1000 days fresh air test eFRM membrane HEPA filters

AAF® INTERNATIONAL
Bringing clean air to life.®

Authors:

Dr. Marc Schmidt |
Vice President Technologies Europe
AAF International

Stefan Laub | R&D
Engineer Europe
AAF Interntional

Summary:

Thanks to its unique membrane technology, the eFRM HEPA filter medium has been the medium of choice for numerous end users in the life science and microelectronics industries for several years. In addition to the low pressure drop, the focus in these segments is on risk minimization through high mechanical stability and chemical resistance.

Due to the extremely low pressure drop, the eFRM filter medium is predestined for use in high-flow HEPA filters such as those used in ventilation systems for high-purity environments. To investigate this application, a test was conducted under real outdoor air conditions. For this purpose, eFRM HEPA filters were subjected to a "1000 days" long-term test in parallel to conventional glass fiber HEPA filters in a two-stage filter system using the AAF test container.

After a description of the test container, the article deals with the short- and long-term behavior of the filters. On a short-term time scale, interesting correlations between the relative humidity and the pressure drop of the HEPA filters can be seen. On the long-term scale, the advantage of the low pressure drop of the eFRM HEPA filters is shown to be maintained even when 100% fresh air is used.

Furthermore, the paper discusses the economic implications resulting from the favorable pressure drop characteristics of eFRM HEPA filters compared to glass fiber-based HEPA filters.
For this purpose, the operating costs as well as the "Total Cost of Ownership" are discussed, especially against the background of the differently increasing electricity costs in different countries. The energy costs from the end of 2021, on which this paper is based, now have to be adjusted upwards on a monthly basis, so the current cost benefits of using eFRM HEPA filters are likely to be higher than the values shown.
The carbon footprint during operation of the different filters will also be discussed.

Although the carbon footprint (due to nationally different energy mixes) is very different between the countries, eFRM HEPA filters offer a significant advantage over conventional glass fiber HEPA filters.
Thus, eFRM membrane HEPA filters are not only an economical, but also an ecologically sound technical solution for particle filtration in high-purity environments.

What's Inside

Figures

Photos

Tables

References

1	https://statista.com
2	https://de.statista.com/statistik/daten/studie/1009521/umfrage/co2-emissionen-durch-stromerzeugung-in-der-eu/

MEMBRANE TECHNOLOGY FOR AIR HANDLING UNITS

eFRM filter media continues to deliver reliability and trusted performance in air handling units, proven in a “1000 days test” under real conditions.

Introduction

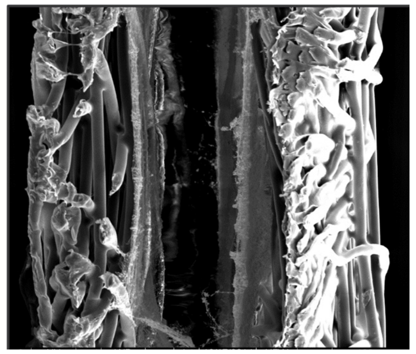

Photo 1: Cross section of eFRM membrane

Thanks to unique membrane technology, eFRM filter media has been the media of choice for multiple end users in the Life Science & Microelectronics industries for several years now as the trusted and proved solution. In addition to the low pressure drop, the focus in these segments is on minimizing risk through high mechanical stability and chemical resistance.

Photo 1 shows a cross-section of an eFRM HEPA filter medium. Two nanoscale eFRM membranes are sandwiched between a synthetic support and cover layer.

Due to the extremely low pressure drop, eFRM filter media is predestined for use in HEPA filters with high volume flow, such as those used in air handling units. Exploring that application, a test was carried out under real conditions. For this purpose, eFRM HEPA filters in separator design were subjected to long-term “1000 days testing” in parallel with traditional glass fiber HEPA filters in a two-stage filter system using the AAF test container.

The total duration of the test was 1030 days, with a net operating time of 911 days.

Test Container

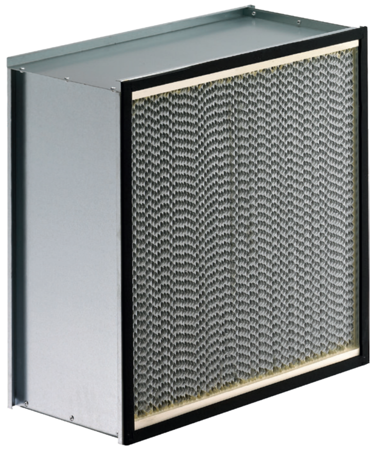

Photo 2: MEGAcel I eFRM membrane HEPA filter

In the AAF 40' test container, four filter systems, each with two stages, are installed in parallel. Each filtration system has a VariCel EcoPak ePM1 55% compact prefilter with glass fiber media in the first stage.
In the second stage, traditional H14 glass fiber HEPA filters AstroCel I HC and H14 eFRM membrane HEPA filters MEGAcel I are installed in two filter systems each.
The filter combination is therefore an ePM1 55% filter, directly followed by an H14 HEPA filter.

The volume flow was monitored with volume flow orifices. The pressure drops of the volume flow orifices as well as those of the respective filter stages were remotely monitored using the AAF Sensor360® system. Also connected to the Sensor360® system was a commercial PM2,5 particle sensor at the air inlet of the container.
A data logger for air temperature and humidity was also installed there.

Photo 3 shows the test container in the Diniar plant in Olaine (Latvia). The pipes on the left side are the air outlets of the four filter systems inside the container.

Photo 3: AAF 40' test container in Diniar plant in Olaine (Latvia

Test Executions

In the first part of the test, the container was operated 24/7 in AAF plant in Emmen (The Netherlands) for 83 days, after an overhaul, the container was transported to the Dinair plant in Olaine (Latvia) and operated there 24/7 for 828 days.

The filters were operated at a flow rate of 3150 m³/h. The volume flow was manually readjusted when necessary.

The prefilters were operated up to the load limit, in one case even above it, so that the filter pack broke. The pressure loss was then above 550 Pa. They were replaced approximately every 3 months. By adding another prefilter in the efficiency range ePM2.5 or ePM10, the service life of the VariCel EcoPak ePM1 55% compact prefilter used could certainly be extended.

Test Conditions

Temperature & relative humidity

The test container was exposed to significant seasonal fluctuations in temperature and relative humidity of inlet air. In winter, temperatures of -10°C were regularly reached, and in some cases even -20°C. This resulted few times in icing of the pre-filters (Photo 4). In summer, the peak temperatures were up to 35°C.

Relative humidity was naturally low in winter, below 10%, but reached values up to 100% in summer.

In the course of the day, relative humidity usually correlates reciprocally with temperature, i.e. it decreases as the air warms during the day and increases as it cools at night.

Photo 4: Iced prefilter

Particle concentration

The measured PM2.5 particle concentrations also show large seasonal variations (figure 1). The PM2.5 mean value was 37µg/m³. For the nearby Latvian capital Riga, the European Environment Agency indicates a PM2.5 mean value of 12µg/m3 for 2018-2020. Both mean values are in the range >7.5µg/m3 and thus in the range of outdoor air category ODA 3 (outdoor air with very high concentrations of particulate matter) according to Eurovent guideline 4/23-2020, which considers the latest recommendations of the World Health Organization (WHO global air quality guidelines 2021).

The measured PM2.5 peak values are in the range 200-370µg/m³. It cannot be ruled out that condensation effects at high relative humidity contributed to the peak values.

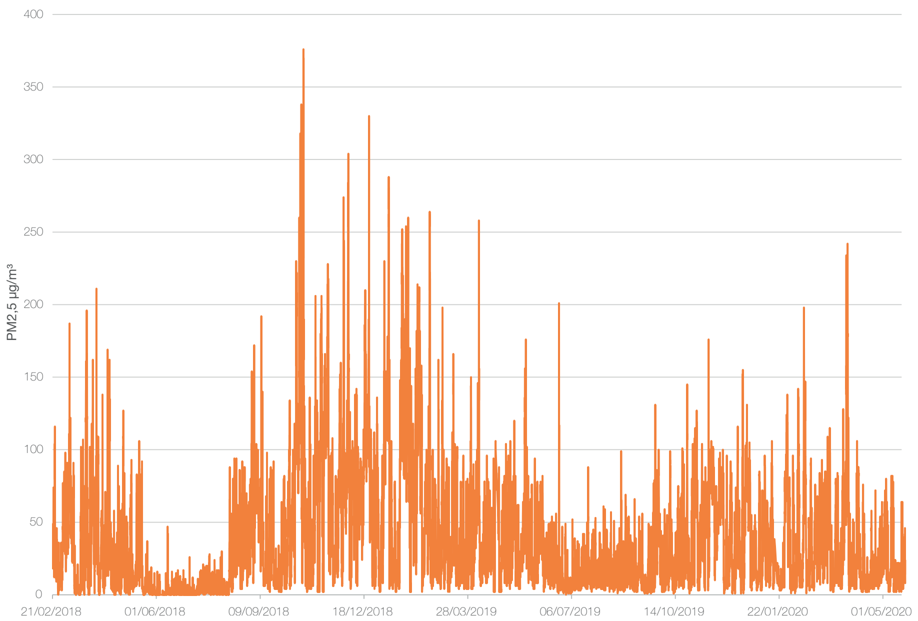

Figure 1: PM2.5 values during test in Olaine (Latvia).

Test Results

Temperature & relative humidity

In the course of the pressure loss it is necessary to distinguish short-term effects from the long-term development. Short-term pressure drop fluctuations were often observed during the day (Figure 2).

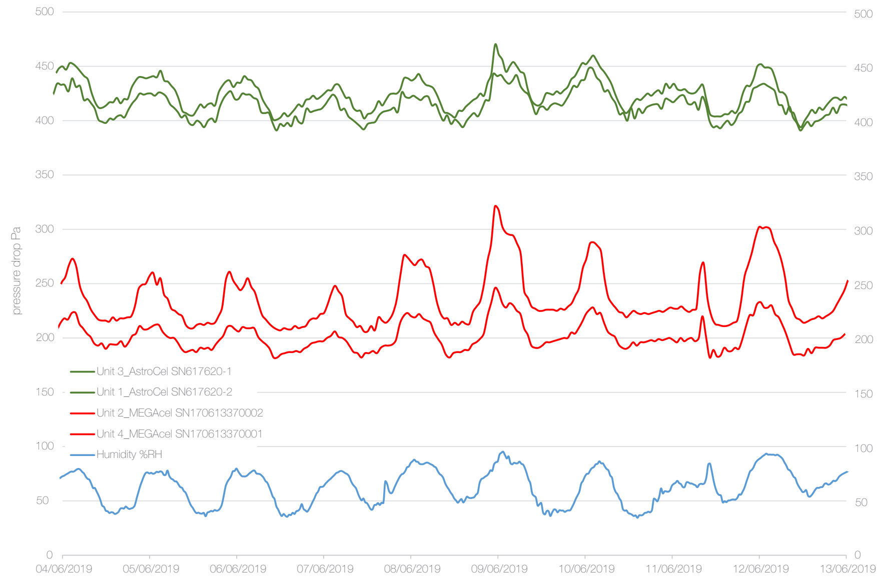

Figure 2: Correlated short-term variations of pressure drop and relative humidity.

Obvious is the significant pressure drop difference between traditional glass fiber AstroCel I HEPA filters and the MEGAcel I eFRM membrane HEPA filters. The glass fiber filters are at a level of 400-450 Pa, while the MEGAcel I eFRM membrane HEPA is significantly lower at 180-320 Pa.

A direct correlation was found between the increase in relative humidity and the increase in pressure drop. This pressure drop increase was observed for glass fiber filters as well as for eFRM MEGAcel I filters. It is reversible in both cases but is slightly higher in the case of eFRM membrane filters. The reasons could be condensation effects in the filter material itself but are still subject to ongoing investigations.

The long-term pressure drop development must be distinguished from this.

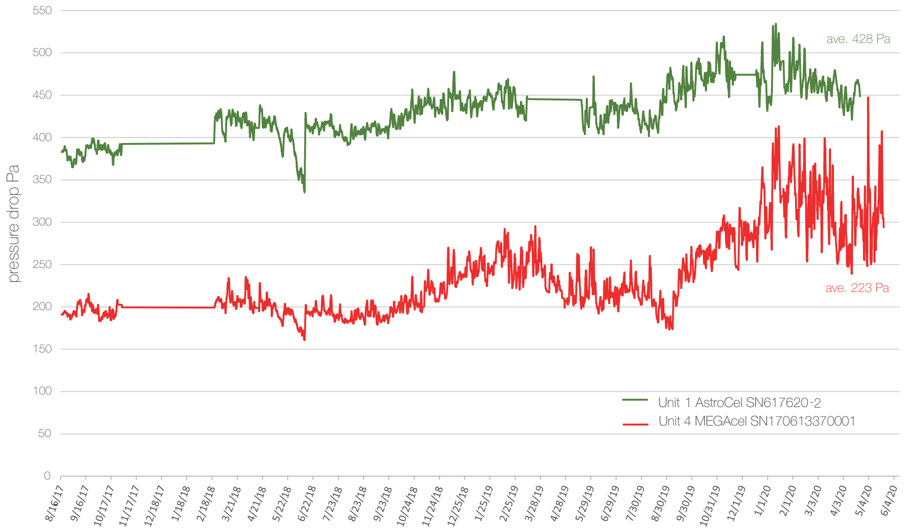

Figure 3: Averaged long-term pressure drop curves for traditional fiberglass HEPA filter and to MEGAcel I eFRM membrane HEPA filter.

Figure 3 shows the long-term development pressure drop development of traditional glass fiber HEPA filter compared to MEGAcel I eFRM membrane HEPA filter.
Initial pressure drop of the MEGAcel I eFRM membrane HEPA filter is with 180 Pa less than half of the traditional glass fiber HEPA filter, which is in the range of 380 Pa. For both filters, there are periodic fluctuations in the pressure drop, which are somewhat larger for the MEGAcel I eFRM membrane HEPA filter compared to the traditional glass fiber HEPA filters. For clarity, the values in the above diagram are averaged over a few days.

As the load increases, the pressure drop of both filters increases, but the values for the MEGAcel I eFRM membrane HEPA filter always remain significantly lower than those for the traditional glass fiber HEPA filter. Towards the end of the test, the pressure drop difference is still about 150 Pa.

Commercial and environmental benefit of MEGAcel I eFRM membrane HEPA filters

Total Cost of Ownership (TCO)

For the cost-optimized operation of a filter system, the Total Cost of Ownership TCO must be minimized. This is essentially made up of the investment costs C_F for the filters plus the energy costs for operating the fan C_E which has to overcome the pressure drop caused by the filters.

$$TCO = C_F + C_E \quad (1)$$

Energy cost

The energy costs to be spent for the operation of the filter are directly proportional to the pressure drop of the filter:

$$C_E = \frac{\dot{V}\cdot\overline{\Delta p}\cdot t\cdot c}{\eta} \qquad (2)$$

C_E energy cost (€)
$\dot{V}$ volume flow (m3/s)
Δp a verage pressure drop (Pa)
t operation time (h)
c electricity cost (€/kWh)
η fan efficiency (-)

Since in a filter installation the basic conditions such as volume flow, operation time, fan efficiency and electricity cost are usually given, the energy costs can only be reduced by selecting a filter with the lowest possible pressure drop.

Figure 4 shows the electricity cost development in some European countries. They vary significantly from country to country. In connection with the COVID pandemic, they rose sharply throughout Europe in 2021. Although there was a slight recovery at the beginning of 2022, a significant recovery is not expected in the context of the Russian war in Ukraine. On the contrary, electricity costs are expected to remain high, if not even rising.

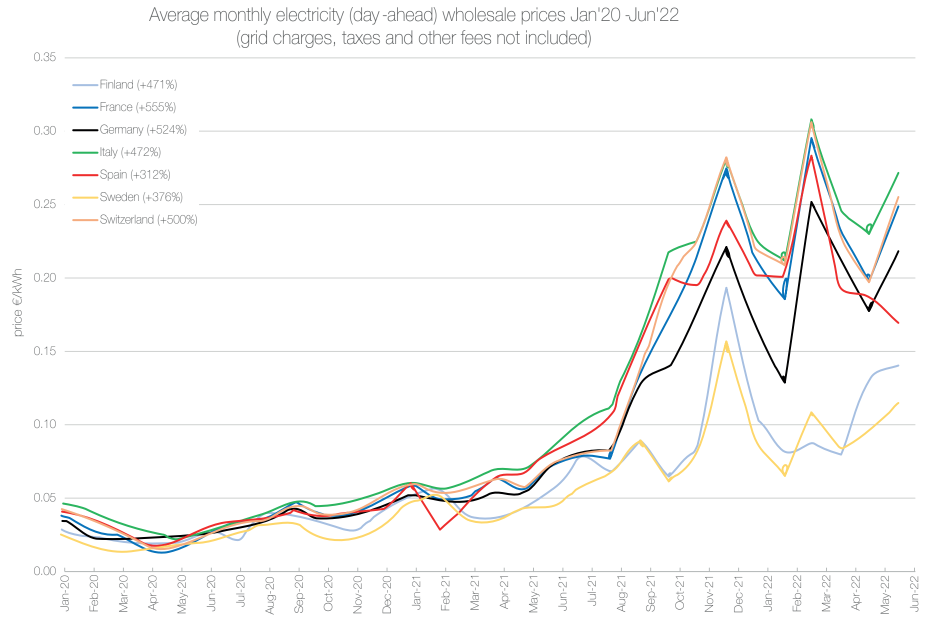

Figure 4: Electricity cost development in some European countries [1].

In June 2022, compared to January 2020, electricity costs were +376% in Sweden, +524% in Germany and even +555% in France. It should be noted that Figure 4 shows only wholesale prices. Depending on the volume consumed, they may be significantly higher for commercial or industrial customers. Grid charges and other fees must also be added. Neither of these are considered in Figure 4.

The selection of a filter with the lowest possible pressure drop is therefore of central importance for the cost-optimized operation of a filter system.

CO2 emissions and footprint

Every power generation is accompanied by certain CO2 emissions. This is commonly referred to as the CO2 footprint. The level of CO2 emissions and thus the CO2 footprint depends on the energy mix of the electricity consumer. Fossil energy sources (coal, gas, oil) naturally generate higher CO2 emissions than regenerable energy sources (wind, sun, water).

For the same electricity consumption, the resulting CO2 emissions therefore vary greatly from country to country. Table 1 shows the level of CO2 emissions from electricity generation in different countries. Naturally, countries with a high use of renewable energy sources or nuclear energy, such as Sweden, Switzerland or France, have relatively low CO2 emissions for electricity generation.

2020	Sweden	Switzerland	France	Finland	Spain	Italy	Germany
CO2 emissions (g/kWh)	9	12	51	69	156	213	311

Table 1: CO_2 emissions from electricity generation in different countries [2].

Example

Let's check energy cost, TCO and CO2 footprint in a concrete application assuming conditions as described for the container test. For that we're assuming the following:

$\dot{V}$	volume flow 0,875 m³/s (3.150 m³/h)
t	operation time 18.000 h
η	fan efficiency 0,5
$\overline{\Delta p}_{glass\ fiber}$	average pressure drop glassfiber filter 428 Pa (see Figure 3)
$\overline{\Delta p}_{eFRM}$	average pressure drop eFRM filter 223 Pa (see Figure 3)

Due to the situation on the energy markets described above, we assume the wholesale prices for electricity in June 2022 and, for simplicity's sake, neglect all grid fees and other charges.

Electricity prices	Finland	Sweden	Spain	Germany	France	Switzerland	Italy
June 2022 (€/kWh)	0,1403	0,1148	0,1694	0,2182	0,2487	0,2552	0,2716
Increase vs. Jan 2022	+417%	+376%	+312%	+524%	+555%	+500%	+472%

Table 2: Wholesale electricity prices Jun 2022 (w/o grid charges and other fees) and increase vs. January 2022 for some countries [1].

Figure 5 compares energy cost for operating a glassfiber HEPA filter with an eFRM membrane HEPA filter in different countries under the conditions mentioned above calculated using formula (2).

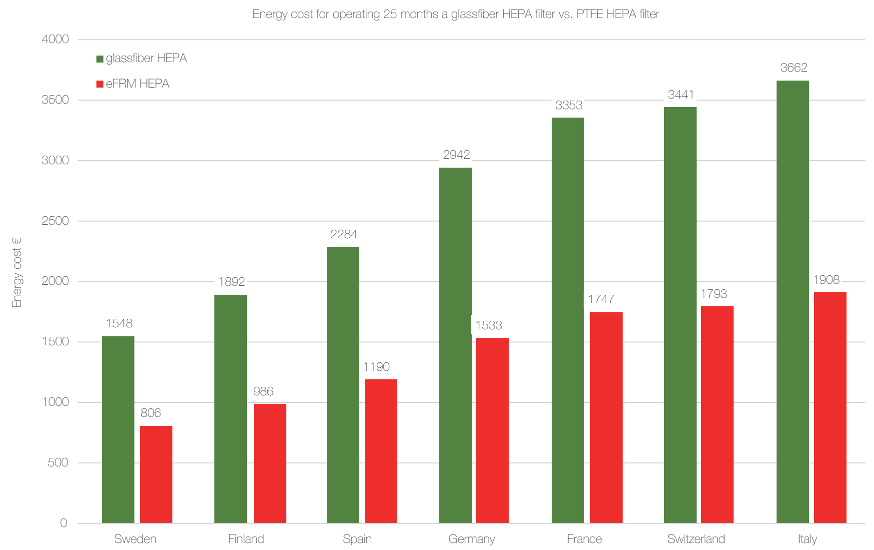

Figure 5: Energy cost for operating glassfiber HEPA filter vs. eFRM membrane HEPA filter in different countries.

The different electricity costs in the various countries result in significantly different energy costs for the operation of a filter. In our example, the costs in Italy are about 2.37 times those in Sweden. Independently of this, a cost saving of approx. 50% is shown in each country when using eFRM membrane HEPA filters.

Calculating Total Cost of Ownership, according to formula (1) the investment cost for the filters are added to the energy cost.

Assuming following investment cost,

$C_{F\ glass\ fiber}$	invest cost of filter with glassfiber filter 300€
$C_{F\ eFRM}$	invest coast of filter with eFRM membrane filter 400€

Figure 6 shows development of Total Cost of Ownership over time for different countries.

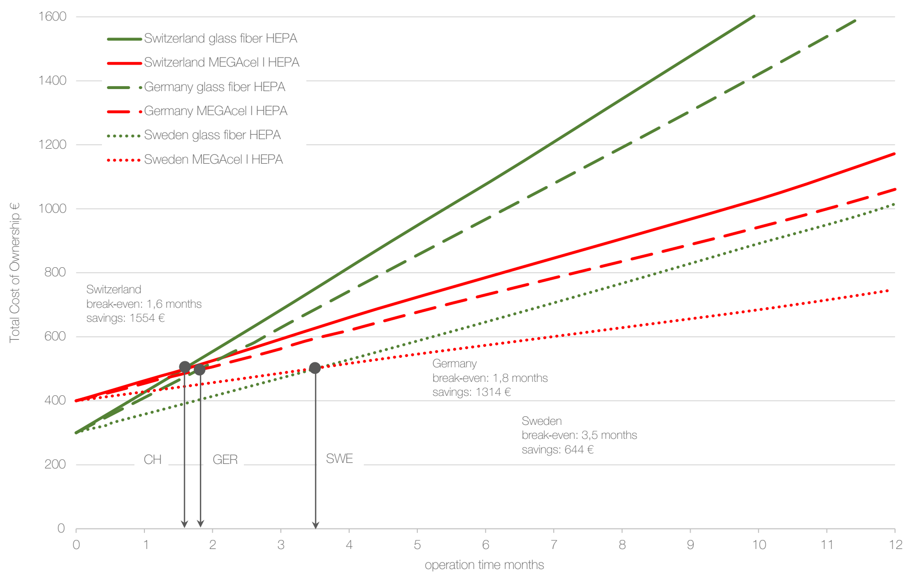

Figure 6: Total Cost of Ownership over time for operating glassfiber HEPA filter vs. eFRM membrane HEPA filter in different countries.

Due to the lower investment costs for the glass fiber filters, their total cost of ownership is initially lower than that of the eFRM membrane filters. However, due to the significantly lower energy costs during operation of the eFRM membrane filters, this ratio reverses over time (Figure 6).

The point at which this happens is the so-called break-even point, from which the operation of the higher quality eFRM membrane filters pays off economically. Different energy costs between the countries hardly play a role for that. The payback periods are always in the range of only a few months (Figure 7).

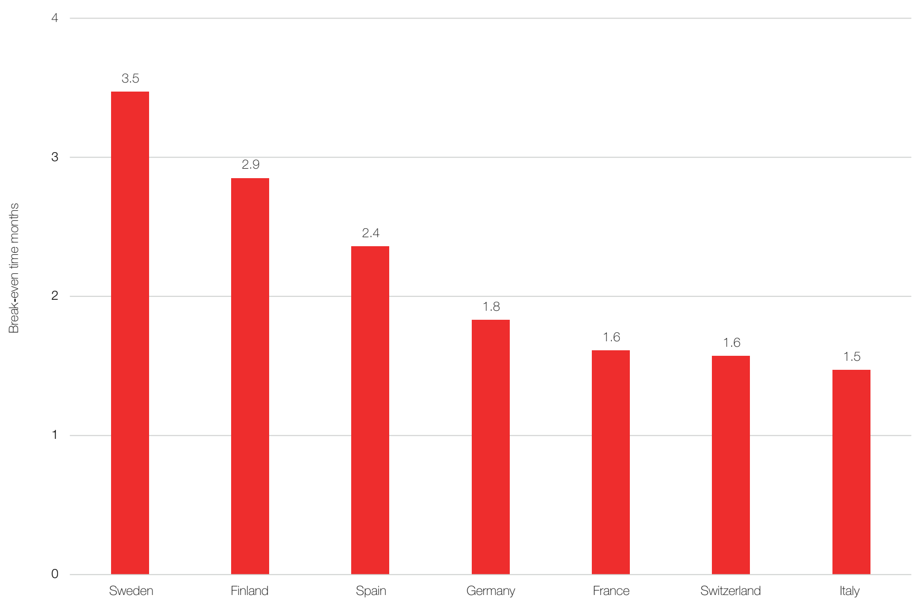

Figure 7: Break Even for operating glassfiber HEPA filter vs. eFRM membrane HEPA filter in different countries.

Figure 8 shows the resulting Total Cost of Ownership over the assumed operation time of 18.000h.

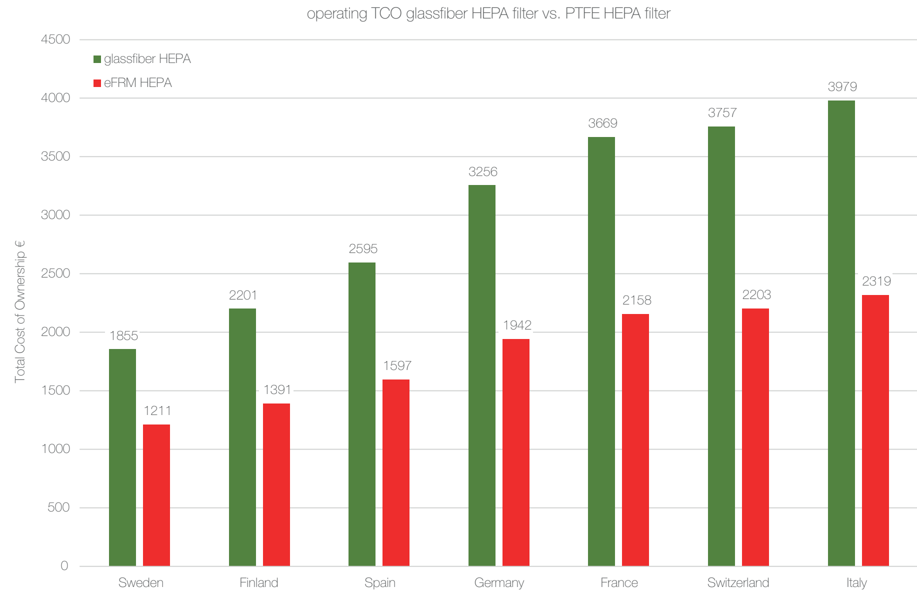

Figure 8: Total Cost of Ownership for operating glassfiber HEPA filter vs. eFRM membrane HEPA filter in different countries (Operating conditions mentioned above).

Due to different energy cost in the various countries, there are significantly different Total Cost of Ownership for the filters. Independently of this, in all countries there are significant cost savings in the range of 35% up to more than 42%.

With the energy consumptions underlying figure 5, the CO2 equivalents shown in Figure 9 can be calculated.

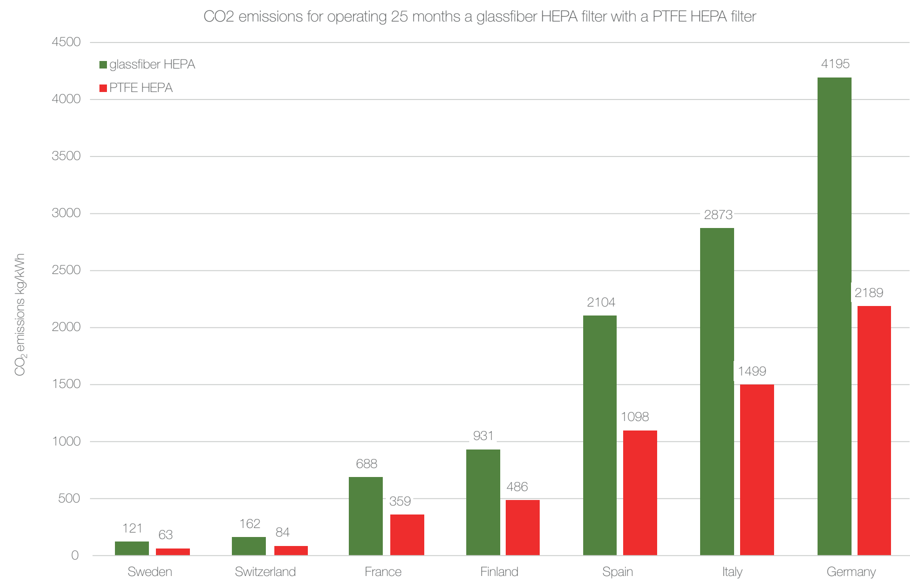

Figure 9: CO2 equivalents for operating glassfiber HEPA filter vs. eFRM membrane HEPA filter in different countries (Operating conditions mentioned above).

The different CO2 equivalents per kWh due to the respective nationally different energy mix (Table 1) lead to very different CO2 emissions in the respective countries. However, due to the very low energy consumption when using eFRM membrane filters, their CO2 emission equivalents are always lower than those of glass fiber filters. The CO2 savings are in the order of 50%.
Thus, eFRM membrane HEPA filters are not only an economical, but also an ecologically sound technical solution for particle filtration in high-purity environments.

AAF Europe / Dinair Sales Offices

Germany and Headquarter Europe
AAF-Lufttechnik GmbH
Odenwaldstrasse 4
64646 Heppenheim
+49 (0)6252 69977-0
Sales.DACH@aafeurope.com
www.aafeurope.de

Denmark
AAF/Dinair APS
Vallensbækvej 63.1
2625 Vallensbæk
Phone: +45 70260166
sales.denmark@aafeurope.com
www.aafeurope.dk

Finland
Dinair Clean Air Oy
Koivuvaarankuja 2
01640 Vantaa
Phone: +358 10 3222610
cleanair@dinair.fi
www.dinair.fi

France
AAF France
9 Avenue de Paris
94300 Vincennes
Phone: +33 1 43 98 42 23
sales.france@aafeurope.com
www.aafeurope.fr

Greece
AAF-Environmental Control Epe
Ifaistou & Kikladon
15354 Glika Nera
Tel.: +30 210 6632015
Greece@aafeurope.com
www.aafeurope.gr

Italy
AAF Srl
Via Friuli, 28/30
21047, Saronno (VA)
Tel: +39 02.9624096
sales.italy@aafeurope.com
www.aafeurope.it

Latvia
Dinair Filton SIA
Rupnicu Street 4
Olaine, Latvia, LV-2114
+371 67069823
Dinair.latvia@dinair.se
www.dinair.lv

The Netherlands
AAF International BV
Hooggoorns 56
7812 AM Emmen
Tel: +31 (0)591 - 701025
aaf.verkoop@aafeurope.com
www.aafeurope.nl

Norway
Dinair AS
Prof Birkelands vei 36
1081 Oslo
Phone: +47 22 90 59 00
post@dinair.no
www.dinair.no

Slovakia
AAF International s.r.o.
Bratislavska 517
91105, Trenčín
Phone: +421 32 746 17 39
aafslovakia@aafeurope.com
www.aafeurope.com/sk

Spain
AAF S.A.
C/ Vidrieros, 10
28830 San Fernando de Henares, Madrid
Tel: +34 916 624 866
Customer.ServiceSP@aafeurope.com
www.aafeurope.es

Sweden
Dinair AB - Head office
Hamngatan 5
SE-592 30 Vadstena
Tel: +46 (0) 143-125 80
info@dinair.se
www.dinair.se

Ånäsvägen 18
511 56 Kinna
+46 (0) 320 20 90 70
order.industries@dinair.se

United Kingdom
Air Filters Ltd (AAF International)
Bassington Lane, Cramlington
Northumberland NE23 8AF
+44 1670 591 790
airfilter@aafeurope.com
www.aafeurope.co.uk/

Bringing clean air to life.®

AAF International
European Headquarters
Odenwaldstrasse 4, 64646 Heppenheim
Tel: +49 (0)6252 69977-0
aafeurope.com

WP_101_EN_092022