as in the production of food and beverages, chemicals and pharma, fuel and energy production, for instance (Application 1).

[17] See definitions in Glossary.

Another end-use is the supply of safe drinking water for public communities (Application 2).

In Figure 2 below, the distribution of significant applications or end-uses for [redacted]'s DUs, broken down by their share (in %) in [redacted]'s total PVDF-dependent sales revenues can be found. It clearly shows that the treatment of Industrial Wastewater and the treatment of Urban Wastewater are by far the two most important applications where [redacted]

[redacted]

FIGURE 2: DISTRIBUTION (%) OF [redacted]'S DU'S APPLICATIONS BY [redacted]'S PVDF-DEPENDENT REVENUES.

Consequently, the use of water and wastewater for all of these applications intensifies the need to protect its quantity, as well as quality. Therefore, effective wastewater treatment is as important as ever, wherein, membrane filtration technology, and in particular UF, plays a crucial role. As previously mentioned, PVDF is one of the most used materials for these UF membranes.

5.2.2. Competition landscape of PVDF UF membranes

Besides [redacted], [redacted] and [redacted] are main PVDF membranes suppliers within the EEA. These companies supply PVDF membranes for industrial process water, municipal drinking water, as well as urban wastewater (tertiary and MBR applications).

Considering that [redacted] is the only [redacted] facility to produce PVDF UF membranes for global distribution, a total of EUR [redacted] million in sales revenue was generated at this site in [redacted] in 2022[18]. In addition, in 2022, [redacted] generated PVDF-related revenues of EUR [redacted] million on a global scale from sales of PVDF membranes, related equipment and services which is an important part of [redacted] total annual sales revenue. Within the EEA, sales revenue amounted to EUR [redacted] million in 2022 for PVDF membranes sales, related equipment and services. The financial figures for [redacted] are provided in Appendix 1: Financial figures for [redacted]. These figures are

[18] Note that there is also a production site in [redacted], China for Asian-based customers which is supplied by the [redacted] unit with membrane fibre for final assembly into modules.

expected to grow in the next three years driven by strong macro trends such as urbanization and related population growth, climate change, sustainable industry and stricter water quality parameters.

According to [redacted]'s estimations, [redacted] generated annual revenues of EUR 75 million and [redacted] of EUR 60 million in 2022 in the EEA from PVDF membranes. As these two companies do not manufacture within the EEA, they respectively only employ 25 - 50 people in the EEA. However, they supply their technology to many European countries. Some other Tier 2 competitors with manufacturing sites in the EEA are [redacted], [redacted], [redacted], [redacted] and [redacted] with respective sales revenues of EUR 15 million or less in 2022.

In the EEA, approximately [redacted] PVDF UF membrane installations were reported by the end of 2022, with nearly [redacted] % ([redacted]) constituting [redacted] PVDF ([redacted]), treating more than [redacted] MLD. The remaining installations (around [redacted]) are from all other PVDF membrane suppliers[19].

As [redacted] has about the same number of installations as all of its competitors together in the EEA, the company leads the membrane industry with the world's largest capacity for membrane manufacturing. [redacted] employs the industry's most advanced manufacturing techniques, which enable the production of top-quality membranes with maximum efficiency. Based on [redacted]'s PVDF-dependent sales revenues, the biggest market for PVDF UF membranes within the EEA exists in Italy ([redacted] %). This is followed by France with [redacted] % and Sweden with [redacted] % shares. Other relevant markets are Belgium, Spain, Portugal, Ireland, and Germany.

5.3. Description of PVDF UF membranes, their mode of action and important advantages

Manufacturing, setup, and filtration principle of PVDF membranes

[redacted] produces its PVDF membranes in a proprietary manufacturing process. As a general description, PVDF powder is dissolved in an organic solvent, then extruded through a nozzle into an aqueous bath followed by a rinsing bath. The membrane formation happens in an aqueous solution. PVDF is the essential material of choice as it has the best chemical resistance and mechanical properties of polymers that can be dissolved in organic solvents. The final product is a hollow-fiber membrane string that is arranged with many additional strings into a UF membrane module. Membrane modules are further arranged into membrane cassettes and finally into complete treatment units (process trains). For a graphical illustration please refer to Figure 3 and Figure 4.

[19] Please note that no competitors were contacted for this assessment. This assumption is purely based on [redacted]'s current knowledge of the subject matter.

FIGURE 3: HOLLOW-FIBER MEMBRANE STRING (LEFT), ARRANGEMENTS OF STRINGS (RIGHT).

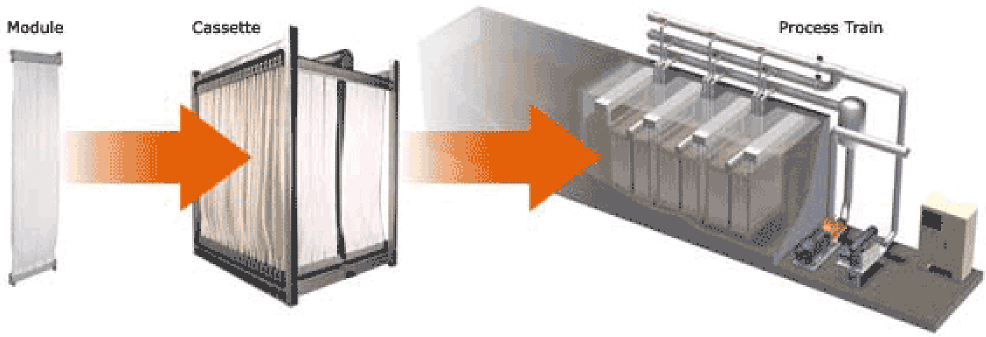

FIGURE 4: BREAKDOWN OF TREATMENT UNIT.

[redacted] offers different PVDF UF membrane products. These products differ in a variety of characteristics, such as filtration mode, dimensions, etc. The membrane modules can be used in a submerged mode of operation where the water is sucked under vacuum through the separating layer (see Figure 5) or in a pressurized mode where the water is forced under pressure to pass the separating layer (see Figure 6).

FIGURE 5: ILLUSTRATION OF VACUUM-DRIVEN MEMBRANE APPLICATION.

FIGURE 6: ILLUSTRATION OF PRESSURE-DRIVEN MEMBRANE APPLICATION.

In both modes of operation, the water is filtered from the outside to the inside of the hollow fiber membrane and the clean water permeate is collected in a permeate header. The water flow of outside-in membranes is illustrated in Figure 7. For cleaning during operation, air is introduced at the bottom of the membrane modules to create turbulence along the membrane surface. Rising air bubbles, along with a feed flush of the membrane modules, scour and clean the outside of the membrane fibers, maximizing membrane performance. For certain applications, strong chemicals (e.g. sodium hypochlorite) are used for cleaning of the outside of the membranes.

FIGURE 7: ILLUSTRATION OF WATER FLOW WITH OUTSIDE-IN HOLLOW FIBER MEMBRANES.

[redacted] manufactures the following types of PVDF membranes: [redacted]. The three types of membranes share the same key functionalities and can be used for all four Applications. Additional [redacted]-type membranes may be developed/marketed in the future.

TABLE 1: PVDF MEMBRANE PRODUCTS MANUFACTURED BY [redacted].

Membrane type	Filtration Mode	Application	Description
[redacted]	Outside-in, vacuum-driven	All	Large diameter supported PVDF hollow fibres, most robust product for challenging uses (including MBR)
[redacted]	Outside-in, vacuum-driven	All	Small diameter PVDF hollow fibres, large cassette configuration for deploying in large drinking water plants and for tertiary treatment
[redacted]	Outside-in, pressure-driven	All	Small diameter PVDF hollow fibres, small pressure-driven membrane modules for flexibility in deploying in variety of industrial process water uses, smaller drinking water plants and for tertiary treatment

In general, the water and wastewater treatment applications include different stages of treatment before and after the dedicated filtration step (e.g. via membrane-based ultrafiltration). These differences in the treatment procedure including advantages of the membrane-based ultrafiltration are outlined in the following two paragraphs.

Water treatment: stages of treatment and advantages of UF membranes

To highlight the advantages of membrane based UF, a short description of the stages performed in conventional water treatment are described. A conventional water treatment plant typically consists of seven unit operations, which are illustrated in Figure 8 and further detailed in the following:

1. **Intake**: the first step in the water treatment process involves pumping of the source water (e.g. groundwater or surface water, like rivers, to the treatment plant) and if required passing the raw water through screens to remove debris from the water source.
2. **Chemical addition and mixing**: various chemicals may be added into raw water as pre-treatment prior to the subsequent treatment process steps:
    - Iron chloride or Aluminium sulphate: to coagulate impurities
    - Hydrated lime or sodium hydroxide: to control pH
    - Polyelectrolyte: to facilitate flocculation
    - Potassium Permanganate: to facilitate removal of manganese
    - Ozone: to oxidise impurities, control algae growth, remove taste and odour
    - Powdered activated carbon (PAC): to remove taste and odour, organic compounds
3. **Coagulation and flocculation**: the chemicals added cause particles in the raw water to aggregate to form larger particles that can be removed. Tanks with slow mixing allow the particles to join to form "floc" (flocculation).
4. **Sedimentation**: large tanks allow the gradual settling of the flocculated particles. Water is collected through weirs at the top of these sedimentation tanks.
5. **Granular media filtration**: gravity filters containing sand are used to remove finer dirt particles and pathogens (those captured in the floc). Gravity filters require a large footprint due to the slow filtering of the water through the sand bed. When head-loss

through the sand bed exceeds a defined value or causes a reduction in water flow, sand filters are backwashed to remove the accumulation of trapped materials.

6. **Disinfection**: the filtered water is disinfected by adding chlorine or ozone in a contact tank. A final dosing of chlorine is required to maintain a disinfectant residual in the distribution system to prevent regrowth of bacteria and other harmful pathogens.
7. **Storage and distribution**: purified water is stored and/or distributed to end-users (municipalities or industry).

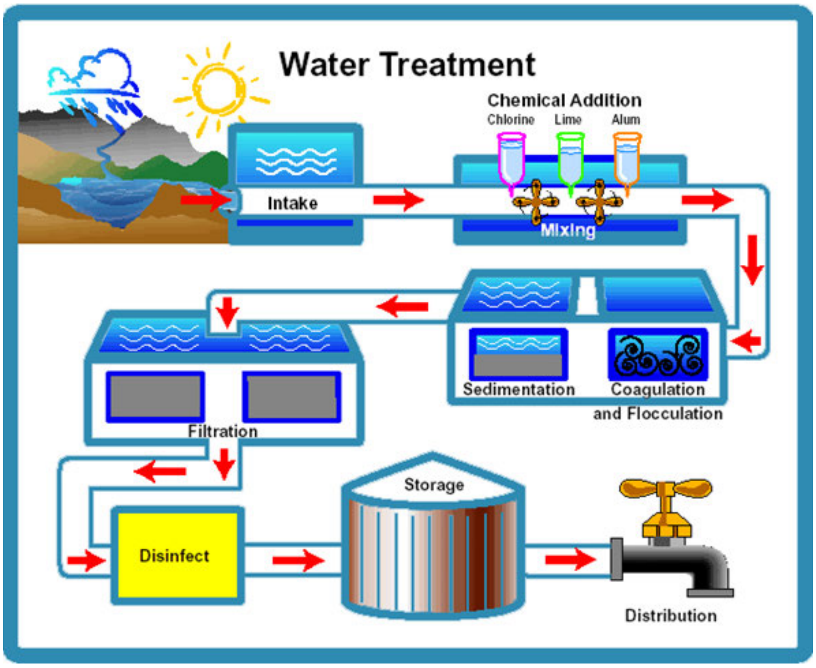

FIGURE 8: SCHEMATIC OF CONVENTIONAL WATER TREATMENT PLANT.

The use of PVDF UF membranes for the treatment of water for either municipal drinking water or for industrial process water, provides the following benefits:

- Reduction or elimination of pre-treatment chemicals.
- Elimination of coagulation and flocculation basins.
- Elimination of sedimentation basins.
- Replacement of sand filtration with a physical barrier so that contaminants are not subject to process upsets or operator error.
- Reduction or elimination of post-disinfection.

The use of PVDF UF membranes significantly eliminates the need for adding coagulants and other pre-treatment chemicals that are necessary in conventional treatment for aggregating small particles into larger particles that can be removed by gravity settling or by entrapment during granular media filtration. In some cases, coagulant can still be added during membrane treatment to destabilize dissolved organic matter present in raw water for colour removal and reduction of potential disinfection by-products. PVDF UF membranes eliminate the need for flocculation and sedimentation basins, as well. The large footprint occupied by the granular media filters is also replaced with the smaller footprint of the PVDF UF membrane systems: 2 to 4 times smaller. Post filtration disinfection can also be eliminated, and dosing of residual disinfectant reduced due to higher quality of finished water provided by membrane treatment.

Overall, the footprint of a PVDF-based UF membrane system can be 4 to 5 times less compared with a conventional treatment process.

Wastewater treatment: stages of treatment, MBR and advantages of UF membranes

Wastewater treatment is typically divided into four main categories: primary, secondary, tertiary, and quaternary treatment. Each of these treatment processes is designed to remove different types of contaminants and impurities from the water:

- **Primary treatment**: The primary treatment process involves physical and/or chemical processes that remove solids from the wastewater. This is typically done using sedimentation tanks that separate solids from the wastewater. The primary treatment process removes at least 50 % of the total solids in the wastewater.
- **Secondary treatment** consists of the following sub-treatments that are operated in a loop:
  - Biological treatment: The biological treatment process involves biological processes that break down dissolved and suspended organic matter in the wastewater. This is typically done by introducing microorganisms, such as bacteria, to the wastewater, which consume the organic matter and convert it into a form that can be removed from the water.
  - Secondary Clarification: The secondary clarification treatment process involves separation of the suspended solids and biomass from the wastewater. In conventional processes this separation is done by gravity settlers where the solids settle to the bottom and the clarified water overflows through troughs at the top. To avoid significant loss of the suspended solids, the biological process and secondary clarifiers must be operated at a suspended solids concentration typically lower than 5,000 mg/l. In MBR, the separation is carried out by the membranes. Since PVDF-based UF membranes provide a physical barrier to prevent loss of suspended solids, in this case the biological process can be operated at higher suspended solids concentrations, 8,000 mg/L or more, thus allowing a much more intensive biological treatment process and therefore smaller footprint. Additionally, the PVDF-based UF membranes themselves occupy significantly less space than secondary clarifiers. Therefore, the overall space required for the membrane bioreactor process with PVDF-based UF membranes is at least 4 times less than for conventional treatment.
- **Tertiary treatment:** The tertiary treatment process involves use of filtration (e.g., sand filtration, membranes) or physico-chemical treatment to further remove solids and contaminants from the clarified effluent (predominantly nitrogen, phosphorus and pathogenic microbes). This type of treatment is frequently used in wastewater reuse applications.
- **Quaternary treatment:** The quaternary treatment process involves additional treatment processes targeting a broader spectrum of contaminants, such as advanced filtration (reverse osmosis) to remove any remaining dissolved constituents from the treated water or adsorption with activated carbon to remove further organic compounds. This type of treatment is typically used in wastewater reuse applications.

The extraordinary benefit of wastewater treatment with [redacted]'s PVDF UF membranes is the combination of secondary and tertiary treatment to one single treatment process (i.e. the MBR treatment). This makes the wastewater treatment very compact and efficient (low space requirement, high treatment capacity) and effective (removal of contaminants). This has a high value especially in population dense areas where integration and reduction of impacts (low spatial requirements) are key. When stringent effluent requirements are needed (tighter nitrogen and phosphorus target, pathogens removal, reuse objectives), the implementation of a tertiary water treatment is mandatory. Membrane solutions have strong benefits in this case due to the membrane's "barrier effect" providing superior water quality for tight discharge or for reuse water quality objectives.

MBRs offer several advantages over traditional wastewater treatment systems. Due to the physical barrier offered by membranes compared to conventional clarifiers, MBRs can be operated at higher biomass concentrations without risk of biomass loss. This allows for a more effective treatment process with improved removal of organic matter and nutrients (nitrogen and phosphorus). In addition, MBR provides improved water quality compared with conventional treatment (low effluent turbidity, ability to meet most stringent targets for effluent nutrient levels, removal of other contaminants, such as viruses, micropollutants and microplastics).

PVDF is the essential membrane material within the high-fouling, high-solid MBR environment due to its chemical stability/inertness, mechanical properties (mechanical strength, wear resistance and flexibility) and ability to tolerate up to 1 million ppm-hours of chlorine, which allows the membrane to be cleaned frequently (daily maintenance cleaning - 200-400 ppm; and bi-yearly recovery cleaning - 1,000 ppm).

5.4. Key performance functionalities provided by PVDF UF membranes for the four (waste-)water treatment applications in scope of this AoA

The key performance functionalities of PVDF-based UF membranes that are required for all four water and wastewater Applications in scope of this AoA are described in detail below. Notably, any alternative membrane must fulfil the entire set of key performance functionalities to be considered a one-to-one replacement for PVDF-based UF membranes.

1. Low spatial requirements (small footprint of treatment plant)

The UF membranes allow to build water / wastewater infrastructures with limited footprint. This is applicable for new facilities providing additional treatment capacities (water volume treated per day) and also for extension of existing facilities facing increasing demand / new treatment requirements. This key performance functionality is required for dense population area, complex site topography where suitable available land is scarce. It avoids reconstruction of infrastructures outside of densely populated areas and related complex network installations. It allows a complete integration of the infrastructures with the surrounding environment. The combinability of treatment steps (membranes combining clarification and filtration for drinking water, MBR combining secondary and tertiary water treatment steps for wastewater) further enhances the footprint reduction of treatment plants. This possibility significantly lowers spatial requirements of the entire treatment plant and thus lowers costs for DUs (lower construction costs, lower operating costs, more flexibility for adaptations of existing plants, reduced planning/ construction time, etc.). Figure 9 is showing an example of MBR upgrade providing 1.75 times the initial flow capacity in one half the space.

FIGURE 9: EXAMPLE OF WWTP FOOTPRINT OPTIMISATION - 42 MLD FOR UPGRADE AND 24 MLD FOR CONVENTIONAL EXISTING LINE.

2. High chemical stability

High chemical stability of the membrane material is required for the resistance to a wide range of operating conditions linked to the applications. This enables membrane usage in applications with aggressive media (e.g. presences of various chemicals in the feed waters, cleaning agents, etc.). The chemical stability of a membrane material is described by:

- **Resistance to harsh chemicals:** 1,000,000 ppm x h sodium hypochlorite (NaOCl) exposure for membrane cleaning. NaOCl is a critical chemical that needs to be used for removing organic constituents and membrane disinfection.
- **Inert properties**: no reaction with media & no leaching ensures suitability for stringent criteria for use in drinking water and for wastewater applications with presence of biomass and potential presence of aggressive compounds like organic solvents. PVDF-based UF membranes are suitable to comply with stringent drinking water and wastewater Directives and Regulations (see chapter 5.1)

Importantly, high chemical stability results in long membrane lifetimes of 10 - 20 years (depending on application) which increases sustainability (less raw material consumption / less waste) of the industry sector and lowers costs for membranes for the DUs.

3. Fouling resistance

Resistance to fouling caused by inorganic and organic constituents that interact with and stick to the surface of the membranes. Natural organic matter, biological substances, surfactants, oil & grease, and other industrial compounds can foul membranes. This is especially important in MBR applications and especially critical for the treatment of industrial wastewater.

4. Mechanical properties

The membrane material needs to have strong mechanical properties to withstand the mechanical impacts that occur during application. The mechanical properties of a membrane material are described by:

- Membrane materials need to have high tensile strength and high flexibility to withstand stretching or pulling movements during applications: Elongation at yield > 25 % (ASTM D638); Tensile modulus <2200 MPa (ASTM D638). This property allows it to cover a wide range of solids loading among applications which require implementation of air bubbles rising outside of the membrane to avoid solids accumulation.
- Membrane materials need to have high wear resistance to withstand impact by abrasive particles during applications (sandblasting effect). The lifetime requirement is >10 years.

Importantly, high chemical stability and good mechanical properties result in long membrane lifetimes of 10 - 20 years (depending on application) which increases sustainability (less raw material consumption / less waste) of the industry sector and lowers costs for membranes for the DUs. The durability of the membrane material allows to reduce heavy maintenance operation for membrane replacement typically including isolation of process train, emptying and cleaning membranes receiving tank, disconnecting cassettes / modules, replacing modules, implement start-up procedures and prepare modules for proper disposal.

5. Separation and removal capacity

The membranes need to be suitable to simultaneously remove several pollutants: particles, pathogens (bacteria, giardia, Cryptosporidium viruses, etc.), colour, small organic compounds , microplastics. The separation and removal capacity of a membrane material are described as follows:

For physical separation, the membranes need to have an optimal barrier effect. This is the ability of membranes to selectively separate different substances based on their pore size (10 to 50 nanometres for ultrafiltration membranes). Membranes act as physical barriers that allow certain substances to pass through while blocking others. This functionality is highly interlinked with chemical stability and mechanical properties. Any damage of the membrane reduces its barrier effect and thus quality of filtered water. In turn, this can negatively impact the health of the public or the environment.

6. Low use of treatment chemicals

PVDF-based UF membranes do not require use of chemicals during the filtration process as is the case for conventional treatment (clarification and sand filtration). This is important for municipal and industrial infrastructures as it minimises risks due to the supply, transportation, and storage of these chemicals (e.g. iron chloride, aluminium sulphate, organic polymer flocculants, etc.) and allows sustainable disposal of residual solids from the treatment process. For example, a drinking water plant with a capacity of 50,000 m3/day and a conventional treatment can typically use one tonne per day of iron chloride and generate 0.5 - 1 tonnes per day of residual solids to be specifically handled.

5.5. Annual volume of the SVHC used

The overall assessed tonnage is 50 – 500 ([redacted]) tons PVDF/year. Table 2 below illustrates the development of the annual tonnage over the length of the substitution timeline (until 2040) under consideration of the positive impacts of [redacted]'s recycling process.

TABLE 2: ANNUAL TONNAGE DEVELOPMENT 2022 - 2040.

[redacted]

5.6. Efforts made to substitute/reduce PVDF use and environmental impact

[redacted] is committed to reduce the company's impact on the environment caused by the manufacturing and EOL of the PVDF membranes. This is in accordance with [redacted]'s Purpose to contribute to human progress by firmly committing to the Sustainable Development Goals set by the UN to achieve a better and more sustainable future for all[20]. To achieve maximum success, [redacted]'s strategy for safe and sustainable design of membranes is divided into four parts: (i) R&D on alternative membrane materials, (ii) reduction of PVDF consumption by improved membrane manufacturing process, (iii) recovery of PVDF from end-of-life ("**EOL**") membranes, and (iv) incineration of EOL membranes (not suitable for PVDF recovery process). Detailed information on the activities (incl. timeline) and targeted results are provided in the following chapters.

5.6.1. R&D on alternative materials – Technical limitation to replace PVDF in membrane formulations

R&D on hollow fiber membranes has been ongoing since the mid-1980s. In the early development of the outside-in hollow fiber membrane, PVDF was selected as the membrane material due to its unique characteristics such as mechanical properties (elongation and flexibility), wear resistance, resistance to harsh chemicals, resistance to fouling, etc. (see chapter 5.4). In the past 30 years [redacted] has further improved their PVDF membranes through continuous R&D efforts. Currently, [redacted] has an R&D team of [redacted] employees including scientists, engineers and technicians dedicated to the development of new hollow fiber membrane products and supporting the manufacturing of these products. In addition, [redacted] draws on the broader resources of the company's scientific experts, academic partner institutions [redacted] and industrial collaborations (e.g., [redacted]).

In 2022, [redacted] kicked off an initial investigation to compare PVDF and PES to better understand the performance gaps between membranes produced from these two polymers. Since the mechanical properties (elongation, flexibility) of PES are similar to many other existing polymers that can be considered for the production of membranes (e.g., chlorinated CPE, PAN); this evaluation provided an overall view of how an outside-in membrane using an alternative to PVDF will perform in the application.

For the performance investigation, a PES membrane was produced on [redacted]'s pilot line. Subsequently, a [redacted]-specific standard accelerated life-expectancy test was conducted to compare the PES versus PVDF membrane. In this test PVDF reached 20 simulated-years (test stopped once 20 simulated-years are reached) whereas the PES membrane began to show cracking and damage already after 1.5 years (see Figure 10).

Additionally, in a recent set of experiments (May 2023), [redacted] carried out bench-scale fatigue testing of hollow fibres made from PVDF, PES, PVC (CPE) and PAN. Testing involved a custom test unit with individually mounted membrane hollow fibres that were subjected to high frequency bending in order to compare the relative mechanical performance of the different membrane materials. Note that the testing was conducted under highly accelerated conditions using PVDF as a benchmark for comparison. Table 3 further demonstrates the significant gap between the mechanical performance of PVDF and all other materials. It should also be noted

[redacted]

that the results correlate well with the observations made in the full module testing where an order of magnitude difference in life expectancy was observed between PVDF and PES (>20 years versus 1.45 years or >13.8 times longer life). In this bench-test, a similar difference in performance was observed (>32 hours versus 4 hours or >8 times longer life). Based on this data, it can be concluded that none of the existing alternative materials provide the required mechanical properties (i.e., combination or strength and flexibility) to replace PVDF.

TABLE 3: MECHANICAL FATIGUE TESTING ON MEMBRANE MATERIALS.

Material	Time to Failure (hours)
PVDF	>32
PES	4
PVC (CPE)	2-4
PAN	<1

Since polymer properties are intrinsic and improvement by R&D does not present a promising substitution approach, [redacted] concludes that currently no alternative polymer is available that can be used/improved for producing outside-in hollow fiber membranes having identical chemical and mechanical properties to meet the requirements (see chapter 5.4) for the applications in scope of this report (see chapter 3).

For the development and implementation of a new polymer, [redacted] developed a substitution plan. Details are provided in chapter 6.1.1.

[redacted]

FIGURE 10: PES MEMBRANE SHOWING CRACKING AND DAMAGE AFTER 1.5 SIMULATED YEARS IN ACCELERATED TEST.

5.6.2. R&D efforts to reduce raw material consumption and carbon emissions

[redacted] has several ongoing projects to reduce the amount of new PVDF raw material used in their membrane production. Besides reducing raw material consumption, two other important drivers for these efforts are the reduction of cost and carbon footprint.

[redacted]

Membrane recycling to recover PVDF (see separate item for details)

Details on the work related to recycling of EOL membranes are provided below. [redacted] has an ongoing collaboration with [redacted] to recover PVDF from EOL membranes and subsequently use this recovered PVDF in the manufacturing of new membranes. The company's target is to use 30 - 35 % recycled PVDF by 2030.

[redacted]

[redacted]

FIGURE 11: PVDF USAGE AT THE [redacted] MANUFACTURING PLANT.

[redacted]

FIGURE 12: CO_2E CONTRIBUTION FROM PVDF + NMP (EMISSION FACTORS: 14.2 CO_2E/KG PVDF, 4.6 CO_2E/KG NMP (SOURCE: ECOINVENT 3.7.1).

5.6.3. R&D efforts to recover PVDF from EOL membranes

[redacted] sees a good opportunity to recycle PVDF from EOL membranes. For this, a recovery process needs to be developed that delivers high purity PVDF that can be used in the production of new membranes.

In 2020 [redacted][21] started collaborating with the company-internal [redacted] to investigate the applicability of recycled PVDF from EOL membranes. In this collaboration [redacted] was responsible for the establishment of the purification process and [redacted] investigated the usability of the recycled PVDF material in the production of new membranes. EOL membranes were transferred to [redacted] from various treatment plants to cover different applications and membrane conditions (e.g. level of fouling, contaminants, etc.). The membranes were cleaned using a proprietary methodology. The recycled PVDF was formulated in different ratios with new PVDF and new hollow fiber UF membranes were formed. The different membrane recipes were characterized for their properties. The outcome of the work on laboratory scale was that not more than [redacted] recycled PVDF can be used to keep the desired membrane product properties.

Since 2021, [redacted] is working in collaboration with [redacted] to further develop this purification process toward pilot and subsequently industrial scale.

[redacted]

FIGURE 13: TIMELINE FOR [redacted] & [redacted] COLLABORATION.

The main issue regarding the PVDF recovery process is that EOL membranes are fouled with a variety of inorganic particulates, organic products, and metal precipitates. To recover the PVDF, [redacted] and [redacted] are working on a two-step process involving (1) removal of contaminants by washing and (2) solvent dissolution and PVDF recovery by re-crystallization. The washing step is aimed at removing the contaminants from the membrane using a combination of different cleaning agents. The second step involves a special process whereby the washed membrane is dissolved in an organic solvent and the PVDF is re-crystallized to separate it from the other membrane constituents like membrane support material (e.g. polyester). Currently work is still being done at laboratory scale with small samples of EOL membranes. The purified PVDF is then used to produce membranes at pilot scale using different ratios of new and recycled PVDF. The membranes are characterised and compared with properties of membranes produced purely with new PVDF. To date, a ratio of [redacted] recycled PVDF in pilot scale membrane manufacturing is achieved.

Based on a preliminary evaluation of the business case for recycling PVDF from EOL membranes, it was concluded that a minimum amount of roughly 500 tonnes/year of recovered PVDF would be needed to run an efficient and economic viable recycling operation. [redacted] has estimated that by 2030 it could be possible to recover approximately [redacted] of PVDF in Europe based on the

[21] [redacted] at that time.

expected membrane replacements and assuming 90 % of membrane modules can be collected for recycling. It is expected that an additional [redacted] of PVDF could be recovered from North America for a total of [redacted] of recycled PVDF. This amount of recovered PVDF would represent [redacted] of the expected annual PVDF consumption for [redacted]'s [redacted] manufacturing plant. Based on this calculation, a 35 % target has been set for optimising the purification process. At least two additional years are required to confirm the feasibility of the 35 % target. However, the collaboration between [redacted] and [redacted] represents strong expertise towards this goal: [redacted]'s mother company, [redacted], is a world leader in recycling and recovery business while [redacted] provides the expertise in chemical processing. Importantly, the recycling of PVDF will need to be extended to the EOL membranes of other PVDF membrane producers to achieve economy of scale for the collection and recovery of EOL membranes and use of recycled PVDF in new membrane production (around 500 t/y).

The following chart lays out the estimated timeline to complete the R&D work, conduct pilot trials for EOL membrane collection and processing, development of robust business plan and make the investments required for large scale collection and processing. Based on this timeline it is expected that by 2030, the recycling of EOL membranes could reduce the reliance on new PVDF by up to 30 - 35 %.

[redacted]

FIGURE 14: TIMELINE FOR IMPLEMENTATION OF EOL MEMBRANE RECYCLING.

Potential PVDF emission by recycling

Due to the very early stage of developing the recycling process no quantified estimations can be provided for potential PVDF emissions caused by it. Since the envisaged recycling of PVDF from EOL membranes involves a solubilisation / crystallisation step (see point (2) above) emissions cannot be excluded. However, since the recycling process is currently in the initial phase of development, potential PVDF emissions can be taken into consideration and appropriate RMMs can be implemented. [redacted] is committed to ensure no PVDF emissions during the recycling process.

5.6.4. R&D efforts to incinerate EOL membranes

Beside PVDF recovery, [redacted] is evaluating incineration of EOL membranes as an alternative disposal route to landfill. The company's plan is to combine PVDF recovery and incineration to achieve the least possible environmental impact. Importantly, approximately 55 % of [redacted]'s customers located in the European Economic Area ("**EEA**") are performing incineration already. Since disposal of EOL membranes is the customers' responsibility, no information is currently available to [redacted] on applied incineration conditions (hazardous / non-hazardous), incineration efficiency / completeness of PVDF destruction and potential emissions of PVDF/PFAS incineration products via air and in ashes. However, with the efforts described below [redacted] is aiming to:

1) Investigate optimal incineration conditions to ensure the highest possible level of PVDF mineralisation (= incineration efficiency).
2) Identify relevant RMMs for potential PVDF/PFAS incineration products emissions via air and in ashes.
3) Transition remaining portion of customers (45 %) currently applying landfill to dispose EOL membranes to established incineration process.

In this respect, points 1) and 2) will be applied to improve the current situation for the 55 % of customers that already apply incineration, if required.

The challenge in this project is the fact that PVDF is the only fluorinated compound present in [redacted]'s membrane modules (< [redacted] %) and only contained in the membrane itself. The rest of the module is made of other polymers either part of the membranes or part of the membranes' holding pieces.

To determine the proper conditions for incineration at industrial scale, an assessment at lab scale simulating membrane incineration under hazardous / non-hazardous incineration conditions is needed. This will be conducted by [redacted]'s Corporate Research Group [22]. More precisely, this step will allow us to determine the right incineration temperature / retention time as a function of destruction objectives. To carry out this experimentation, [redacted] is working with its [redacted] In addition, [redacted] is in contact with the American Chemical Council ("**ACC**") to collaborate on a program to carry out pilot scale tests followed by an industrial scale trial.

The results from the industrial pilot scale will be aggregated with a global model including:

- modules collection covering EEA, bringing the used modules to a conditioning site.
- modules conditioning preparing the used modules for downstream treatment.
- shipment and final disposal of conditioned modules at incineration facilities.

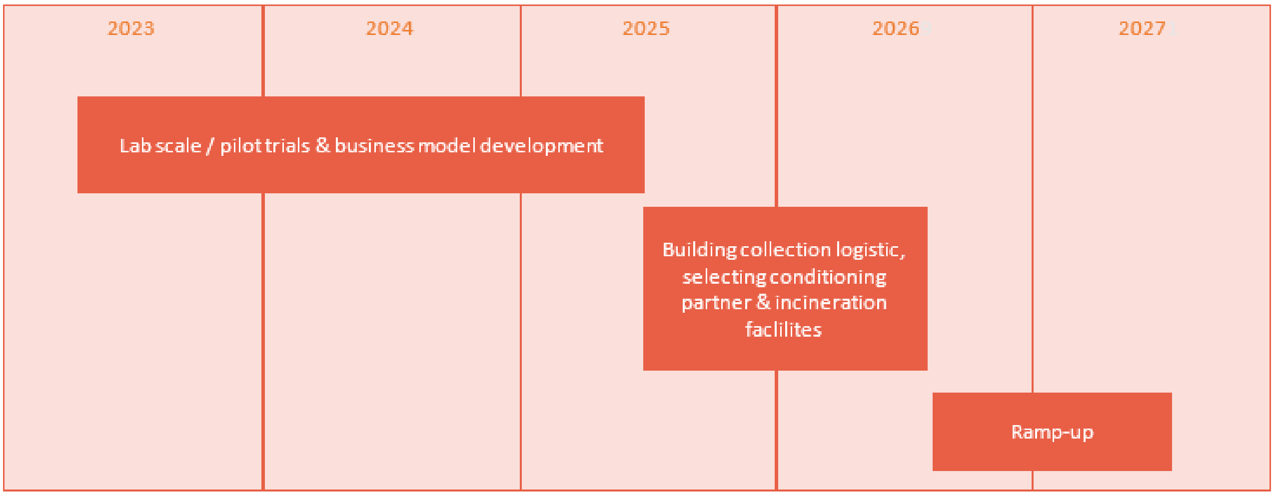

FIGURE 15: TIMELINE TO REACH 100 % INCINERATION WITHIN THE EEA.

[22] Note: [redacted] is conducting at least two other planned studies on incineration of PVDF, at least one will also involve the incineration of EOL membranes.

Importantly, incineration is much more cost intensive compared to landfill. For comparison:

- Non-hazardous landfill disposal cost: 60 to 100 EUR / ton
- Non-hazardous incineration cost: 100 to 250 EUR / ton
- Hazardous incineration cost (1100°C): 600 to 1000 EUR / ton

These costs will need to be carried by DUs (water/wastewater treatment plants). For a medium size treatment plant an exemplary cost calculation is provided in the following:

- Wastewater treatment plant with 15,000 m³/day capacity
- Total membrane module mass: 13,000 kg
- Minimum membrane life: 10 years
- Landfill disposal cost at EOL: ~ EUR 1000 (transport not included)
- Incineration cost at EOL: ~ EUR 11 000 (conditioning & transport not included)

However, these additional costs on DUs side are not considered significant and therefore do not hinder [redacted]'s incineration strategy. As described in the beginning of this chapter, the company's strategy is to achieve 100 % incineration under correct conditions and with least potential for environmental impact.

5.6.5. Performance comparison of alternatives

[redacted] has evaluated potential alternatives to PVDF-based UF membranes. The evaluation is based on experimental data, company and [redacted] Group expert knowledge gathered over decades. The assessment of alternatives is done by comparison of the critical performance criteria derived from the applications in scope of this report (see chapter 5.4). In Table 4, an overview on the technical performance (incl. colour-coded assessment) of relevant alternatives is provided. Importantly, to date, no alternative is available that can be used by the DUs as one-to-one replacement to PVDF-based UF membranes in their specific applications.

A general assessment of the availability, economic feasibility and hazard & risk of the alternatives is provided in the section below.

TABLE 4: PERFORMANCE COMPARISON OF ALTERNATIVES (CONVENTIONAL TREATMENT AND ALTERNATIVE MEMBRANE MATERIALS).

	Alternative 1: conventional treatment	**Alternative 2: PES-based UF membrane**	**Alternative 3: CPE-based MF membrane**	**Alternative 4: PAN-based UF membrane**	**Alternative 5: Ceramic-based microfiltration (MF) membrane**
Low spatial requirements (footprint)	Not sufficient → conventional treatment plants have 2 to 4 times higher spatial requirements compared to PVDF-based membrane plants (Mannina, Odegaard, & Hallvard Olsson, 2018) (Parks, 2011). Additionally, no combination of secondary & tertiary treatment is possible.	Partly sufficient → PES-based membrane plants have 1-2 times higher spatial requirements depending on membrane configuration and flux.	Not sufficient → CPE-based membrane plants have 2 times higher spatial requirements compared to PVDF-based membrane plants.	Not sufficient → PAN-based membrane plants have 2 times higher spatial requirements compared to PVDF-based membrane plants.	Not sufficient → Ceramic-based membrane plants have 5 times higher spatial requirements compared to PVDF-based membrane plants.
Chemical stability	Materials selected to handle exposure to media and chemicals for life > 10 years.	Not sufficient → PES 5x lower chlorine resistance compared with PVDF (used for cleaning and disinfection) (Arkema); (Malczewska & Zak, 2019) (Li, Su, Wen, & Huang, 2021)	Not sufficient → CPE 4x lower chlorine resistance compared with PVDF (used for cleaning and disinfection) (Rocha da Costa, 2015)	Not sufficient → PAN 10x lower chlorine resistance compared with PVDF (used for cleaning and disinfection) (Yinghua, 2021)	Sufficient → material able to handle a wide range of chemicals.
Fouling resistance	n/a	Partly sufficient → PES membranes in pressurised configuration can be operated at similar flux to PVDF but at lower flux for MBR submerged flat-plate.	Partly sufficient → CPE submerged flat-plate membranes have lower fouling resistance compared with PVDF HF and flat-plate.	Partly sufficient → PAN membranes have lower fouling resistance in treating surface waters and sewage, good fouling resistance for oils.	Sufficient → ceramic membranes show similar fouling resistance to PVDF.
Mechanical properties	Materials selected to support mechanical stress for life > 10 years	Not sufficient → PES lacks flexibility for outside-in hollow fibre membranes (resulting in cracking of the membrane)	Not sufficient → CPE lacks flexibility for outside-in hollow fibre membranes (resulting in cracking of the membrane)	Not sufficient → PAN lacks flexibility for outside-in hollow fibre membranes (resulting in cracking of the membrane)	Partly sufficient → Outside-in ceramic plates lack long-running references to demonstrate mechanical robustness; ceramic plates are brittle and therefore prone to thermal or pressure shock

	Alternative 1: conventional treatment	**Alternative 2: PES-based UF membrane**	**Alternative 3: CPE-based MF membrane**	**Alternative 4: PAN-based UF membrane**	**Alternative 5: Ceramic-based microfiltration (MF) membrane**
Separation and removal capacity	Insufficient → separation and removal capacity of conventional treatment not comparable to PVDF membranes. Additional treatments required which increase spatial requirements of the treatment plant.	Sufficient → separation and removal capacity of PES-based membranes comparable to PVDF (if membrane is intact – see Mechanical properties).	Partly sufficient → lower separation capability of CPE-based membranes compared to PVDF due to larger pore size.	Sufficient → separation and removal capacity of PAN-based membranes comparable to PVDF (if membrane is intact – see Mechanical properties).	Partly sufficient → lower separation of Ceramic-based membranes compared to PVDF due to larger pore size.
Low use of treatment chemicals	Not sufficient → metal salts and organic polymers added to water to remove contaminants, generation of sludge requiring disposal.	Sufficient → no chemicals/additives needed for treatment.	Partly sufficient → Metal salt addition sometimes needed for preventing fouling and/or improving contaminant removal due to larger pore size compared to PVDF membranes.	Sufficient → no chemicals/additives needed for treatment.	Partly sufficient → Some metal salt addition sometimes needed for preventing fouling and/or improving contaminant removal due to larger pore size compared to PVDF membranes.

General assessment of availability and economic feasibility of alternatives

All alternatives described in Table 4 are commercially available. However, due to technical limitations they are not considered technically suitable for one-to-one replacements in applications/plants specifically optimally designed with PVDF-based UF membranes. As described, a suitable alternative needs to be a one-to-one replacement to ensure optimal plant construction / plant operation without detrimental impact.

Please note that in the event that the use of PVDF-based UF membranes would be restricted without the requested 15.5-year derogation (calculated from EiF in 2025, see chapter 6.1.1) the EU society and industry would be heavily impacted. This is because on the one hand, existing water/wastewater treatment plants designed for using PVDF-based UF membranes would not have a 1-to-1 replacement and therefore could not treat the required flow and quality and on the other hand, the construction of new water/wastewater treatment plants relying on the unique performance functionalities of PVDF-based UF membrane technology (see chapter 5.4) simply could not be built at required places.

In case of restriction, the following theoretical scenarios apply:

- **Scenario 1:** where technically possible, heavily re-construct existing treatment plants to enable other treatment technologies/membranes. Importantly, this option involves building of additional treatment lines since the treatment capacity (water volume treated per day) of plants applying PVDF-based membranes cannot be fully compensated within the existing footprint by any alternative and related re-construction measures (see Table 4– critical function 1). Re-construction and construction of new treatment capacities is estimated to take between 5 to 7 years (including obtaining permits and the conduct of public procurements procedures) and requires a substantial investment per plant:
    - Small (≤ 1,000 m^3/d plant capacity): Up to EUR 2 million
    - Medium (> 1,000 to ≤ 10,000 m^3/d plant capacity): EUR 2 to 10 million
    - Large (> 10,000 to 100,000 m^3/d plant capacity): EUR 10 to 70 million
- **Scenario 2:** to build new treatment plants to compensate for treatment capacity loss from implementation of other treatment technologies / alternatives. With all necessary steps (finding land, authority approval, construction, etc.) building a new treatment plant takes 5 - 7 years and requires a substantial investment per plant:
    - Small (≤ 1,000 m^3/d plant capacity): Up to EUR 5 million
    - Medium (> 1,000 to ≤ 10,000 m^3/d plant capacity): EUR 5 to 25 million
    - Large (> 10,000 to 100,000 m^3/d plant capacity): EUR 25 to 250 million
- **Scenario 3:** new water/wastewater treatment plants relying on the unique performance functionalities of PVDF-based UF membrane technology (see chapter 5.4) would be limited to such extent that they simply cannot be built at required places, e.g. cities where land is scarce and/or topology is complex, within the boundary limits of industrial sites. Where possible, construction of new water / wastewater infrastructures would require making complex and 1.5 to 2.5 times more expensive construction projects like underground and/or multi-floors treatment facilities. This is especially the case for publicly owned treatment plants since these additional costs are simply not justifiable to taxpayers.

Besides the risk of endangering water supply and safe water discharge in the EU, scenarios 1 and 2 are clearly not considered economically feasible by [redacted]'s DUs. Please refer to the analysis [redacted]'s DUs survey for justification (see chapter 6.3).

Concluding, the commercially available alternatives are not technically suitable as one-to-one replacements for [redacted]'s DUs. Due to their technical infeasibility as one-to-one replacement they are also not economically feasible as outlined in Scenario 1 and Scenario 2.

General assessment of hazard & risk of alternatives

Since there is currently no alternative material identified that has promising properties to become a one-to-one replacement no related hazard & risk assessment can be provided. In general, chemicals – especially new ones - and their hazards & risks are not always known. To prevent regrettable substitution [redacted] will therefore need to carefully approach substitution. Therefore, hazard and risk classification of potential alternatives will be part of initial R&D investigations.

6. SOCIO-ECONOMIC ANALYSIS

6.1. Continued use scenario

6.1.1. Substitution plan including best-case estimated timeline

Based on their performance, comparison of other alternative membrane materials (see chapter 5.6.5), [redacted] developed a best case estimated timeline to substitute PVDF-based UF membranes. The stages of the substitution timeline are described in the following. A graphical illustration is presented in Figure 16.

Importantly, the substitution timeline is developed for the scenario of replacing the PVDF-based UF membranes one to one with an alternative-based UF membrane. The substitution timeline does not consider a switch to a completely different treatment technology. This is because PVDF-based UF membranes currently offer the only available option for providing high quality treated water (meeting compliance obligations under EU legal requirements) in the small footprint required by relevant municipal and industrial DUs (see chapter 5.1).

In addition, for existing DUs, once a specific plant setup is decided and constructed, little to no adaptations are possible regarding the core treatment unit. In other words, a plant designed for water/wastewater treatment via UF membranes will always rely on the usage of UF membranes and cannot simply switch to a completely different treatment technology. More specifically, in case a PVDF UF membrane is chosen, customers need to be able to replace the membranes with PVDF UF membranes once end-of-life (10 - 20 years) is reached. Otherwise, critical parameters like plant capacity (water volume treated per day) and water quality cannot be met. Notably, these parameters are pre-defined during plant design and need to be guaranteed throughout a plant’s service life (40 - 50 years). Besides technical arguments, costs are another important factor for customers. PVDF UF membranes have the best price-to-lifetime ratio available on the market.

Stage 1: Development of new polymer / polymer blend with suppliers (≥ 4.5 years)

This stage involves developing a new type of polymer system or special polymer-blend which is currently not available commercially. This requires close collaboration with external polymer researchers and consequently cooperation with a polymer manufacturer that would be able to market the new polymer system or polymer-blend. The goal of this stage is to develop a new polymer that matches the performance and characteristics of PVDF on laboratory scale (1 - 10 kg). For this purpose, iterative development rounds involving synthesis of new polymers, testing of physicochemical properties (e.g. solubility, solution viscosity, flexural modulus, elongation at yield, stability to oxidation) and, based on test results, adaption of formulations need to be considered. Besides, [redacted] needs to manufacture actual UF membranes from the new polymer. This is required to further conclude on the new polymer’s technical suitability and its potential to be manufactured into a UF membrane. The key parameters shown in Table 5 will need to be evaluated for the produced membranes (Note: all parameters are linked to the performance requirements of PVDF-based UF membranes described in chapter 5.4). Throughout the development process, safety/toxicology/ecotoxicology criteria will be considered for new polymers and membrane production to prevent a regrettable substitution scenario.

TABLE 5: ASSESSMENT PARAMETERS OF STAGE 1.

[redacted]

[1] exposure for membrane cleaning (NaOCl is a critical chemical used for removing organic constituents and disinfection)
[2] [redacted] standard accelerated test

Based on the current stage of R&D, [redacted] estimates that at least 4.5 additional years are required to develop a new polymer formulation that can be investigated further in scale-up trials for polymer manufacturing.

The work packages for this stage are defined as follows:

- Q2 2023 to Q4 2023: Literature review & building of cooperations with external experts and polymer manufacturers
- Q1 2024 to Q2 2026: Development of polymer blends and additives, evaluation of key parameters defined in Table 5
- Q3 2026 to Q4 2027: Lab scale membrane trials with polymer blends and additives to select membrane formulation alternatives

Please note that R&D success is highly speculative and cannot be guaranteed. For this reason, [redacted] will continue with the search for additional candidates, even after starting pilot scale investigations with a certain polymer formulation. This process is required to have a backup solution in case of polymer failure at a later stage of development.

Stage 2: Formula freeze and pilot scale production of polymer and membrane + accelerated life expectancy testing and field trials (≥ 5 years)

Once laboratory scale investigations are successful for a new polymer blend (i.e. desired physicochemical properties are achieved), the formulation is considered ready for pilot scale trials on polymer production. This stage involves designing, purchasing, and installing the required equipment for pilot scale polymer manufacturing (ca. 100 kg). Trials will need to be completed on relevant production related parameters for the polymerization process and optimization of the polymerization rate, production yield, and post-treatment (e.g. purification). All the above is the responsibility of the chemical supplier.

In parallel, the membrane manufacturing process needs to be brought to pilot scale (ca. 100 kg) too. For this purpose, [redacted] needs to design, purchase, and install the relevant pilot scale equipment and afterwards examine the membrane manufacturing concerning all parameters that are important for scale-up trials and commercialization. Relevant production related parameters to be investigated for the membrane manufacturing process are process chemicals (e.g. solvent), process temperature, stage separation process from polymer raw material to membrane, production yield, post-treatment, initial investigations for production peripherals (e.g. wastewater treatment, solvent recovery), etc. During Stage 2, [redacted] needs to conduct extensive accelerated life expectancy testing and extensive field trials with the new UF membrane. In this stage, the [redacted]-specific standard accelerated life-expectancy test is conducted on a statistically relevant number of full-size membrane modules to compare the new membrane versus the PVDF membrane and must demonstrate the ability to achieve the simulated 20 years of service life. Testing of the membrane in field trials will also be necessary during this stage to validate that the alternative polymer can match the performance of PVDF in the applications. This will require production of membranes and modules that can be placed in field pilot test equipment or directly into customer plants to collect data on the performance of the membranes (flow and water quality from the membranes). The field trials need to be performed for all of [redacted]'s treatment applications (see chapter 3) to assess if the new polymer is capable to stand up under real-life conditions. Notably, the field tests are not performed over the required 10 - 20-year lifetime of their membranes. After 2 - 3 years in the respective application, the membranes are removed and investigated comparing the critical properties of the membrane (permeability, rejection, burst pressure, tensile modulus, etc.), degree of fouling, structural damage, etc.

Based on their long-term expertise, [redacted] estimates that this stage takes at least five years (at least two years for polymer and membrane scale-up activities and at least three years for accelerated life expectancy testing and field trials for validation of membrane performance) to be completed. However, Stage 2 only adds four years to the overall substitution timeline due to a one-year overlap to Stage 3. No overlap to Stage 1 is possible because investment in pilot scale production is not reasonable before freeze of formulation.

The work packages for this stage are defined as follows:

- Q1 2028 to Q3 2028: Design and construct pilot equipment for polymer production and membrane pilot manufacturing
- Q4 2028 to Q4 2029: Membrane pilot manufacturing trials, formulation and process optimization
- Q1 2030 to Q2 2030: Produce membranes for accelerated testing and field trials
- Q3 2030 to Q4 2032: Carry out accelerated testing and field tests to validate new membrane formulation

Stage 3: Scale up trials for polymer and membrane production including polymer and membrane certifications (≥ 4 years)

Once sufficient certainty on the success of the substitution project is gathered from Stage 2, further iterative up-scaling trials to approx. 1,000 kg need to be conducted. Currently, [redacted] estimates that for the polymer as well as the membrane production process at least two stages of up-scaling are required between pilot (0.1 t) and commercial scale (> 100 t). This involves basically the same topics as described in Stage 2. However, more focus will already be on the production design, i.e. low spatial requirements, engineering of production equipment, material handling systems, utilities, etc. During Stage 3, the polymer supplier and [redacted] will perform the certification processes for both the new polymer blend and certifications required for the new UF membrane.

[redacted] estimates that at least five years are required for this stage. However, Stage 3 only contributes three additional years to the overall substitution timeline due to overlaps to the preceding and subsequent stage.

The work packages for this stage are defined as follows:

- Q1 2032 to Q4 2032: Expansion of polymer pilot production for larger scale manufacturing trials (100 kg to 1000 kg)
- Q1 2033 to Q4 2036: Carry out polymer production and membrane scale-up trials. Additional accelerated testing and field trials with larger number of membranes including multiple field trial sites
- Q1 2033 to Q4 2036: Certification of polymer and membrane for water contact including Germany (Kunststoff-Trinkwasser), France (ACS), Italy (ICIM), Hungary (ANTSZ), Poland (PZH), Unites States of America (NSF-61 and NSF-419), UK (DWI)

Stage 4: Scale up of polymer production / manufacturing investment and structural measures for membrane manufacturing (≥ 3 years)

In Stage 4, the polymer supplier as well as [redacted] need to take the final steps for production at commercial scale. Importantly, [redacted] needs to implement a completely new production line in parallel to the existing one. Only having the two processes active in parallel for a certain period ensures transition to 100 % alternative in Stage 5 without impacting EU supply. Logically, the installation of a second production line at the site in [redacted] involves significant financial investments and structural measures to enable setup of the necessary production equipment (for handling and processing of the alternative polymer). Besides installation of equipment, the time required for permits / authority approvals needs to be considered in Stage 4.

[redacted] estimates that Stage 4 takes at least three years. However, Stage 4 only contributes two additional years to the overall substitution timeline due to a one-year overlap to the preceding stage.

The work packages for this stage are defined as follows:

- Q1 2035 to Q4 2035: Design of commercial scale production equipment for polymer manufacturing and [redacted] membrane manufacturing
- Q1 2036 to Q4 2038: Installation and commissioning of production equipment at polymer manufacturer and [redacted] ([redacted])

Stage 5: Ramp-up of membrane manufacturing (≥ 2 years)

In Stage 5, [redacted] needs to initiate commercial production of alternative membranes. Importantly, this production ramp-up is performed with a steady increase of production volume until the quantity for 100 % supply is achieved. Since experience needs to be gained with the new process, [redacted] estimates that the ramp-up takes at least two years. To ensure supply to all DUs while making the transition to the alternative, the PVDF-based process needs to be active in parallel.

The work packages for this stage are defined as follows:

- Q1 2039 to Q4 2039: Ramp-up of production of new membrane and 1st order delivery
- Q1 2040 to Q4 2040: Ramp-down of PVDF membrane production, depletion of inventories

Derivation of derogation timeline required to substitute PVDF-based UF membranes

Based on the above-described timelines, including all relevant overlaps, the substitution of PVDF-based membranes at [redacted] requires at least 17.5 years calculated from Q2 2023 (the time point of submitting comments to the present public consultation). This means that from the expected EiF date of the PFAS restriction in Q2 2025, a derogation of at least 15.5 years is required for [redacted] to substitute PVDF-based UF membranes while ensuring supply with critical components to EU water and wastewater treatment plants. A graphical presentation of the timeline is provided in Figure 16.

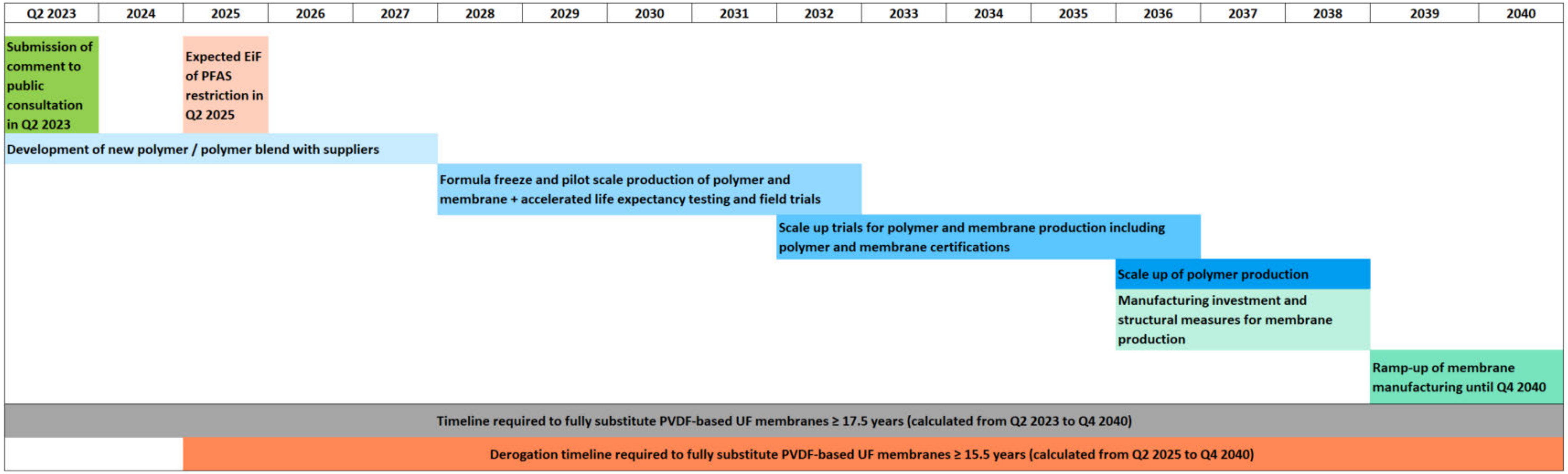

FIGURE 16: [redacted]'S PLAN TO SUBSTITUTE PVDF-BASED UF MEMBRANES.

6.1.2. Factors affecting substitution

The following factors impact the substitution of PVDF-based membranes:

- Non-availability of one-to-one replacement to PVDF-based UF membranes (see chapter 5.6.5.
- Economic disproportionateness to re-construct existing treatment plants and/or build new ones. In this respect, it needs to be highlighted that public treatment infrastructures are financed by public financing. Thus, a restriction induced necessity to re-construct treatment plants and/or build new needs to be financed by people's tax money with potential increase of water tariffs directly impacting consumers (see chapter 5.6.5).
- Criticality of water supply due to climate change, urbanization, growing population and sustainability targets of industry (see chapter 5.1).
- Reliance of public (e.g. municipalities) and private (e.g. manufacturing site) DUs on PVDF-based UF membranes to ensure water supply and safe wastewater discharge both in required quality and quantity (see chapter 5.1 and 5.6.5).

6.1.3. Monitoring of implementation of Substitution Plan

[redacted] follows the well-established Stage-Gate process for the management of R&D and product commercialization. As part of the Stage-Gate process, regular progress reviews are conducted with project stakeholders and progress is reported to the company's senior leadership. The Stage-Gate process has specific deliverables and checklists for each stage of the project. The project will be assigned to a project manager with responsibility to manage schedule, budgeting and reporting. The project manager is also responsible for assessing resource requirements for the project and working with functional managers to ensure appropriate resourcing of the project to meet project deliverables and timelines.

Since the Substitution Plan requires the collaboration between [redacted] and one or more polymer suppliers, these collaboration agreements will be established with detailed project plans and timelines integrated into [redacted]s overall project schedule. Cross-company project teams and senior steering committees will be established to ensure there is proper coordination between the parties and project milestones can be met.

6.2. Risks associated with continued use

Within the CSR, the different life stages of PVDF membranes were identified: manufacturing, operation, and end-of-life. The sources of potential PFAS emissions to the environment at each stage were identified, as were RMMs.

PVDF is purchased from [redacted]. It is polymerized exclusively from 1,1-difluoroethylene (VDF), not involving other per- and polyfluoroalkyl substances. In 2022, a total of [redacted] tons of PVDF were used at the [redacted] site for the manufacturing of PVDF membranes.

For the manufacturing stage of PVDF membranes, potential emission sources for PFAS/PVDF include dust, wastewater, and other waste articles. Of the tonnage used, less than [redacted] % hence less than [redacted] kg of PVDF, were emitted as dust in areas where PVDF raw material is handled. To capture these emissions, one unloading area is swept or vacuumed in case of any incidental spills and the other unloading area is equipped with a filter system. Additionally, these two areas are regularly cleaned. The waste from cleaning is collected and disposed of as hazardous waste. Contaminated water coming from the removal of incidental spills of PVDF raw material is disposed of and sent for incineration. In the process steps after PVDF was dissolved, exhaust ventilation systems are installed.

As discussed and referenced in the CSR, the concentration of residual monomer (VDF) in PVDF was determined to be < 50 ppb and therefore considered to be of limited relevance for further environmental assessments of PVDF used for membrane manufacturing. The leaching of PFAS by-products from PVDF raw material into water was examined, and no PFAS concentrations above analytical detection limits were identified. Moreover, the leaching potential of PVDF raw material was examined by TOF analysis. The results indicated low concentrations (ng/L), resulting in a potentially leachable amount of [redacted] g TOF/a in relation to the annual tonnage of [redacted] t (2022). The TOF leaching from raw material may end up in the spinline wastewater and subsequently in the on-site [redacted] MBR wastewater treatment plant as no TOF was found to be leaching from newly produced membranes (see section 4.3.3). [redacted] will carry out further investigations to understand the nature of this potential [redacted] g TOF/a emission and their fate.

During the production of PVDF membranes, around 1,000 to 1,300 m^3 of industrial wastewater are emitted per day, which is directed to the on-site MBR wastewater treatment plant before entering a municipal wastewater treatment plant. Wastewater samples confirmed that no typically measured PFAS or TOF were found in concentrations above analytical detection limits. It is assumed that also no PVDF is emitted by industrial process wastewater as PVDF is not considered to be able to pass in any form (solubilized or suspended) through the MBR with ultrafiltration membrane (pore size about 10 to 50 nm). Finally, any other waste produced during the manufacture of PVDF membranes, such as organic chemical waste, PVDF packaging or scrap membranes, is either incinerated or disposed of in landfills for non-hazardous waste. The exact amounts per waste type can be found in section 4.2.4 of the CSR. Since analyzed PFAS and organic fluorine compounds in wastewater samples were below analytical detection limits, it can be assumed that none of the analyzed PFAS is expected in the sludge produced by the WWTP. Nonetheless, [redacted] is also committed to further investigate this matter.

The next stage in the lifecycle of PVDF membranes is their service life. PVDF raw material, freshly produced membranes, and PVDF membranes operated in water technology process for years (4–20 years) have been tested for PFAS and TOF emissions. No PFAS releases above analytical detection limit and/or including analytical background were detected in membrane leachates. Foulants removed from used membranes contained some PFAS above the background levels. However, as these foulants are considered to accumulate PFAS from different sources during the use phase these measurements are interpreted as independent from PVDF membranes. This also relates to a measurement of leachate of a cleaned membrane, which showed concentrations of PFBS above the limit of detection. The correlated concentration of PFBS in the foulant as well as the leachate of the uncleaned membrane were considerably high and indicate a remaining contamination. Leachate of cleaned, used membranes from the other five scenarios did not result in PFBS values above the detection limit.

The last stage concerns the end-of-life phase of PVDF membranes, which is currently handled by incineration or disposal in landfills for non-hazardous waste. In a survey, downstream users (DUs) were asked about their methods of disposing of the [redacted] UF membranes. Different methods such as non-hazardous landfill (29 %), municipal incineration (14 %) and hazardous waste incineration (21 %) emerged. Regarding incineration, it is concluded that no estimations of PFAS/PVDF releases from the incineration of waste can be made, due to the lack of reliable degradation and/or release rates for PVDF. Moreover, [redacted] has commissioned a study on this topic, and results are expected before the end of 2023.

Concerning the disposal to landfills, an anaerobic biodegradability study on PVDF breakdown/stability has been conducted on behalf of [redacted]. The calculated biodegradation rate is so small that it cannot be interpreted as biological degradation. In addition, PFAS levels in the supernatant and solids of control groups were higher than or comparable to the range of values detected for the membrane and PVDF powder groups. The overall study shows evidence that PVDF is stable in landfill conditions.

From the data summarized above it was concluded that the emission potential during the life-cycle of PVDF-based membranes is extremely small and controlled. Leaching of typically measured PFAS from raw material, membranes after production and during various stages of their service life are below analytical limit values or in the range of the laboratory background. Similarly, TOF measurements of membrane leachate resulted in values below the limit of detection. A very small amount of TOF ([redacted] g TOF/a) may leach from raw material during manufacturing process (observed from laboratory leaching tests). [redacted] will carry out further investigations of at the manufacturing plant to understand if there is any actual TOF emission, the nature of this potential emission and its fate. Apart from this, emissions to the environment from the manufacturing process are controlled due to the implemented RMMs and the technical prerequisites of the process. The database for the estimation of potential emissions from waste treatment at the end of service life via incineration and landfilling is currently weak, and release rates of PVDF or degradation products have not been identified. However, recent new information suggests limited potential for the creation of PFAS during incineration.

As no complete data set or release rates were available for the incineration route, it was concluded that no estimate on these emissions is possible at this time. Further analysis on any potential release through incineration can be completed once planned incineration studies have been completed. As the nature of potential emissions from the manufacturing side due to raw material leaching are subject to more detailed analysis, no emission data were considered available for further assessment under this SEA.

6.3. Restriction scenario

As the AoA supports the absence of an economically and technically feasible one-to-one alternative to PVDF for [redacted] membranes for the four Applications covered by this submission, the SEA provides an evaluation of the most likely restriction scenario. This restriction scenario is described from the perspective of [redacted]. Being the EEA market leader in this segment, the impact of the restriction scenario on the EEA society can be seen to provide a representative picture for all stakeholders.

It must be noted that the restriction scenario is described for the collective use of PVDF UF membranes for all four Applications considered in this assessment. Examples of individual Applications are however provided as case studies to provide a holistic view of the implications as far as possible.

As derived in the AoA, the restriction scenario foresees a timeline of 15.5 years beginning from Q2 2025 (EiF) to Q4 2040. Accounting for the transition period of 18 months after EiF, the impact realisation period is assumed to commence from the beginning of 2027.

A restriction of PVDF in [redacted] membranes will result in the corresponding business closure for [redacted] in the EEA. [redacted] would be forced to close operations at the [redacted] production plant in [redacted] and relocate its entire [redacted] UF membrane production outside the EEA, where it will continue to supply the rest of the global market. Based on current knowledge, competitors are not known to have a technically and economically feasible alternative readily available for commercialization and can be anticipated to be in a similar position[23].

Consultation on restriction scenario with [redacted]'s DUs

To understand the behavioural response of its DUs to restriction of PVDF in [redacted] membranes in the EEA, a survey comprising questions on the plant capacity, reasons for installing the [redacted] membranes, restriction scenario and associated impacts was conducted by [redacted]. A total of 14 DUs, representative of the entire business, were considered for this survey. Figure 17 shows that the majority of the DUs consulted are active in the treatment of urban sewage water for discharge to the environment (n=11; 79 %) or treatment of industrial wastewater for discharge to the environment (n=4; 29 %)[24]. As mentioned before, these Application areas are the highest contributors to [redacted]'s revenue (see Figure 2).

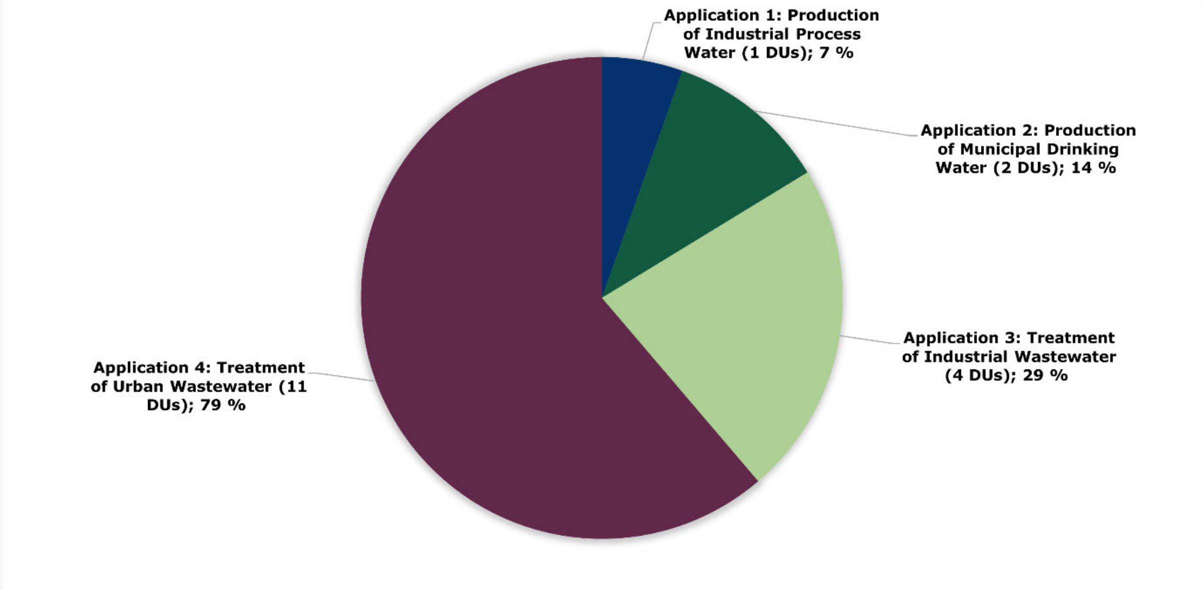

FIGURE 17: NUMBER AND DISTRIBUTION (%) OF [redacted]'S DUS SURVEYED BY APPLICATION.

Discussion on results

The DUs unanimously advise that there is no technically or economically feasible alternative technology as efficient as the [redacted] technology especially due to its higher packing density and lower footprint. Given the discontinuation of the [redacted] product line in the EEA in the restriction scenario, the DUs would be first required to theoretically evaluate potential alternative technologies suitable for their own processes followed by a long pilot period. Test pilots conducted by the DUs prior to technology selection for their

[23] Please note that no competitors were contacted for this assessment. This assumption is purely based on [redacted]'s current knowledge of the subject matter.

[24] Note that the sample size of the DU survey is 14. However, the question related to these results allowed each DU to select multiple answer options and thus 18 options were selected in total.

plants demonstrated that [redacted] membranes provided the best and, in many cases, the only option based on a number of critical evaluation criteria including reliability to meet flow and treated water quality requirements, space constraints and cost considerations.

In the absence of their core technology without a readily available, technically, and economically feasible alternative, DUs with urban and industrial wastewater treatment plants would be forced to build additional new treatment plants to make up for lower treatment capacity from existing plants retrofitted with conventional concrete clarifiers or membranes with lower packing density and output (non-PVDF flat-sheet or ceramic flat-plate). In the case of municipal DUs located in urban centers where land availability is limited, locating new treatment plants will be a major challenge and could require extensive new infrastructure (e.g. new conveyance, pumping stations).

The supply chain in section 5.2.1 presents the physical flow of inputs and outputs related to the use of PVDF UF membranes in the EEA. It further projects the economic flows through the market segment or the value chain (upstream and downstream) that would be affected due to a restriction. Based on the restriction scenario, the cost impact categories that will be assessed for [redacted] and the supply chain in the following sections are operated below.

[redacted]

- Producer surplus losses (resulting from business closure).
- Additional one-off investment costs (resulting from capital costs of site closure).
- Social cost of unemployment (resulting from job dismissals due to business closures).

2. Supply chain

Downstream users

- Consumer surplus losses (resulting from changes in water tariffs).
- Additional one-off investment costs (resulting from capital costs).
- Additional operating costs (resulting from higher energy consumption and more frequent replacement due to shorter lifetime of non-PVDF membranes or alternative water filtration technologies).

End-users or Consumers

- Consumer surplus losses (resulting from changes in water tariffs).
- Other welfare losses (resulting from reduced efficiency of water treatment).

The cost impact categories due to a restriction have been analysed in detail in the following sections. Each of these implications has been described and monetised wherever feasible.

6.4. Impact assessment

6.4.1. Socio-economic impacts on [redacted]

Producer surplus losses

The restriction scenario explicitly describes a business closure of [redacted]'s [redacted] line in the EEA. The [redacted] facility manufactures the [redacted] product line not only for Europe but also globally, profits[25] of which are realised in [redacted]. As a result of relocating manufacturing outside the EEA, significant profit losses are expected.

Assumptions

According to SEAC's guidance on evaluating losses in producer surplus (ECHA, 2021), these foregone profits are the result of premature retirement of productive capital assets and represent losses to the EU society. Based on this methodology, these foregone profits can be accounted for as producer surplus losses for the remaining service lifetime of [redacted]'s capital assets at the point of decision making. This remaining service lifetime is based on the period of time needed by competitors to take over the affected entity's market share for products dependent on the substance use.

Consequently, the following assumptions were made to monetize producer surplus losses within the EEA due to foregone profits incurred by [redacted]:

- To maintain a conservative approach and in line with SEAC's guidelines (ECHA, 2021), foregone profits were considered to accrue over a period of 2 years only.
- The valuation of producer surplus losses uses EBIT as a proxy. EBIT losses have been considered to start occurring in 2027.
- For the valuation, [redacted] anticipates projected earnings before interest and taxes ("**EBIT**") of [redacted] in 2027 for its [redacted] product line that is generated in the EEA for all activities. Additionally, [redacted] anticipates a projected EBIT of [redacted] in 2027 to be generated from the [redacted] facility from sales of the [redacted] line in and outside EEA. Thus, for this assessment, a sum of [redacted] is considered to be foregone in the EEA in 2027.

Results

[redacted] anticipates a projected EBIT of [redacted] in 2027 for its [redacted] product line in the EEA. Based on the methodology recommended by ECHA on the estimation of producer surplus losses, at least two years of profit losses (2027 and 2028) have been considered. Using a social discount rate of 4 %, these producer surplus losses amount to an NPV of [redacted] in 2025 or an annualised value of [redacted] per year for 15.5 years.

Social cost of unemployment

A business closure would most certainly result in job dismissals. As of April 2023, [redacted] employs a total of [redacted] in the EEA of which [redacted] are related to the [redacted] product line. In the restriction scenario, all FTEs ([redacted]) at the [redacted] facility will be dismissed. The remaining [redacted] supporting the [redacted] product line are spread all over the EEA and will be also dismissed.

Assumptions

Following the methodology presented in a report commissioned by ECHA (Dubourg, 2016), the social costs related to expected job losses are valued under consideration of the following components:

[25] See Appendix 1: Financial figures for [redacted]

- The value of lost output/wages during the period of unemployment;
- The cost of acquiring a new job;
- Recruitment costs;
- The "scarring costs" (i.e., the impact of being made unemployed on future earnings and employment possibilities);
- The value of leisure time during the period of unemployment.

The latter component is defined as a negative cost (i.e., a benefit) of unemployment. As such it is subtracted from the total cost resulting from the first four components.

The figures from the aforementioned paper have been updated with recent data, using 2021 estimates on wages presented by Rogers and Marques (Rogers & Marques, 2021) and data on the duration of unemployment in 2021 as reported by Eurostat (Eurostat, 2022 a). Moreover, the figures for average wages were projected to 2027 by using an average Labour Cost Index ("**LCI**") based on the LCI values registered between 2016 and 2020 and provided by Eurostat (Eurostat, 2022 b). Note that, although data estimations of Rogers & Marques on wages are already available for 2022, for consistency issues, data of 2021 have been used for the estimation of social costs. This calculation leads to a monetary value of the total cost of losing one job of EUR [redacted] (NPV 2027) in [redacted].

For EU-27, this calculation leads to a monetary value of the total cost of losing one job of EUR 98,151 (NPV 2027), relating to the population-weighted average of EU-27 as described by Dubourg (2016, S. 18). This average was used for the social costs due to job losses for all remaining 220 FTEs supporting the [redacted] product line and spread all over the EEA.

Results

As per the methodology above, the cost of losing one job in [redacted] and EU-27 in 2027 is valued at EUR [redacted] and EUR 98,151 respectively. Based on this estimate, the social cost of unemployment for [redacted] dismissals in [redacted] is valued at approximately [redacted] in 2027. Using a social discount rate of 4 %, the social cost of job dismissals amounts to an NPV of [redacted] in 2025 or an annualised value of [redacted] per year for 15.5 years.

Similarly, the social cost of unemployment for the remaining [redacted] dismissals spread throughout the EEA is valued at approximately [redacted] in 2027. Using a social discount rate of 4 %, the social cost of job dismissals amounts to an NPV of [redacted] in 2025 or an annualised value of [redacted] per year for 15.5 years.

Additional one-off investment costs

Besides the above-mentioned socio-economic cost impacts, other welfare losses in terms of additional capital costs are expected for [redacted]. Resulting from the relocation of production, one-off investment costs including write offs, decommissioning and clean-up of existing facility in [redacted], is estimated at [redacted] in 2027. Using a social discount rate of 4 %, this one-off investment cost for dismantling the facility amounts to an NPV of [redacted] in 2025 or an annualised value of approximately [redacted] per year for 15.5 years.

Additional capital cost required for relocation of equipment and technology is estimated between [redacted] million in 2027. Using a social discount rate of 4 %, this one-off investment cost for relocation amounts to an NPV of [redacted] in 2025 or an annualised value of [redacted] per year for 15.5 years.

Summary of socio-economic impacts for [redacted]

A business closure for [redacted]'s [redacted] product line will result in socio-economic impacts valued at [redacted] in 2025 or [redacted] per year for 15.5 years for the EEA society. Table 6 summarises these implications for [redacted].

TABLE 6: SUMMARY OF WELFARE LOSSES FOR [redacted] DUE TO BUSINESS CLOSURE.

Socio-economic impact factor	NPV 2025 (in EUR million)	Annualised value (per year for 15.5 years)
Producer surplus losses	[redacted]	[redacted]
Social cost of unemployment	[redacted]	[redacted]
Welfare losses due to one-off investment cost for dismantling [redacted] facility	[redacted]	[redacted]
Welfare losses due to one-off investment cost for relocation of equipment and technology	[redacted]	[redacted]
Sum	[redacted]	[redacted]

6.4.2. Socio economic impacts on the supply chain

In the restriction scenario (see section 6.3) the change to conventional sedimentation treatment or other non-PVDF membranes with lower packing density and output (non-PVDF flat-sheet or ceramic flat-plate) for the DUs, overall, would result in the use of chemicals and less efficient water treatment processes seriously impacting the quantity and quality of water that could return to humans or the environment.

Application 1

Application wise, the Industrial Process Water covering customer segments such as chemicals & pharma, oil & gas, food & beverage, the general industry and others (see Figure 1) will be impacted. A restriction of PVDF membranes might affect specific water quality objectives for certain industries interfering with regular business operations. Furthermore, a mismatch between the plant capacity required for the industry needs and a reduced plant capacity from using another technology might evolve.

Applications 2, 3 and 4

Concerning the Production of Municipal Drinking Water, strict water quality objectives have to be met, which would also need to be ensured in a restriction scenario. Therefore, DUs might have to make costly adaptations to guarantee the same quality, whilst at the same time, ideally, maintaining the same quantity of drinking water.

MBR technology using PVDF hollow fibre membranes has in many instances become a very effective treatment technology replacing old conventional gravity settling and sand filtration whilst playing a critical role in the provision of advanced wastewater treatment needed to allow urban WWTPs to effectively comply with the UWWTD; aimed at environmental protection of water bodies including sensitive areas (areas subject to eutrophication, surface freshwater intended for the abstraction of drinking water etc.).

Membrane filtration also provides high-quality reclaimed water, helping cities to meet the WRR as well as other legislations fostering the recycling of urban and/or industrial wastewater. The potential role of treated wastewater reuse as an alternative source of water supply is now well acknowledged and embedded within European and national strategies. In the restriction scenario, where the quality and quantity of reclaimed water is affected; meeting these objectives could be delayed or potentially not feasible.

Reverting to conventional technologies for these DUs would additionally result in disruptions in delivery of water and wastewater and massive capital investments to retrofit alternative treatment solutions, in most cases requiring an expansion to the plant to treat the needed capacity lost by removing membranes.

For instance, one of [redacted]'s DUs situated in Brussels, Belgium operates a WWTP with a capacity of 162 MLD where the current land requirement for [redacted] hollow fiber PVDF membranes is 1,575 m^2 (45 m by 35 m). For this WWTP, the most cost-effective way to replace [redacted] PVDF membranes would be to buy commercial/industrial land immediately to the west of the existing facility to build additional MBR tanks and infrastructure approximately 3 times the size of the existing MBR and infrastructure (see Figure 18). This implies that in the restriction scenario, the plant would require 4,725 m^2 (3 x 45 m by 35 m) - of additional land for the best available non-PVDF polymeric membrane alternative.

FIGURE 18: PRESENTATION OF ADDITIONAL LAND REQUIREMENT FOR FLAT SHEET POLYMERIC IN COMPARISON TO EXISTING MBR WITH [redacted] IN BRUSSELS.

In some cases, this would even lead to the construction of completely new plants in alternative locations due to existing footprint constraints. Additionally, non-PVDF membranes have a reduced life expectancy requiring more frequent replacement in the restriction scenario.

Downstream users

Before elaborating the impacts of the restriction scenario, it is important to reiterate the importance of PVDF UF membranes. As part of the survey, DUs highlighted their reasons to choose the PVDF UF membranes over other available technologies including:

- Enhanced quality of treated water effluent mandated by strict permeate discharge regulations including reliable effluent free of total suspended solids (“**TSS**”), enhanced nitrogen removal and enhanced physical-chemical and microbiological quality;
- Ability to increase capacity at plants with a small plant footprint preventing additional land acquisition in expansion of existing plant; and
- Opportunity to increase process automation increasing treatment reliability and reducing operator workload.

It was also explained that the [redacted] technology is a very effective technology to serve as pre-treatment for reverse osmosis (“**RO**”) technology wherein provision of optimal quality water for robust operation of the RO technology is critical. Additionally, the use of the [redacted] product line was essential in establishing reuse of treated water after application of additional polishing steps. <u>In general, PVDF UF membranes were described as a highly effective and efficient method of water and wastewater treatment offering decisive advantages for water/wastewater treatment compared to other membrane materials and technologies.</u>

The majority of [redacted]’s DUs treat industrial, as well as urban wastewater, to meet environmental quality standards. These WWTPs are highly complex in their infrastructure such that once a specific plant setup is decided and constructed little to no adaptations are possible regarding the secondary treatment (central treatment unit). In other words, a plant designed for water/wastewater treatment with UF membrane will always rely on the use and availability of UF membranes and cannot simply switch to a completely different treatment technology (e.g., sand filtration, bio-filtration, etc.) without additional investments and supply interruptions. More specifically, in case a PVDF UF membrane is chosen, customers need to be able to replace the membranes with similar PVDF UF membranes once end-of-life (10 - 20 years) is reached. Otherwise, critical parameters like plant capacity (water volume treated per day) and water quality cannot be met.

Therefore, it is first important to describe complexity and extent to which existing systems using PVDF UF membranes would need to be adapted as a result of switching treatment technologies in reactor designs specifically built for UF membranes with the aid of some practical examples from [redacted]’s DUs. The impact assessment in the subsequent sections rests on these complexities that will be borne by the DUs.

Case study 1*: Henriksdal Sweden MBR by Stockholm Vatten och Avfall in Stockholm, Sweden (Application 4: Treatment of Urban Wastewater with MBR)*

Stockholm Vatten operates two WWTPs (Bromma 290,000 p.e. and Henriksdal 780,000 p.e.), which are located in the city. The population of Stockholm is increasing and the development of these plants necessarily has to be coordinated with the needs of Stockholm City on a sustainable and long-term basis.

Sweden's commitment to the Baltic Sea Action Plan ("**BSAP**") and the WFD are leading to more stringent effluent requirements and the wastewater treatment in Stockholm will require an upgrade to handle these challenges (Stockholm Och Avfall, 2022).

Need met by PVDF UF membranes

To meet the city's growing population, feasibility studies showed that an alternative where Bromma WWTP is decommissioned, and the wastewater is transferred to Henriksdal WWTP (which is extended for increased capacity) was the best socio-economic alternative. Additionally, a tunnel to divert wastewater from Bromma to the Henriksdal site is being constructed. In this particular case, the installation is underground in hard rock tunnels (see Figure 19).

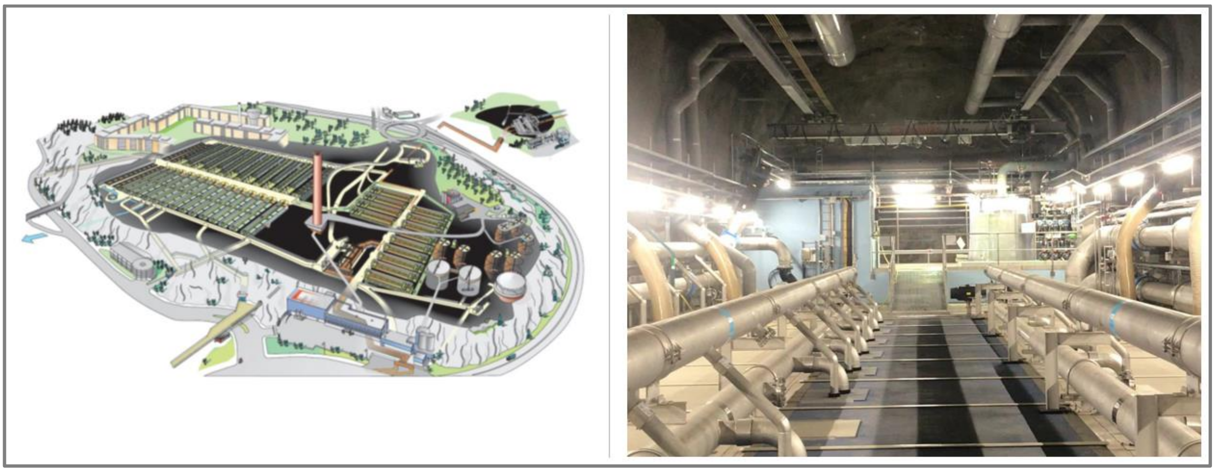

FIGURE 19: INFRASTRUCTURE PICTURE OF THE HENRIKSDAL WWTP MBR IN STOCKHOLM, SWEDEN.

As Henriksdal WWTP is situated inside a mountain in the city, only membrane ultrafiltration was expected to work due to low spatial constraints (low footprint) and very costly construction works for other alternatives. Ceramic membranes could not provide sufficient membrane surface area or flow (even if membranes are operated at high fluxes). The entire cost of the project is estimated at SEK 10.5 billion (EUR 0.92 billion[26]) of which the reconstruction of Henriksdal's WWTP accounts for about 80 %. Once the expansion is completed, the WWTP will be able to treat 864 million litres of wastewater per day by use of [redacted]'s MBR technology which integrates its [redacted] membrane.

Resulting benefits

As a result of the PVDF UF membrane technology, the following environmental benefits are anticipated:

- Reduction of nitrogen and phosphorus emissions;
- Separation of microplastics before discharge into the Baltic Sea;
- Meeting the increased environmental requirements under current and future legislation;

[26] Note: Exchange rate of SEK 1 = EUR 0.088 EUR as of April 14, 2023.

- Removal of several discharge points (due to new sewer tunnel) along Lake Mälaren reducing the emissions of untreated wastewater during heavy rain in the region by 50 %;
- Removal of malodorous sludge management in the vicinity of residential area of Åkeshov and Hammarby sjöstad.

Potential impact of a restriction

As a consequence of a restriction, replacing with a different membrane product would be very difficult and expensive unless it is a similar product to the PVDF UF membrane. Furthermore, it might interfere with given footprint constraints, considering the central location of the wastewater treatment plant. A likely scenario would involve the construction of additional treatment capacity at another site nearby Henriksdal which is also built inside a mountain. This would take several years and require an estimated additional capital cost of several hundred million Euros for Stockholm Vatten och Avfall. In addition, during the time required to build a new plant, the Henriksdal plant will not be able to comply with its environmental permit resulting in penalties from authorities and very bad publicity. The water discharged from the plant into the Baltic Sea would contain higher levels of phosphorous and nitrogen and thus increase the risk of eutrophication. Citizens of Stockholm will experience a deterioration of water quality in the sea.

Case study 2*: Drinking water treatment plant in Italy (Application 2: Production of Municipal Drinking Water)*

This drinking water plant is one of the major references in Europe with immersed [redacted] technology designed to treat up to 95 MLD and providing safe drinking water to 150.000 people living in a highly touristic area in Italy (population doubling during peak tourist season).

Back in early 2000, the municipality initiated a thorough investigation to strengthen its water sources to cope with increasing demand due to population expansion and a growing tourism intake during the summertime. The main source at the time was a watershed that collects water from rainwater and receives very little treatment before the same water is injected in the main network serving the population. This available reserve was considered insufficient and new water sources had to be explored for exploitation. The result of the investigation led to the conclusion that advanced treatment of deteriorated surface river water was the only viable solution to meet the future needs.

Membrane technology was selected as the best-in-class treatment scheme to transform contaminated raw water to reliable and safe drinking water. Among the different membrane configurations available in the market, [redacted] immersed technology proved to be the best membrane due to its robustness to cope with highly deteriorated water coming from a major Italian river with high contamination from various industrial and municipal discharges.

FIGURE 20: INFRASTRUCTURE PICTURE OF THE DRINKING WATER TREATMENT PLANT IN ITALY.

Resulting benefits

As a result of the membrane technology, the following benefits were proven:

- The plant can consistently produce safe drinking water regardless of the deterioration level of the source water quality;
- The robustness of [redacted] membranes allowed for a considerable simplification of the treatment scheme which resulted in the lowest capital investment and running costs during operation;
- The plant demonstrated a great flexibility to treat low to high flow depending on the demand generated by the broad fluctuation of the population served by the plant;
- The level of automation offered by the [redacted] membranes allowed the end-user to operate the plant with minimum presence of qualified personnel.

Potential impact of a restriction

After eight years of operation, the drinking water plant represents a key strategic water asset for the region that over the years also faced several events of severe drought due to climate change. The end-user has recently started to plan a phased replacement of membranes starting in 2024 (due to their end-of-life period) to ensure the plant continues to deliver precious water without any disruption.

A potential restriction of PVDF UF membranes would cause the municipality to start a long and costly process to plan for alternative solutions, with a risk of compromising on both quantity and quality of the final product with a negative social and economic impact on the region.

Case study 3*: Pulp and paper plant in Portugal (Application 3: Treatment of Industrial Wastewater with MBR)*

A facility that produces bleached Eucalyptus Kraft Pulp (capacity over 200,000 Mt per year), mostly suited for tissue production, was facing increasing pressure through stringent environmental EU and national regulations, impacting effluent discharge. The facility needed to revamp its wastewater treatment plant while reducing its water footprint. The plant is located near a river, so it was very important for the pulp company to select the right technical solutions to provide the best water quality effluents and comply with the more demanding discharge parameters.

With its long-term objective to increase its pulp production capacity, it was also essential for the company to expand the water treatment capacity from 37,000 m3/day to 50,000 m3/day while complying with the local and EU regulations. In other words, the plant was faced with the task of increasing the amount of process-related water consumption while decreasing the amount of wastewater generated.

FIGURE 21: INFRASTRUCTURE PICTURE OF INDUSTRIAL WW TREATMENT PLANT IN PORTUGAL.

Need met by PVDF UF membranes

A robust evaluation of different technical solutions was made by the pulp plant. The most cost-effective solution to address the water challenge and position the pulp producer for expansion and growth was installing a new MBR. This enables the facility to comply with the more restrictive discharge requirements thanks to the physical barrier of the PVDF UF membranes. The MBR system is equipped with [redacted] hollow-fiber membranes which achieve superior effluent quality while reducing energy consumption with an increasing membrane lifespan. Advanced COD, colour, and lignin removal could also be achieved. To avoid extracting river water during the dry season, the [redacted] membrane system enables reusing water back into the pulp mill as process water.

Resulting benefits

- Cost Savings: By incorporating [redacted] membrane technology, the MBR system eliminates the need for secondary clarifiers, tertiary treatment and reduces the civils works. Its robustness and cost-effective treatment systems allowed the client to secure high-quality water supply, lower raw water intake and energy consumption, and minimise environmental impact.

- Water Reuse: With implementation of this solution, reuse will be optimised, thus the need to capture water from the river will be reduced by 20%.
- Compliance: By using [redacted] membranes, the pulp facility can ensure consistent treated water quality while being fully compliant with the EU and local requirements. EU legislation lists MBR as a technology that has the potential to be applied successfully in advanced wastewater treatment in the pulp and paper industry[27]. The full package allowed the client to continue operating its pulp production while respecting the surroundings and the environment.

Potential impact of a restriction

- High penalties from the authorities due to non-compliance with mandatory regulations;
- Significant additional investments required by the plant due to need for re-designing and re-constructing the wastewater treatment process;
- Risk of withdrawing an unsustainable amount of water from the river source, leading to the river running dry in the long-term;
- Bad publicity in the news and a high risk of plant shutdown.

Case study 4*: Industrial plant, Italy (Application 1: Production of Industrial Process Water: effluent tertiary treatment with PVDF UF membranes to produce demineralized water)*

Started in 2015, this facility is an advanced 550 m3/h production plant of demineralized water starting from the effluent of the existing conventional wastewater plant.

The industrial plant was required to optimise its water footprint in order to limit the extraction from fresh water sources (river) and, at the same time, increase capacity to deliver clean water to a nearby facility. The aim was aligned to the corporate objective to meet overall water savings among all the different locations.

[27] Note: MBR is listed as a technique in the "Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board" (European Commission, 2015).

FIGURE 22: INFRASTRUCTURE PICTURE OF THE INDUSTRIAL PLANT IN ITALY.

During the feasibility and pilot test studies, alternatives to PVDF UF membranes such as PES/PVP/PAN/Cellulose chemistry were not considered feasible as they have limited resistance to the organic solvent, BTEX, MTBE and hydrocarbons[28]. The [redacted] reinforced membrane, on the other hand, was selected based on its robustness to treat tough wastewater leaving the existing clarifiers and to consistently deliver high-effluent quality. The reliability of the PVDF UF membrane performance was a key aspect of the treatment scheme in order to have the downstream RO process function smoothly and without interruptions.

Resulting benefits

Despite the deteriorated river quality together with a limited amount of water flowing due to increasing periods of droughts, the facility was able to function smoothly and to deliver the required output whilst limiting the water footprint. In addition, the water reuse plant allowed for extra water to be delivered to a nearby power station for cooling purposes and also contributing significantly to sustainability objectives.

The compactness of PVDF UF membranes allowed the plant to be built with an optimized footprint which is critical for industrial sites where land is either limited or meant for

[28] Note: MBR is listed as a technique in the "Best Available Techniques (BAT) Reference Document for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector" (European Commission, 2016).

expanding the main process. Furthermore, the UF plant lends itself for an advanced automation, benefitting the site to employ only few workers to operate the reuse plant while having the high-skilled personnel focusing on the high-value refinery process facility.

Potential impact of a restriction

The consequences of UF membrane restriction would cause major costs for planning and alternative equipment. Additionally, a negative impact is foreseen to the economic viability of the facility if the availability of water is compromised. In the last couple of years, prolonged events of droughts affected the amount of water flowing in the nearby river canal even more significantly. A wastewater reuse scheme based on PVDF UF membranes is the only path to produce value while protecting the environment.

Summary of socio-economic impacts on DUs

As all of these case studies show, PVDF UF membranes are often a preferred solution based on different criteria. Therefore, the lack of an acceptable alternative technology coupled with a restriction of PVDF UF membranes has a direct impact on plant performance for water production (water quality and water quantity being produced) and for wastewater treatment (water quality and water quantity being discharged to the environment).

As such, the welfare losses and additional costs to the EEA society from the restriction scenario to the DUs include the following:

1. **Additional one-off investment costs** including capital costs of:
    - Purchasing and installing new equipment;
    - Reconstruction of existing plant to adapt to new technology;
    - Purchase and development of new land.
2. **Additional operating costs**
3. **Producer surplus losses**

These cost categories are further explained and monetised, wherever possible, in the sections below.

Additional one-off investment costs

These one-off investment costs include capital costs for re-construction of the existing plant, as well as costs for procurement of new machinery and equipment to adapt and expand footprint to install a less efficient alternative technology in 2027.

Assumptions

As described in the AoA, the options to replace PVDF UF membranes with a one-to-one alternative technology such as media filtration or another membrane material such as PES or ceramic, range from poor to fair, depending on the Application.

For high solids, water and wastewater applications where [redacted] membranes are used, there are no low-cost alternate technologies or membrane materials. This is especially true for MBRs, where [redacted] operates in high solids and in a very small footprint. For this reason, and due to the fact that the number of [redacted] installations in the EEA are overwhelmingly MBR, the focus of this capital cost estimate derivation for DUs in the EEA is for MBRs only.

Again, there is no other technology that could replace membranes already operating in an MBR. Only bio-filtration could possibly treat the same flow in the same small footprint, but not necessarily meeting the same treatment objectives. In any case, biofiltration would require completely new construction and was thus not considered in the analysis. Only the top ceramic membrane and the top polymeric CPE flat sheet membranes were evaluated. The key attributes for these membranes are provided in Table 7.

TABLE 7: COMPARISON OF [redacted] PVDF AND BEST AVAILABLE CERAMIC AND POLYMERIC MBR MEMBRANES.

		Polymeric PVDF	Ceramic	Polymeric CPE
Configuration		Outside-in hollow fiber	Outside-in flat plate	Outside-in flat sheet
Product		[redacted] ([redacted])	[redacted]	[redacted]
Unit		[redacted] (MBR)	[redacted]	[redacted]
Length	m	2.14	2.060	2.186
Width	m	1.74	0.702	0.944
Height	m	2.74	1.734	2.923
Membrane area per unit	m2	3151	100	450
Membrane area equivalent	m2	3151	200[1]	450
Membrane footprint intensity	m2/m2	846	69	218
Operating flux (average day)	l/m2/hr	30[2]	27[3]	20[4]
Flow (average day)	m3/hr	94.5	5.4	9
Pore size	microns	0.035	0.1	0.2
Specific air scour rate	m3/h/m2	0.05-0.1	0.54	0.1-0.4
Life expectancy	years	10-20 years	5-15 years[5]	6-8 years
Estimate Price	EUR/m2	20-30	100-150	30-50

[1] Two [redacted] units can fit within width of [redacted] unit

[2] Flux demonstrated with 1000+ full-scale plants in operation

[3] Demonstrated during 30 days pilot study (flux performance benefited from elevated operating temperature of 32 C) - Decarolis et al., Evaluation of Ceramic MBR Technology for Water Reuse, Proceedings 2016 Membrane Technology Conference, San Antonio, TX, USA

[4] Based on publicly available bid proposals

[5] Consultation with industry experts. Small installed capacity in Europe operating more than 10 years.

For purposes of comparison, it was assumed that a ceramic membrane needs nine times the membrane tank footprint in an MBR application where there is no flux advantage and ceramics have substantially less membrane surface area. For flat sheet polymeric, four times the membrane tank footprint would be required in MBR applications.

Since the gap between feasibility for ceramics and flat sheet polymeric is so large for MBR, only polymeric (non-PVDF) flat sheet membranes were assumed as a suitable option to replace PVDF UF membranes in the restriction scenario.

Methodology for MBR Capital Cost Estimate

To determine a range of capital costs for PVDF UF membranes DUs, capital costs of recent wastewater plants built in France and Sweden were compared. Some examples are presented below. To determine a cost per person equivalent, an estimate of 150 L/person/day was used (Plat B et al., 2019).

TABLE 8: COMPARISON OF CAPITAL COSTS OF RECENT WASTEWATER PLANTS BUILT IN FRANCE.

	Case 1	**Case 2**	**Case 3**
Reason for plant expansion	Plant expansion was performed with overall discharge water quality improvement, underground below existing building	Expansion to existing plant plus sludge incineration	New Plant
People served with expansion	130,000	695,000	157,500
Additional people served	30,000	200,000	
Capital Expense	EUR 25,000,000	EUR 80,700,000	EUR 70,000,000
CAPEX/person	EUR 833 CAPEX/Person (EUR 5.6 million /MLD)	EUR 404 CAPEX/Person (EUR 2.7 million /MLD)	EUR 444/Person (EUR 3.0 million /MLD)

Figure 23 below shows the size of the wastewater treatment plants for cases 2 and 3.

FIGURE 23: SIZE OF WASTEWATER TREATMENT PLANTS FOR CASES 2 AND 3.

As mentioned in Case study 1 in 2013, Stockholm Vatten och Avfall, the city of Stockholm's water company, commissioned a study to investigate options for its future wastewater treatment needs, including the requirement to meet more stringent treated water quality objectives expected from the Baltic Sea Action Plan and the WFD. Two of the options were considered relevant for this assessment on capital costs, namely, Alternative 2 and Alternative 4.

Alternative 2 involved the decommissioning of the existing WWTP in Bromma and transferring of wastewater to a new plant to be built outside of Stockholm. The capital costs for both the plant itself and a new pipeline were estimated. A total capacity of 277 MLD needed to be built at this new facility and was expected to cost SEK 5,289 million (EUR 604 million in 2023 adjusted for inflation). The expected cost for the new sewer pipeline line was SEK 5,334 million (EUR 609 million) for a total cost of EUR 4.4 million/MLD[29].

Alternative 4 involved the decommissioning of the WWTP in Bromma and transferring of wastewater to a refurbished and expanded Henriksdal plant in Stockholm. The Henriksdal plant would have an additional 364 MLD capacity at an estimated cost of SEK 3,910 million (EUR 609 million in 2023 adjusted for inflation). The pipeline costs for the transfer from Bromma to Henriksdal were estimated to be SEK 1,445 million (EUR 165 million) for a total cost of EUR 2.2 million/MLD. Alternative 4, which included an MBR with [redacted] membranes was ultimately selected. The expansion was accomplished by blasting a rock into the mountain to create more volume for the existing underground plant.

Total capital cost impact on total [redacted] installed base

Based on the references above, the range of wastewater plant capital costs for site expansions and construction of new plants were estimated between EUR 2.2 - 5.6 million per million litres per day. Notably, this includes not only the portion of treatment that the MBR would fulfil but all infrastructure for a wastewater treatment plant. Thus, a lower bound of EUR 2.2 million and an upper bound of EUR 5.6 million per MLD were used to estimate a CAPEX range for [redacted]’s DUs.

Table 9 presents the capital cost estimate to replace PVDF UF membranes for [redacted]’s DUs in different customer segments in the EEA. The total CAPEX cost impact for PVDF UF membranes customers in the EEA is estimated to be between EUR [redacted] billion in 2023. Assuming constant values in 2027 (impact realisation period) and using a social discount rate of 4 %, this one-off investment cost for expanding capacities of WWTPs for DUs amounts to an NPV of EUR [redacted] billion in 2025 or an annualised value of approximately EUR [redacted] million per year for 15.5 years (see Appendix 2: Explanation on NPV calculations).

[29] These values are adjusted for inflation using a rate of 29% between 2013 and 2023.

TABLE 9: CAPITAL COST ESTIMATE TO REPLACE [redacted] MBR FOR DUS IN THE EEA.

[redacted]

Additional Operation costs

Due to lower performance and reduced life expectancy, the impact on these DUs will be significantly higher operating cost due to more frequent replacement of membranes. Additionally, higher energy consumption of conventional alternative technologies (for instance, when replacing PVDF UF membranes with microfiltration flat sheet) is expected. These impacts have, however, not been monetised due to lack of appropriate data.

Producer Surplus losses

For industries where process water is reused, DUs have indicated that the restriction scenario will impact business continuity. In the absence of a one-to-one alternative, any supply disruptions would lead to profit losses as downstream delivery of products would be affected. Additionally, the lack of high-quality wastewater treatment would cause reputational damages for the DUs. These impacts have, however, not been monetised due to lack of appropriate data.

Other Welfare losses

In the restriction scenario, construction of a new and/or expansion of the existing plant might lead to disruptions in delivery of industrial process water and treated wastewater.

To meet the capacity required, ideally the total treatment capacity in a region must be bigger than the actual population to anticipate any changes over the life cycle of the wastewater treatment plants and to account for the industrial pollution load when authorised by local authorities. Given the regulatory complexities around this theme, it is difficult to estimate how long a potential gap would exist in the restriction scenario.

For urban WWTPs, due to environmental regulations and the large amount of connected population to the WWTP, it remains impossible to accept an alternative solution that delivers compromised quality or capacity. Urban WWTPs are mandated by the authorities to operate their WWTP and meet their environmental water quality standards and wastewater collection limits during collection, treatment and discharge of domestic and industrial wastewater. A revised stricter UWWTD is expected to be adopted at EU level and implemented by the EU Member States in the coming years which will dramatically increase the need for municipal facilities to invest in advanced water and wastewater treatment using PVDF UF membranes. If it is not possible to meet these regulations, consequences could entail severe legal actions and/or financial fines for DUs.

End users/ Consumers

As DUs point out, the absence of PVDF UF membranes in the EEA would result in a switch to conventional old technology with the addition of other treatment steps. The restriction scenario comes at a significant cost of construction ("**CAPEX**") as well as operation ("**OPEX**"), including for plants recently built. DUs also mention that substitution with any other technology would lead to differences in the treated water quality and quantity. Additionally, as the reconstruction of wastewater plants is associated with significant costs, this may be passed on to the end consumer in terms of increase in water tariffs. A study conducted in 2020 (Damkjaer) showed that cost recovery by means of increasing water tariffs, reflecting the cost of pollution, is quite common, as the drivers for changes in urban water and wastewater tariffs in 568 cities across 192 countries were examined. It was thereby concluded that among the reasons behind increasing these tariffs, are changes in water and wastewater infrastructure. These costs would be borne by the EU taxpayers.

The added value of PVDF UF membranes, in general, to the EEA society comes from its applications that serve the society with safe drinking water, protected water bodies and availability of reclaimed water for agricultural irrigation, landscape irrigation, industrial use and environmental enhancements (see section 5.2.1).

The DUs unanimously argued that in the restriction scenario, it would be extremely difficult to guarantee the same quality and quantity of purified wastewater due to lower functionality of the conventional/ alternative technologies. For instance, if choosing a conventional activated sludge followed by tertiary filtration, a detrimental impact on effluent quality is expected. Alternative membrane solutions would lead to larger footprint and increased OPEX due to reduced lifetime. As a result, the availability of reclaimed water may be severely reduced in the restriction scenario.

The potential role of treated wastewater reuse as an alternative source of water supply is now well acknowledged and embedded within EU and national water strategies. Water reuse is a top priority in the Strategic Implementation Plan of the European Innovation Partnership on Water, while maximisation of water reuse has been a specific objective since the introduction of the earlier mentioned Blueprint Strategy.

Water reuse offers several advantages. For instance, water recovery for industry can avoid the use of freshwater and reinforce industry sustainability. Water recovery for irrigation purposes can lead to an increase in yield, groundwater recharge and also avoid the use of freshwater (EIB, 2022). Such advantages would be hampered in the restriction scenario and there is a high potential to interfere with targets set by national and EU regulatory bodies.

Additionally, the restriction scenario creates opportunity costs related to all the other uses which can no longer be addressed due to reduced plant capacity and quality, thereby reducing the economic value of reclaimed water.

6.4.3. Distributional impacts

As explained in section 6.4.1, a significant share of [redacted]'s employees would have to be dismissed in case a PFAS derogation is not granted for the PVDF UF membranes. Therefore, severance costs would be incurred by [redacted], as employees would have to be compensated for their job losses. Severance payments can be considered as a transfer of money within the society from employer to employee, thus the net benefit within the EEA is zero. Therefore, severance costs are not included in a quantified form in the impact assessment. Nonetheless, the amount of such compensation costs is considerably large.

In addition, wastewater treatment plants might incur considerable fines and high penalties if they do not comply with obligatory environmental water quality standards or cannot meet wastewater collection limits. However, due to their distributional nature, fines are perceived as transfer payments and not costs.

6.4.4. Compilation of socio-economic impacts

[redacted]'s market position as a leader in PVDF UF membranes closely reflects the impact of a restriction in this segment. The Applications within the scope of this submission are crucial for the wellbeing of the society. The closure of the [redacted] line for [redacted] would result in massive producer surplus losses and social cost of unemployment in the EEA.

Section 6.4.2 explains that the reconstruction of industrial and municipal water and wastewater treatment plants in the restriction scenario would imply high capital (one-off) and operating costs. While in some cases an expansion may be needed, others may require completely new infrastructures. For end-users and EEA society in general, welfare losses due to significant costs for DUs and compromised water quality and quantity are evaluated. Welfare losses are also expected due to reduced economic value of reclaimed wastewater and consequent increase in water tariffs.

Table 10 presents an overview of the economic and social impacts that would occur in case of a restriction. Overall, socio-economic costs of at least [redacted] per year for 15.5 years or [redacted] in 2025 would be incurred by [redacted] and its DUs only due to a restriction. Notably, this value does not account for distributional impacts and impacts which could only be described qualitatively.

It must be emphasized that these impacts only present a partial picture of the overall impacts of a restriction. The impacts are only quantified for [redacted] and its DUs. The overall impacts of a restriction incurred by other stakeholders in the value chain of PVDF membranes in the EEA society are expected to be much higher.

TABLE 10: SOCIETAL COSTS ASSOCIATED WITH RESTRICTION.

Description of major impacts	Monetised/quantitatively assessed/qualitatively assessed impacts
1. Monetised impacts	**€ [per year] [Over 15.5 years]**
Producer surplus loss for [redacted]	[redacted]
Social cost of unemployment ([redacted] and EU-27) for [redacted]	[redacted]
One-off investment costs for dismantling for [redacted]	[redacted]
One-off investment costs for relocation for [redacted]	[redacted]
One-off capital costs for DUs	[redacted]
Sum of monetised impacts	[redacted]
2. Additional qualitatively assessed impacts	
[redacted]	Distributional impacts such as severance payments (see section 6.4.3)
DUs	Additional operating costs (resulting from higher energy consumption and more frequent replacement due to shorter lifetime of non-PVDF membranes) Producer surplus losses (resulting from disruption in delivery of services) Reputational damages
End users/Consumers	Consumer surplus losses (resulting from changes in water tariffs) Other welfare losses (resulting from reduced efficiency of water treatment)
3. Additional quantitatively assessed impacts	**€ [per year] [Over 15.5 years]**
Distributional impacts such as costs for fines and penalties for DUs	n/a

6.5. Combined impact assessment

The comparison of impacts draws from the previous impact assessment and compares socio-economic costs of a restriction with the risk to the environment of a continued use. Overall, a restriction would result in at least [redacted] socio-economic costs per year for 15.5 years between Q2 2025 and 2040. Section 6.2 describes the risks from potential emissions to the environment across different life stages of PVDF membranes including manufacturing, operation and end-of-life. Appropriate RMMs at [redacted] ensure that no PVDF emissions to the environment occur across the different life stages of PVDF and are not to be expected in the future. As no releases were found across the membrane lifecycle, risks to the environment are effectively precluded from this assessment.

TABLE 11: SOCIO-ECONOMIC COSTS OF RESTRICTION PER UNIT OF RELEASE FOR [redacted].

	[Per year] [Over 15.5 years]
Total costs	[redacted]
Total releases	No releases considered available for further assessment
Ratio	n/a

7. CONCLUSION

PVDF-based UF membranes play a key role in the EU's strategy for safe drinking water and wastewater. Applicable Directives and Regulations are described in chapter 5.1. Importantly, the need of PVDF-based UF membranes is expected to increase in the future, particularly in the EU, due to several factors including:

- The need for cleaner and safer water is increasing.
- As populations continue to grow and urbanise, suitable water and wastewater treatment infrastructures need to be in place for ensuring that communities in urban areas have access to clean water and surrounding water bodies remain safe and protected. In this regard, the generally low space availability of urbanised areas presents an important aspect to be considered in the future.
- Climate change is expected to have a significant impact on water resources in the future, leading to changes in water quality and availability.
- For municipalities, the more stringent limits for contaminants including particles, pathogens, nutrients, microplastics and micro-pollutants in wastewater are critical in terms of technology selection. The implementation of wastewater reuse will mitigate water shortage due to severe droughts met in several EU countries.
- For industry, wastewater treatment with re-use is among the key topics to ensure sustainable manufacturing and to compensate for the projected future water shortage.

Therefore, water and wastewater management are one of the major topics for current and future society. It is utterly important that all surface waters and groundwaters are protected and managed in a sustainable manner. It needs to be ensured that all drinking water is safe for human consumption and that levels for contaminants like pathogens (parasites, bacteria, and viruses), micropollutants (such as pesticides, pharmaceuticals, PCPs, EDs) and microplastics are kept under the agreed-on EU thresholds. Logically, all wastewater that is created by any human consumption and use needs to be purified in the highest possible quality to guarantee safe discharge to feed the EU/ global water circle. Due to their performance and their market integration, [redacted]'s PVDF-based UF membranes play a critical role in all points mentioned before. PVDF UF membranes offer decisive advantages for water/wastewater treatment compared to other membrane materials like PES/CPE/PAN and ceramics and conventional technologies (e.g. physico-chemical clarification, sand filtration, etc.).

In this regard, the PFAS Restriction Proposal is highly critical for the EU society considering the non-availability of a one-to-one replacement for PVDF-based UF membranes. According to [redacted]'s substitution plan at least 17.5 years (calculated from Q2 2023 - the timepoint of submitting the comments to the present public consultation) are required to develop a suitable one-to-one replacement. This means that from the expected Entry into Force date of the PFAS restriction in Q2 2025, <u>a derogation of at least 15.5 years is required for [redacted] to substitute PVDF-based UF membranes while ensuring supply with critical components to EU water and wastewater treatment plants.</u> To reduce the impact on EU water supply, [redacted] suggests including the following time-limited derogation into the restriction proposal:

"Industrial PVDF-based ultrafiltration membranes required to be installed into (a) new water or wastewater treatment plants designed after EiF (including extensions of/changes to existing plants) subject to special conditions (low spatial requirements) for high quality purification of industrial and urban wastewater, process water and drinking water and (b) existing water or wastewater treatment plants ensuring possibility for maintenance and replacement during the operational life of the plant, both (a) and (b) until at least 15.5 years after EiF."

Importantly, the substitution timeline is developed for the scenario of replacing the PVDF-based UF membranes one-to-one with an alternative-based UF membrane. The substitution timeline does not consider a switch to a completely different treatment technology. This is because PVDF-based UF membranes currently offer the only available option for providing high quality treated water (meeting current and future EU regulations) in the small footprint required by relevant municipal and industrial DUs. In addition, for existing DUs, once a specific plant setup is decided and constructed little to no adaptations are possible regarding the core treatment unit. In other words, a plant designed for water/wastewater treatment via UF membranes will always rely on the usage of UF membranes and cannot simply switch to a completely different treatment technology. More specifically, in case a PVDF UF membrane is chosen, customers need to be able to replace the membranes with PVDF UF membranes once end-of-life (10 - 20 years) is reached. Otherwise, critical parameters like plant capacity (water volume treated per day) and water quality cannot be met. Notably, these parameters are pre-defined during plant design and need to be guaranteed throughout a plant's service life (40 - 50 years). Besides technical arguments, costs play another important role for customers. PVDF UF membranes have the best price-to-lifetime ratio available on the market.

However, [redacted] is eager to increase the sustainability of the manufacture, application, and disposal of their PVDF-based UF membranes. For this purpose, the company developed a sustainability commitment that will fully apply during the required 15.5-year derogation. For the actions forming the sustainability commitment, [redacted] considered the entire lifecycle of their membranes starting from membrane manufacture and through disposal at end-of-life (EOL).

Based on the impact assessment, a restriction of PVDF membranes would result in socio-economic impacts valued at EUR [redacted] million in 2025 or EUR [redacted] million per year for 15.5 years for the EEA society whilst any releases to the environment across all life cycle stages are controlled. It must be emphasised that these implications only present a partial picture of the overall impact of a restriction. The impact under this submission is only quantified for [redacted] and its DUs. The overall impact of a future PFAS REACH Restriction on the EEA society are expected to be much higher.

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APPENDICES

Appendix 1: Financial figures for [redacted]

Figure 24 and Figure 25 below display [redacted]'s annual sales revenues and annual Earnings before interest and taxes (EBITs) respectively that are dependent on the production of PVDF UF membranes.

[redacted]

FIGURE 24: ACTUAL AND FORECASTED PVDF-DEPENDENT ANNUAL SALES REVENUE FOR [redacted] IN EUR MILLION.

[redacted]

FIGURE 25: ACTUAL AND FORECASTED PVDF-DEPENDENT ANNUAL EBIT FOR [redacted] IN EUR MILLION.

Appendix 2: Explanation on NPV calculations

Annualised value cost C_t is set out below

$$C_t = \frac{I \times s}{1 - (1+s)^{-t}}$$

Where C_t is the annualised investment cost in year t

I = Investment
t = year (until year n)
s = discount rate

The equation to use for calculation of the Present Value (PV) of costs is set out below:

$$PV_c = \sum_{1}^{n} \frac{C_t}{(1+s)^t}$$

Where PV_C is the present value of the costs

t = year (until year n)
s = discount rate
C_t = cost in year t

The equation to use when calculating the Present Value of benefits is:

$$PV_B = \sum_{1}^{n} \frac{B_t}{(1+s)^t}$$

Where PV_B is the present value of the benefits

t = year (until year n)
s = discount rate
B_t = benefit in year t

The Net Present Value (NPV) is calculated as the benefits minus the costs:

$NPV = PV_B - PV_C$

Appendix 3: Product Data Sheet [redacted]

Appendix 4: Product Data Sheet [redacted]

Appendix 5: Product Data Sheet [redacted]