FILTRATION / PFAS

Follow-up of KEMI – Ahlstrom-Munksjö call on Oct. 20th, 2021

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Air filter classification and multi-stage filtration systems

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Air filter classification*

- The main determinant to select an air filter is its filtration class, which is determined by its particulate filtration efficiency performance.

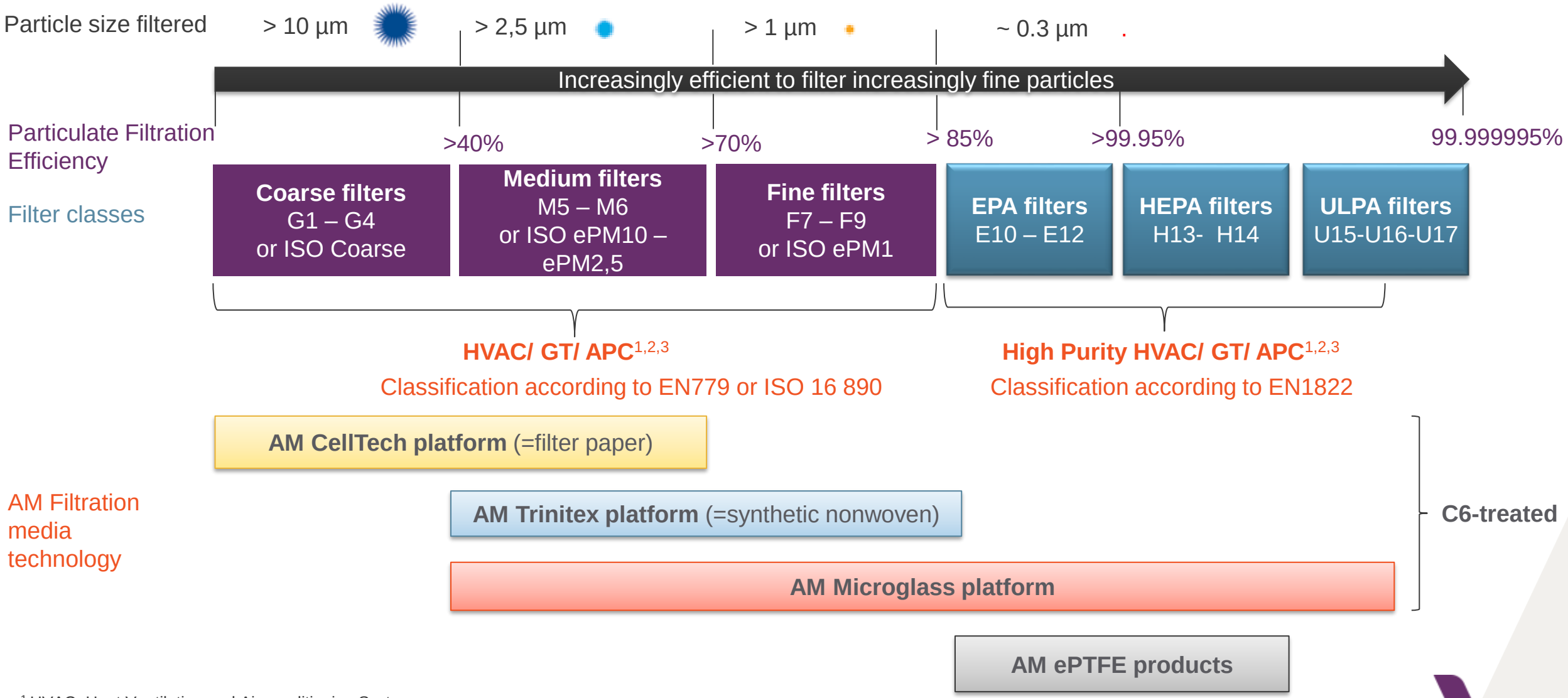
- The air filter classification covers a wide range of particulate filtration efficiency levels: from coarse (65% of > 10 µm particles) to medium, fine and EPA/ HEPA/ ULPA filters (100% of < 1 µm particles).

- This classification allows to find the optimal performance to:
  - filter particles of a certain size i.e., from > 10 µm up to 0.3 µm
  - meet air quality requirements/standards in downstream applications
  - optimize dust collection → to achieve high dust holding capacity and longer life-time
  - reduce pressure drop properties → to ensure low energy consumption and CO_2-emissions

- Each filtration class has a given role in air filtration systems and, therefore, it is not technically wise to replace coarse, medium or fine filters by higher efficiency filters (e.g. EPA/HEPA/ULPA).

**Liquid filtration also relies on multi-stage filtration with different levels of efficiency and standards than for air filtration, which also rely on C6 (e.g., removal of water droplets from fuel).*

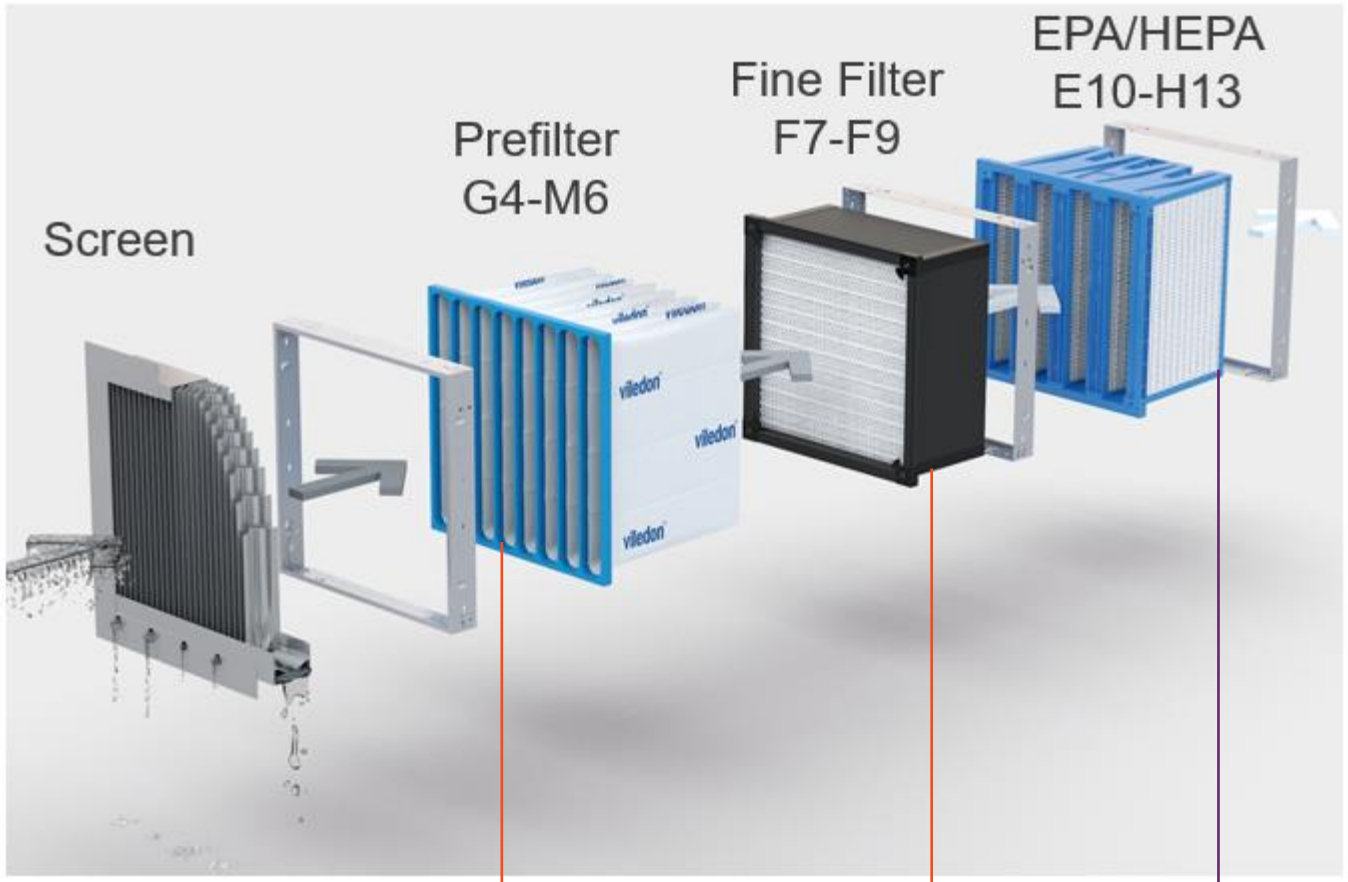
Filtration media per air filter classification



[1] HVAC: Heat Ventilating and Air conditioning System
[2] GT: Gas Turbine
[3] APC: Air Pollution Control

Multi-stage filtration system: Example of static GT-filtration

From coarse to high filtration efficiency



Source: Freudenberg

Typically C6-treated microglass media or synthetic media

Typically C6-treated microglass media

- In static GT-filtration applications, each filtration stage requires a C6-treatment on the media to achieve water-repellence **and** oil-repellence
- C6-treated microglass media is the benchmark technology for the 3-filtration stages. C6-treated synthetic media can be used for pre-filtration and fine-filtration stages.

ePTFE membranes

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ePTFE filter « overdesign »

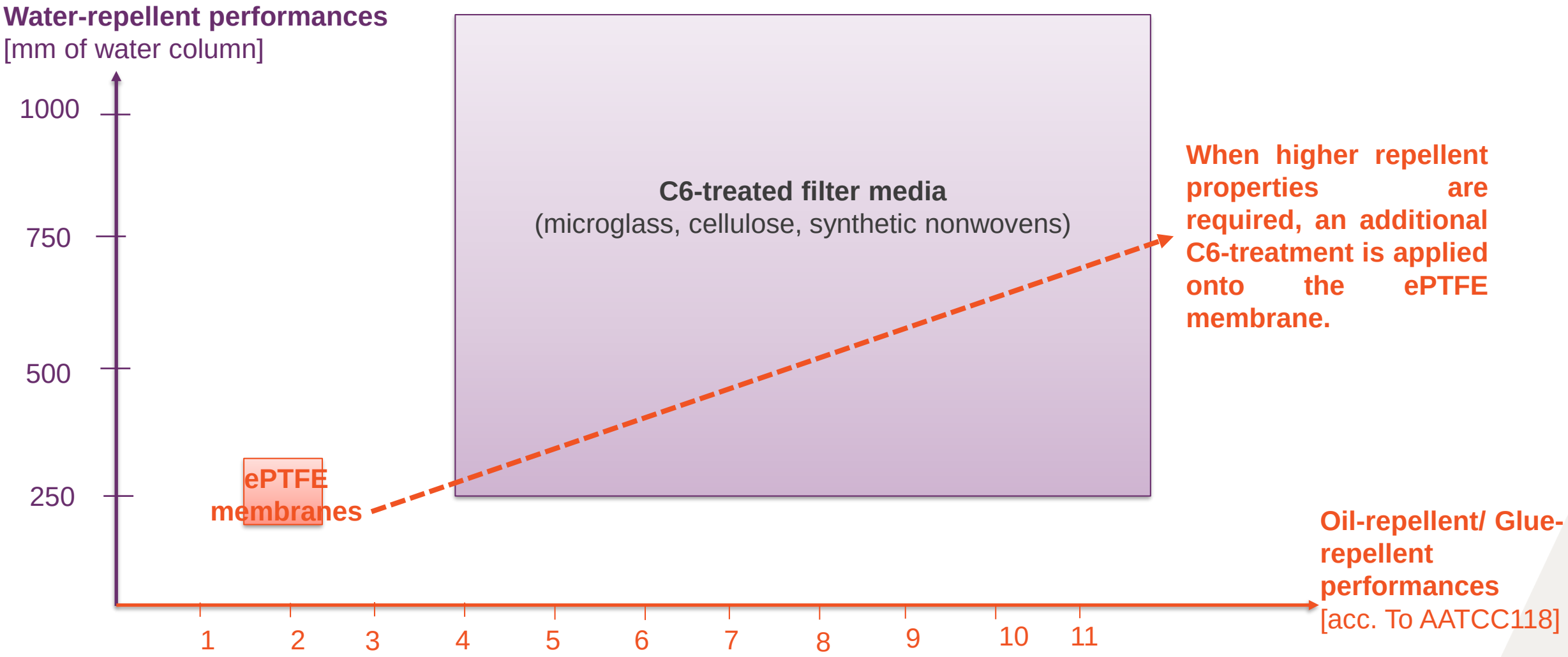
- ePTFE membranes can only be used for EPA/ HEPA filters (i.e. not for coarse, medium and fine filters)
- Replacing medium or fine filters by ePTFE filters will lead to the following consequences:
  - Lower dust holding capacity* leading to 2 to 3 times more frequent replacement of filters due to increasingly fast loading and filter clogging, as the pore size is smaller.
  - 2 to 13 times increased pressure drop** leading to increasing energy consumption, as more energy would have to be supplied by the filtration units in order to push the air flow through the filter.

Filter class	**Dust holding capacity, DHC at 300 Pa** [g/m²]	**Pressure drop, DP at 5,3 cm/s** [Pa]
H14 media with ePTFE	11-17	134-156
F9 media (microglass or synthetic)	32-37	40-70
M6 media (microglass or synthetic)	30-45	10-20

*The maximum quantity of dust that can be retained by a filter, which is strongly correlated with filter life time and thus with early replacement of filters.

**If pressure increases when the air is trying to get through a filter, there is higher resistance to flow.

ePTFE repellency performance: Lower water- and oil-repellency



Socio-economic implications of transitioning to ePTFE

Increased consumption of PFAS:

- ePTFE contains ca. 10 times more PFAS than a microglass media treated with C6 (cf. table below).

	C6-treated microglass media	ePTFE Multi-layer structure
HEPA	0,15 g of PFAS/m²	1-2 g of PFAS/m²

Concerns regarding production and requalification:

- It is easier to change the chemical additives used in the production process (e.g. C6) than the filtration media (e.g. microglass vs ePTFE membranes)
- A change of the filtration media will require a complete change of production lines for filtration media producers.
- It will also force filter manufacturers to change their pleating technology, leading to investments in new pleating lines i.e., from rotary pleaters (=benchmark technology to pleat microglass media) to knife pleaters (=benchmark technology to pleat ePTFE-based filtration media).
    - This shift will come with a loss of productivity since pleating speed is lower with knife pleaters.
    - This may also lead to redesigning of the filter element and additional requalification by downstream users.

Socio-economic implications of transitioning to ePTFE

Broader socio-economic implications:

- ePTFE filters will be min. 6 times more costly.
- ePTFE is only an affordable option in niche markets where microglass media do not meet specific requirements (e.g., special segments of APC or glass-free requirements for cabin and HEPA filtration applications, high mechanical strength for Pulse-Jet GT)
- ePTFE filters account from 2% to 5% of filtration cartridge market shares depending on the filtration application
- ePTFE membranes are widely used in filters bag in APC applications, which account for 85% of the filters used in these applications. AM is not present on the filter bag market.

Bag filters (on the left) and APC filter units with bag filters (on the right)
→ Application where ePTFE membranes are widely used. AM is not present on that market

Cartridge filters (on the left) and APC filter units with cartridge filters (on the right)
→ Application where AM is present and where ePTFE membranes are marginal

PFPE/ C2

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Perfluoropolyether (PFPE, also know as C2)

C2 does not represent a suitable alternative to C6 due to the following reasons:

- C2 treatment costs min. 4 times more than C6-treatment
  -The price of the chemical is minimum twice the one of C6
  -The dosage has to be doubled to achieve acceptable repellent properties

- Lower repellent properties despite increased dosage (cf. table below)

Repellent agent	C6	PFPE/ C2
PFAS content in the final product	1.75%	3.5%
H2O Repellency mmH2O	1100	600
Oil Repellency - Kit 3M #	9/10	7

- Only one reliable chemical supplier identified, which is at high risk of production discontinuation due to its heavy reliance on food packaging applications (as PFAS-free alternatives are available for this use).

C4

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C4 side-chain fluorinated polymers:

- To the best of our knowledge, they are not commercially available on the market. They are not proactively offered by C6-suppliers as alternatives to C6.
- They have not been tested by AM, but we anticipate a lower WOR based on the transition from C8 to C6.

C4 sulphonate chemistry:

- Seems to be available on the market, although it has never been offered as a solution by suppliers.
- It can degrade into perfluorobutane sulfonic acid (PFBS) which, unlike PFHxA, is listed as a Substance of Very High Concern (SVHC).
- No R&D work expected due to worse hazard profile.