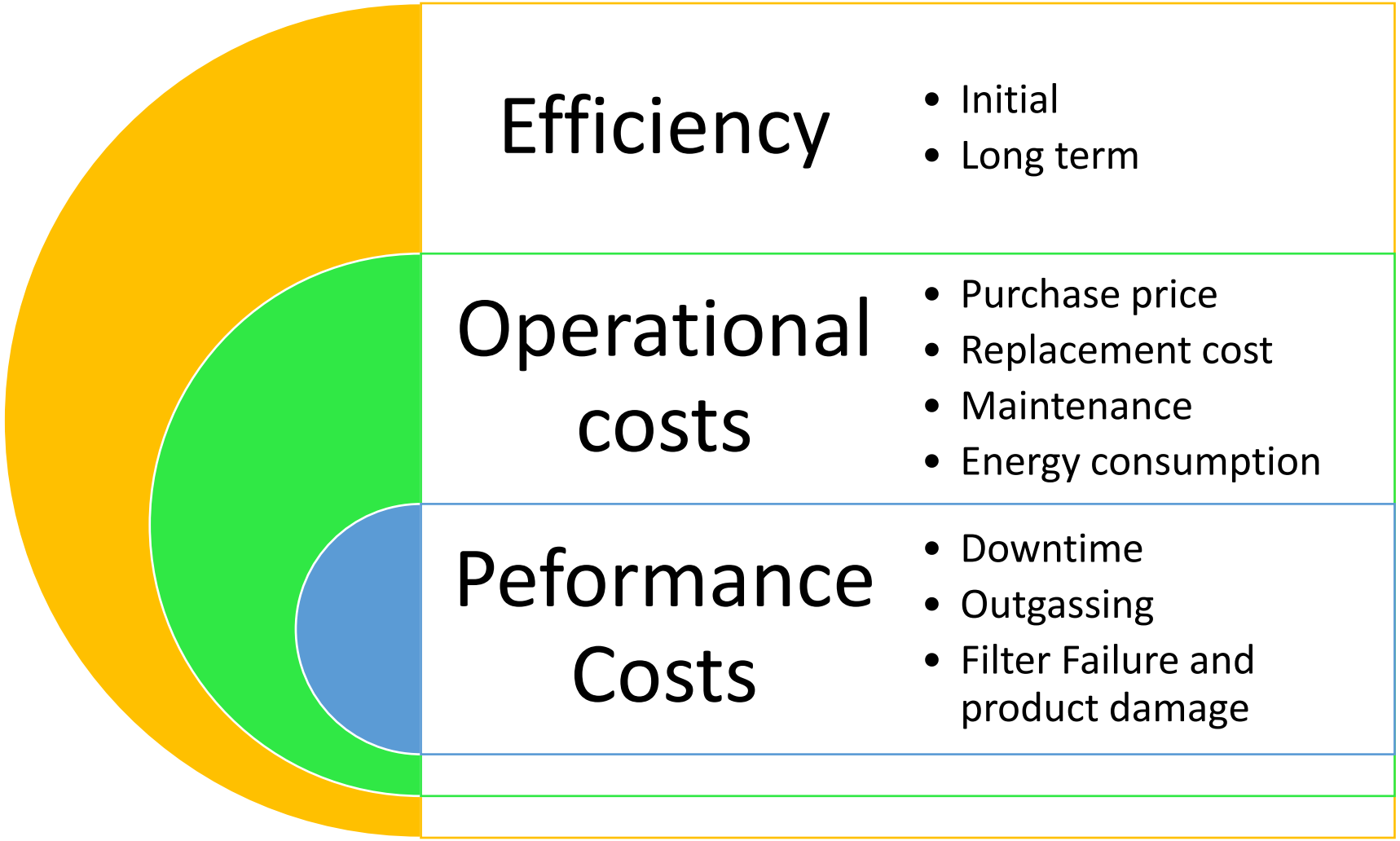
Cleanroom HEPA Filters

Total Cost of Ownership (TCO) Factors

Work in Progress and continually revised

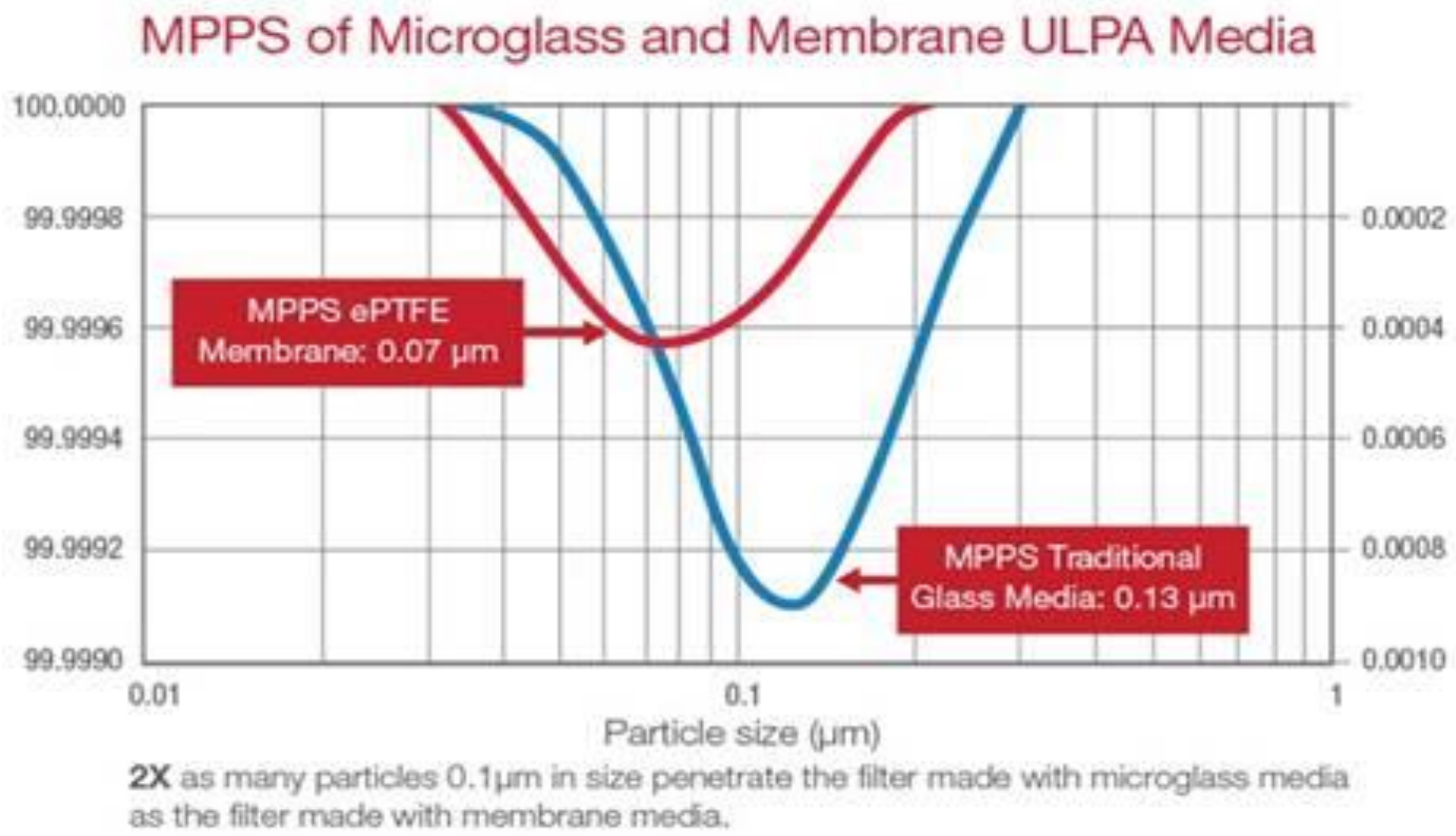

Efficiency
Initial
Long term
Operational costs
Purchase price
Replacement cost
Maintenance
Energy consumption
Peformance Costs
Downtime
Outgassing
Filter Failure and product damage

Company	TCO Factors
AAF	Membranes have advantages over glass. MPPS not the best way to compare media efficiency
AES Clean	Views of a purchaser and installer
Ahlstrom	Improved stiffness and mechanical resistance reduce glass fragility
Camfil	Polymeric thick media has more effective filtration area with less risk of failure than glass
Filtration Group	The filter module design impacts efficiency as much as the media
H&V	Glass with clean pleats has better efficiency/energy ratio
M+H	
Nitto Denko	ULPA with two membrane layers sandwiched between non wovens; low outgassing
Parker Hannifin	

AAF

- Membrane media outperforms microglass media in terms of tensile strength, abrasion resistance, and burst pressure.
- Higher 0.1 micron capture even if MPPS of 0.3 is the same

Particles that are 0.5µm in size or smaller tend to follow increasingly erratic paths as particle size decreases, a phenomenon known as the diffusion effect. As such, HEPA and ULPA filters are often rated according to their most penetrating particle size, or the size of particles that most readily pass through them. As depicted in this line graph, filters that achieve the same efficiency rating, in this case ULPA filters rated at 99.999%, are not necessarily equal in their MPPS performance



Microglass media filters still have their place, such as high-temperature applications. However,
membrane media offers compelling reasons to make a switch in HEPA and ULPA filter media.

- When purchasing HEPA and ULPA filters from AAF Flanders, media production, testing, and packaging are all performed in an ultra-modern ISO-Certified controlled environment, eliminating the potential for contamination during the manufacturing process.
- Microglass media frequently suffers damage during shipping, handling, installation, and testing, leaving cleanroom operators exposed to contamination risks from leaks that may escape the attention of the naked eye.
  Membrane media clearly outperforms microglass media in terms of tensile strength, abrasion resistance, and burst pressure.

Membrane media offers a lower differential pressure than microglass media. Not only does this trait improve the energy efficiency of HVAC equipment, but it also reduces the wear and tear on this equipment

MINI-PLEAT EFRM HEPA FILTERS

Product Overview
•Patent pending, polymer-based, dual-density, expanded Fluororesin Membrane- eFRM
•Minimum 99.99% at 0.3 µm, H13, and 99.995% at MPPS, H14
•Polyalphaolefin (PAO) compatible
•Lowest pressure drop mini-pleat HEPA filter available for pharma, life sciences
•Lightweight anodized aluminum frame
•Gel, gasket, or knife-edge seal available
•Thermoplastic hot-melt separator

Designed specifically for the unique requirements and challenges of the pharmaceutical industry, the MEGAcel II eFRM mini-pleat HEPA filter has the proven durability, polyalphaolefin (PAO) compatibility, high particulate filtration efficiency, and lowest pressure drop to meet the demands of pharmaceutical manufacturing.. AAF says it is the lowest Total Cost of Ownership of all mini-pleat HEPA filters.

AES Clean Technology

Perspective of filter purchaser and installer

AES Clean Technology is a leading supplier of pharmaceutical modular cleanrooms. They offer fast track project execution for biopharmaceutical projects. Delays due to damaged HEPA filters during installation are to be avoided. The company will be supplying information on its HEPA filter selection criteria and experience

Ahlstrom

Stiffness and mechanical resistance are optimized to improve productivity

Ahlstrom-Munksjö Glass High Efficiency Air Glass High Efficiency Air offer covers a wide range of full mechanical efficiency media from E10 to U17 according to EN1822 standard and a complement range for Americas based on MIL-STD-282 testing method.
Portfolio is characterized by low pressure drop and high dust holding capacity, plus superior media uniformity which guarantees the best filtration performances along the filter life.
Stiffness and mechanical resistance are optimized in order to deliver improved productivity during the filter manufacturing process; an excellent choice for deep-pleat and mini-pleat applications

Ahlstrom-Munksjö Glass High Efficiency Air – Key Grade Characteristics

	Basis Weight	Efficiency Class		Thickness	Pressure Drop @ 5.3 cm/s	MD Tensile	MD Stiffness
Grades	g/m²	EN1822 @ 1.7 cm/s	% Efficiency 0.3 µm @ 5.3 cm/s	µm	Pa	N/m	g
DOPH1001	72	E10	-	430	80	1200	0.9
DOPH1003	72	-	87	430	85	1200	0.9
DOPH1101	72	E11	-	430	100	1200	0.9
DPOH1103	72	-	95	430	115	1200	0.9
HEPH1201	72	E12	-	420	215	1200	0.9
HEPH1203	72	-	99.92	420	235	1200	0.9
HEPH1301	72	H13	-	420	255	1200	0.9
HEPH1303	72	-	99.97	420	280	1200	0.9
HEPH1401	75	H14	-	450	320	1200	1.0
HEPH1403	75	-	99.99	450	325	1200	1.0
ULPU1501	75	U15	-	450	390	1200	1.0
ULPU1601	78	U16	-	470	440	1200	1.0
ULPU1701	78	U17	-	470	530	1200	1.1

Camfil

- Depth loading Media increases effective filtration area
- Much less risk of failure than glass

What Makes Camfil's Megalam EnerGuard so unique?

The filter failure rate at installation is significantly less than 1%.

The robust nature of the filter significantly reduces the chances of product failure and expensive cleanroom downtime. Robust filters have less of a chance of damage during transportation, installation, handling, and filter service that translates to cleanroom operating profits.

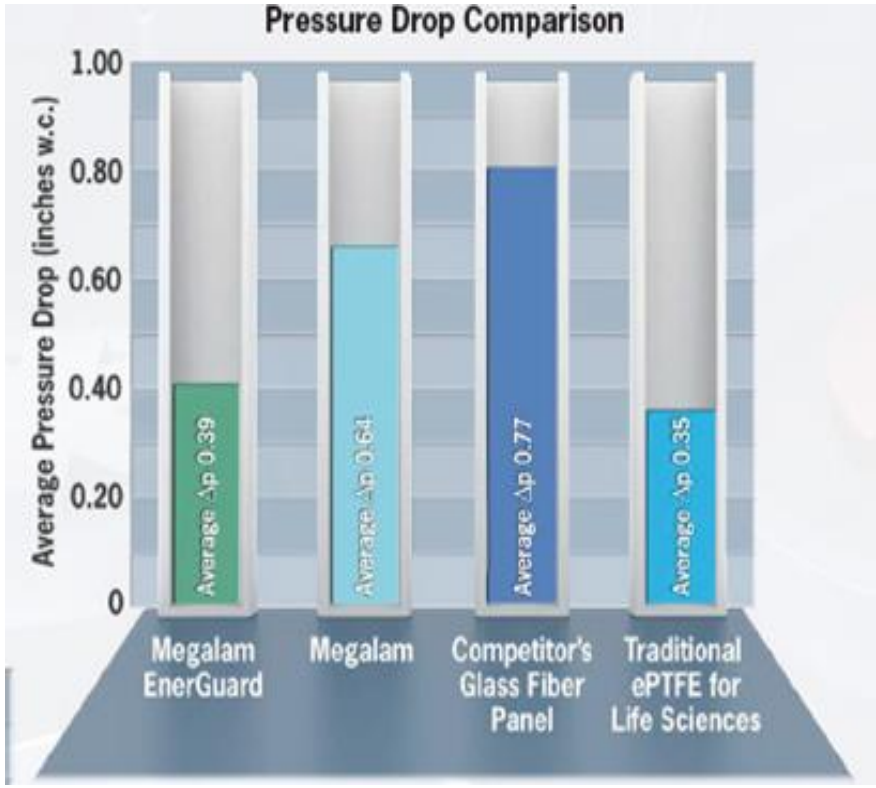
The Megalam EnerGuard filter life is equal to traditional micro-glass media filters and lasts twice as long as other media filters.

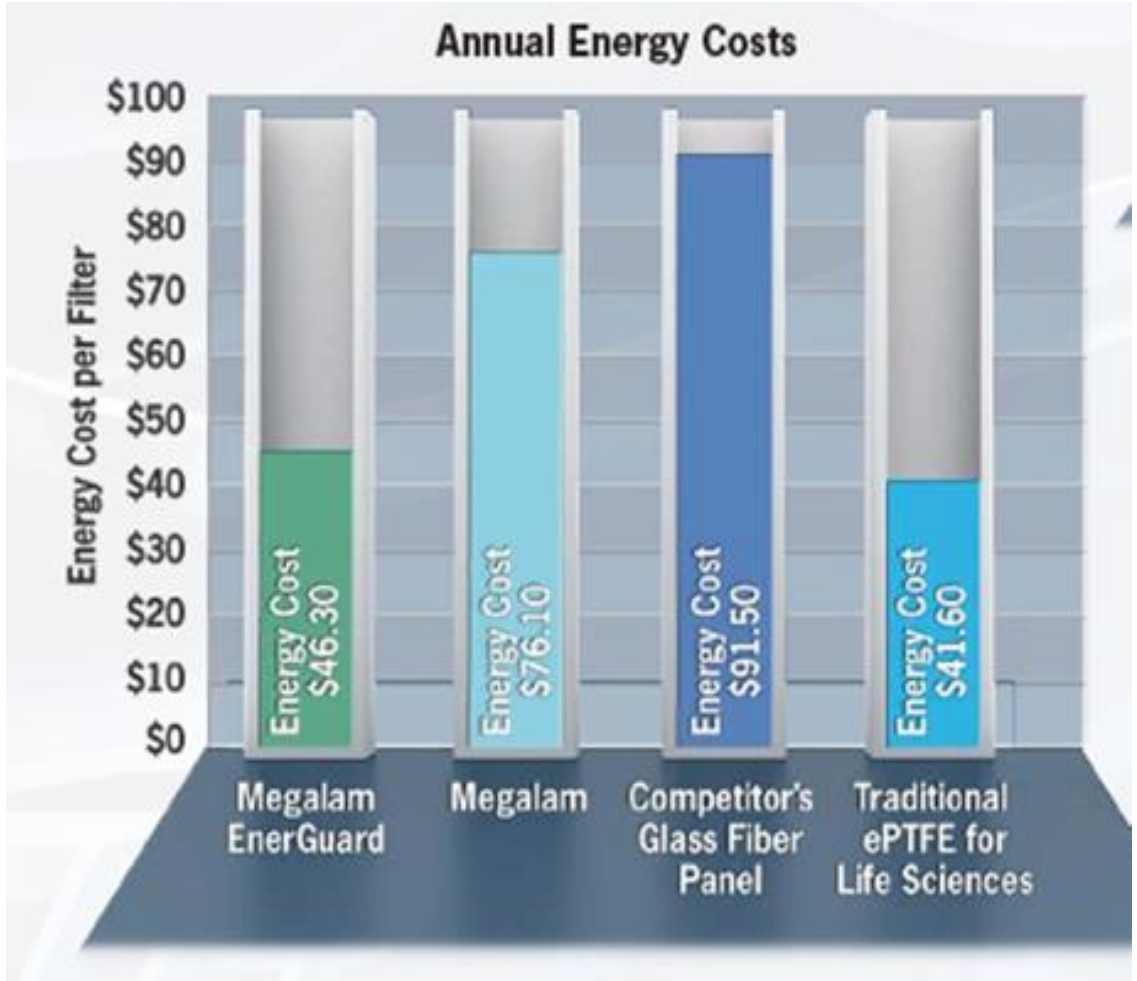
Depth-loading media increases the effective area of particle capture substantially to maintain consistent low-pressure drop and increases the period between filter replacements.

EnerGuard efficiency is guaranteed to maintain rated values. They are available in H13, H14, and U15 efficiencies and in standard and customized pack depths.

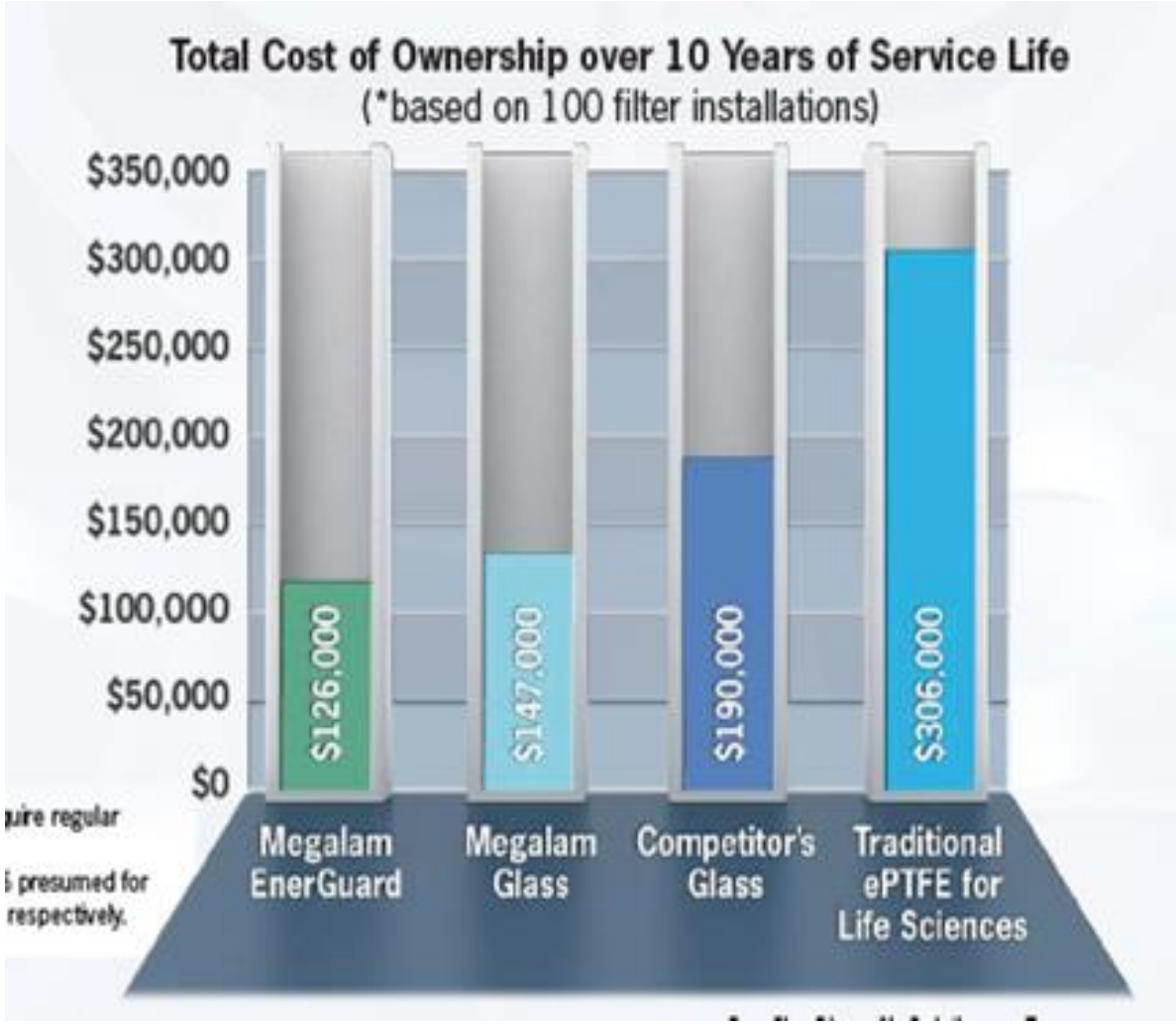
EnerGuard Installation Cost Comparison				
	Megalam EnerGuard <1%	Other HEPA Filters 10-30%		
Failure Rate	0%	10%	20%	30%
Filters Failed	0	10	20	30
Replacement Filter Costs	0	$3,000	$6,000	$9,000
Process Downtime (during replacement)	*0 weeks	1-2 weeks	1-2 weeks	1-2 weeks
Installation and Certification Cost per Filter	**$300	**$300	**$300	**$300
Total Reinstallation and Recertification Costs	0	$3,000	$6,000	$9,000
Total Reinstallation Costs	**$0**	**$6,000	**$12,000	**$18,000

*Assumes 1 spare will be available at time of initial installation **Installation $150/filter; Certification $150/filter


Pressure Drop Comparison
Average Pressure Drop (inches w.c.)
1.00
0.80
0.60
0.40
0.20
0
Average Δp 0.39
Average Δp 0.64
Average Δp 0.77
Average Δp 0.35
Megalam EnerGuard
Megalam
Competitor's Glass Fiber Panel
Traditional ePTFE for Life Sciences


Annual Energy Costs
Energy Cost per Filter
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$0
Energy Cost $46.30
Energy Cost $76.10
Energy Cost $91.50
Energy Cost $41.60
Megalam EnerGuard
Megalam
Competitor's Glass Fiber Panel
Traditional ePTFE for Life Sciences

Once the installation is complete, it’s common to find several of the expensive, delicate new HEPA air filters were damaged in the process. Production can’t be started up again until the damaged filters are replaced. This creates expensive unplanned production delays, not to mention the large upfront cost of replacing filters twice unnecessarily. This expense is avoided with EnerGuard



Filtration Group

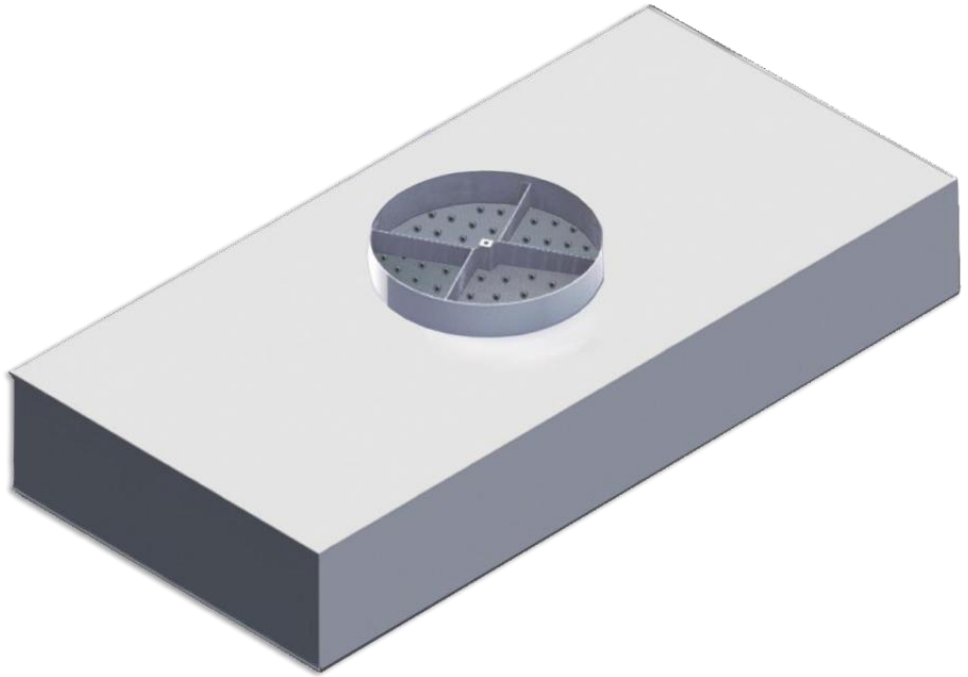
The filter module design is as important as the media

Flowstar Cleanroom Panels and DTMs have minipleated wet laid microglass media. Minimum removal efficiencies of 99.99% (HEPA) on 0.3 um particles and up to 99.9995% (ULPA) on 0.12um particles are designed for easy installation, optimal performance and longer life.

Product Type	Standard Pack Depths	Filter Frame Depths	Seal Options
Cleanroom Panels	2.0" -5.5" (2 thru 5.5)	2.72" - 5.88"	Gasket, Gel, Knife Edge
Ducted Terminal Modules	2.0" -4.0" (2, 2.5, 3 and 4)	5.25" - 7.25"	Gasket, Knife Edge

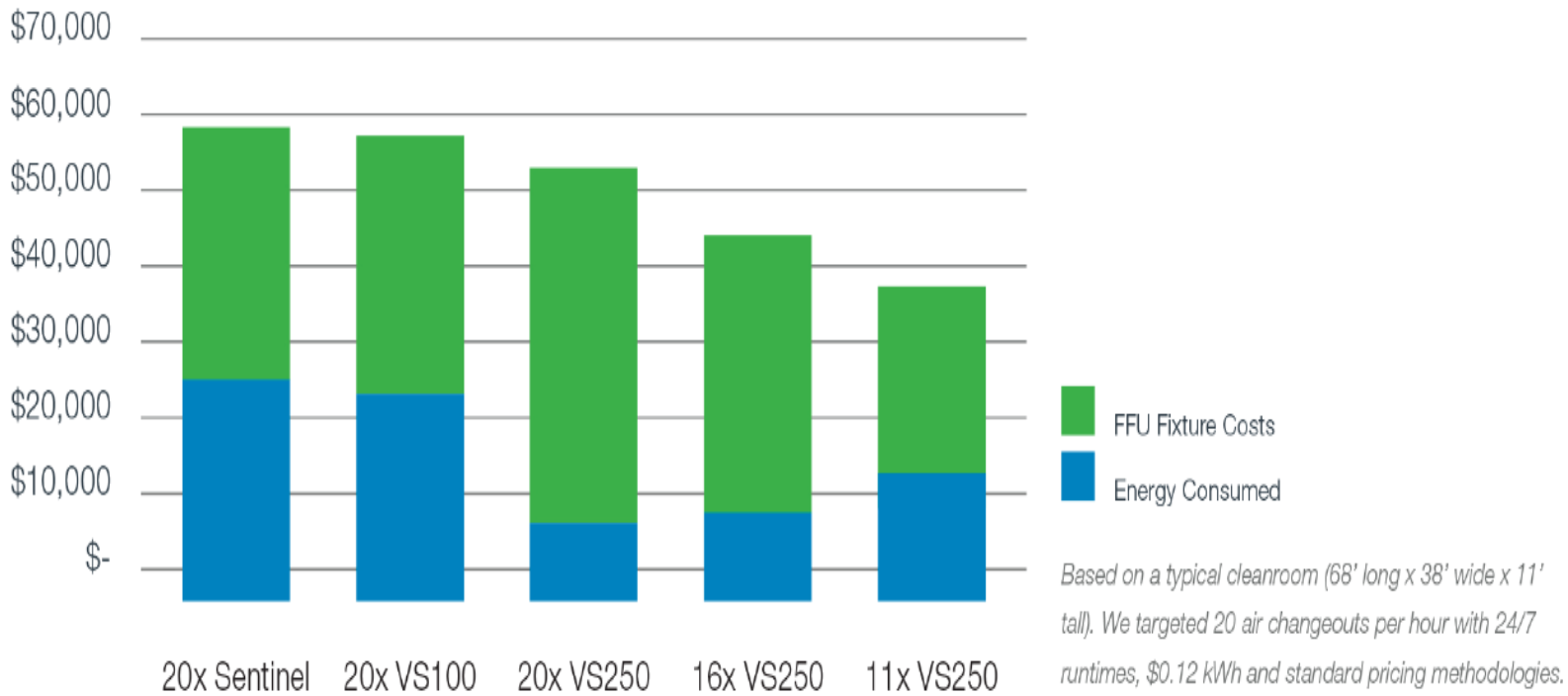
The Flowstar CED (Critical Environment Diffuser) is a room side serviceable diffuser with HEPA or ULPA gel seal filters. The unit is constructed of extruded aluminum with a clear anodized finish that is completely sealed at the factory with a two component polyurethane. Filters are gel seal and available in 99.99% at 0.3 micron up to 99.9995% at most penetrating particle size (MPPS).

- 99.99% HEPA – 99.9995% ULPA filtration 2”, 3” & 4” media pack configurations
- Extruded aluminum with clear anodized finish diffuser and filter
- Removable hinged perforated grille with 1/4 turn fasteners and safety chain
- Filters tested and certified to IEST recommended practice for HEPA and ULPA Filters



VS250 Lowers Your Total Cost of Ownership (TCO)

In the graph below, we compare energy consumption and fixture costs. In the first three examples, we incorporated 20 units and decreased the quantity of the VS250 to reduce the TCO while maintaining the CR ISO 7 classification. The more efficient your system is, the likelihood for contamination is lessened, and the lower your total cost will be.



Based on a typical cleanroom (68' long x 38' wide x 11' tall). We targeted 20 air changeouts per hour with 24/7 runtimes, $0.12 kWh and standard pricing methodologies.

Hollingsworth & Vose

- Media Processing Costs need to be considered
- Clean pleat leads to lower pressure drop
- Microglass media has better energy/efficiency ratio than others

Media performance (and lower energy usage) Filter media are porous or permeable substances — such as paper or nonwovens — positioned to catch and hold certain particle sizes. Filters are designed to meet a certain level of efficiency at a given airflow. In order to meet a given filtration efficiency, media has to be selected carefully. When air is pushed or pulled through a filter, a gradient or pressure drop is created. The pressure drop and media performance is directly related to the media face velocity (velocity of air passing through). Stated more broadly, performance is the ability to deliver required filtration efficiency at a given airflow with a certain pressure drop. In a technical context, media filtration performance is expressed in a gamma (also referred to as alpha) value. This value states the relationship between the penetration of a given filter media at a specific velocity and the subsequent pressure drop.

Penetration and efficiency are inversely related, with penetration assumed to be 100% minus efficiency. The formula shows that the greater the pressure drop, the greater the amount of energy needed by a fan or ventilator to push or pull a given amount of air through a filter, the lower the gamma value. The higher the gamma value, the less energy needed. Thus higher gamma values are optimum in terms of the amount of energy consumed. In short, filter media is a critical component of filter design because it plays a primary role in determining the overall total cost for operating a filtration system over its working life.

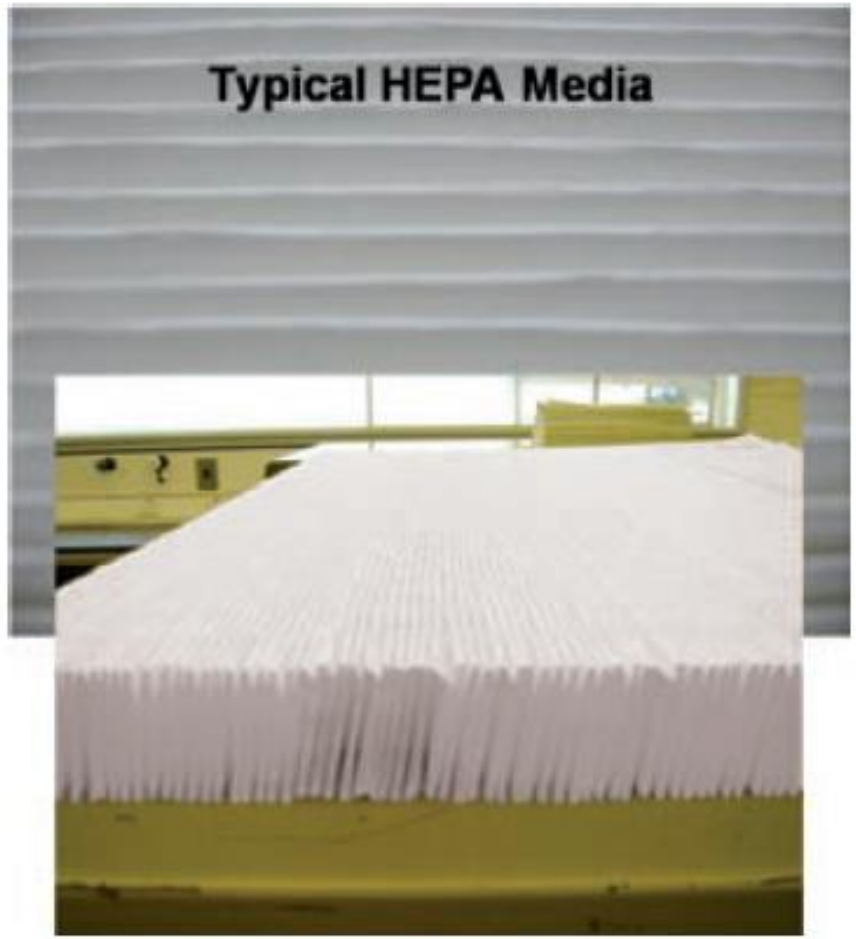
Media processability The cost of producing filters consists of more than the material costs of the various components such as frames, adhesives, and media. Considering the cost of machine time and labor, the manufacturing steps associated with preparing and integrating media into each filter can account for significant cost factors. Media processability is therefore a major part in the cost of filter production. There is both a qualitative and quantitative aspect to media processability. Quality refers to the ease of pleating the media while producing the “ideal” pleat profile. The speed at which media can be pleated with the least amount of wasted time and scrap is a quantitative factor.

System design and operation The total cost of ownership consists of the hardware (filter elements, housing, fans, installation, etc.) and operating costs of the filtration system. The operational expenses depend upon the level of filtration efficiency required. The choice of media has a direct impact on operating costs because selecting a high-gamma filter media may lessen the initial cost of building a filtration system. For instance, a lower pressure drop can translate into smaller motors for air handling equipment. As stated earlier, the operational costs relate to the energy needed to deliver a specified amount of air. The smaller the pressure drop across a filter, the less energy and expense consumed in order to accomplish filtration. Optimizing media design For all the reasons given above, filter manufacturers have for some time been requesting an improved class of filter media for their users in HEPA and ULPA applications. This media would incorporate critical characteristics such as high gamma and high efficiency for reduced pressure drop and high performance. It would optimize processability for improved running time, throughput, and yield. Finally, it would allow reductions in manufacturing efforts and costs for filter makers, in air handling system costs for designers, and in operating costs for users. Fortunately, a new generation of filter media designed to answer these requirements has recently been developed and is being adopted by leading filter manufacturers.

Next-generation filter media Newer filter media with higher standards for media performance, processability, and cost efficiency are now helping provide improved HEPA/ULPA filtration for cleanrooms and critical spaces in electronics fabrication, pharmaceutical production, hospitals, food processing, and other industrial uses.

Through an extensive development effort involving many pleating trials, coupled with an investment program in advanced media manufacturing equipment, Hollingsworth & Vose has designed its new PerForm™ line with significantly improved processability. As a result of this and other improvements, pleater machine setup times are reduced. These media run fast, with a clean pleat formation on rotary pleating equipment. Expensive pleater scrap is greatly reduced. These advantages in processability also bring benefits for performance. Designing PerForm media with a superior pleat definition improves laminar flow characteristics. (See figure 1)

This clean pleat formation contributes to a lower pressure drop in a given filter, compared to the same filter with inferior pleat definition.

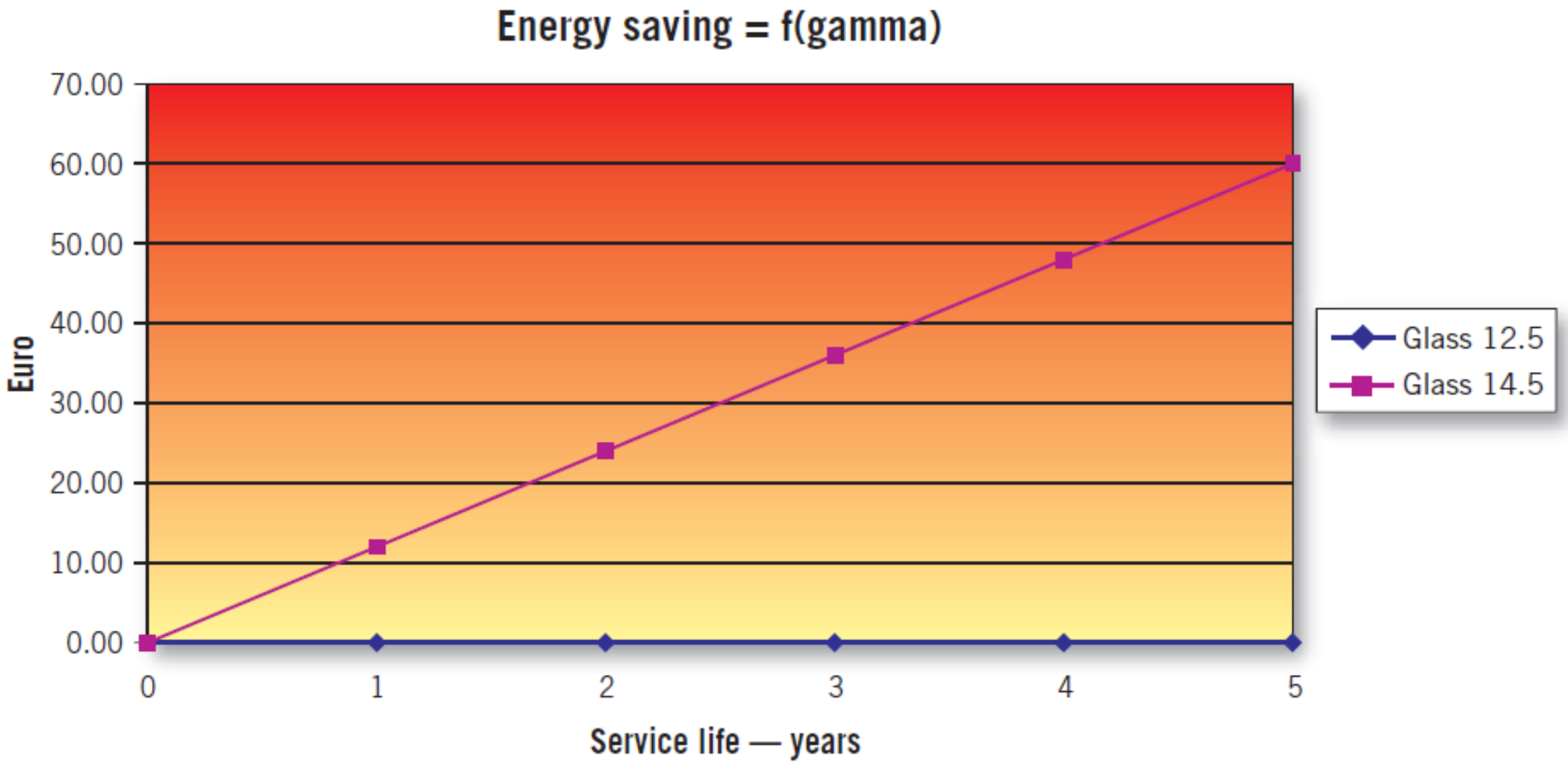

Typical HEPA Media


PerForm H&V HEPA Media

The PerForm product family is offered in grades ranging from sub-HEPA through ULPA performance. Compared to standard media, this media offers efficiencies at a 9% to 16% lower pressure drop. As mentioned previously, this brings economic benefits.

As a rule of thumb (depending on the cost of electrical energy), reducing filter pressure drop by 1 Pa creates an air handling equipment energy saving of approximately 1 (currently about $1.55 U.S.) per filter per year.

Based on this assumption, the accompanying graph shows energy savings for a filter containing 10 m2 of media; it contrasts one microglass-based media with a gamma value of 12.5 against another showing a higher gamma value of 14.5.


Energy saving = f(gamma)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Euro
0
1
2
3
4
5
Service life — years
Glass 12.5
Glass 14.5

The PerForm media product line (see overview chart below) has been designed to reduce both total cost of ownership and total cost of manufacture. It offers filter makers the opportunity to optimize the lifetime, cost, energy impact, and value of their most advanced designs.

Product family overview

Perform Grade ref	HC3393	HC4393	HB5793	HB5493	HB5593	HB5693	HB5893	HA8393
Grammage, gsm	70	70	70	70	70	70	70	75
Air Resistance	210	235	260	280	295	315	360	385
DOP Pen, %	0.100	0.30	0.015	0.008	0.005	0.002		
CNC, cm/s							1.3	1.7
CNC, Pen, %							0.0002	0.00011

Mann + Hummel -Tridim

Tri-Dim Filter Corporation’s Tri-Pure™ HEPA/ULPA Panel filters are designed for use in cleanroom applications where a compact footprint and high efficiency filtration is needed. Applications include medical, pharmaceutical, microelectronics as well as other cleanroom disciplines.

The Tri-Pure™ HEPA/ULPA Panel filter features include a low profile, from only 2.75” (70 mm) cell sides to allow for maximum space utilization in space sensitive applications. All Tri-Pure™ HEPA/ULPA Panel Filters are available in efficiencies from 99.99% @ 0.3 micronsized particles to 99.9995% on 0.1 to 0.2 micronsized particles, which is typically the MPPS (Most Penetrating Particle Size) for this filter in most applications. Tri-Pure™ HEPA/ULPA Panel Filters are available with either a gasket seal or gel seal as needed per application

Nitto Denko

- PTFE outperforms glass for HEPA and ULPA
- For ULPA two membrane layers sandwiched between non -wovens
- Low outgassing

Temish is a PTFE stretched material manufactured by Nitto. As a Japanese company that produces industrial tapes, polarisation films, insulation materials, and several other products, Nitto's technology offers this solution as filter bags for the dust collector of incineration facilities.

The collected dust particles are filtered at the surface, then shaken off by vibration to keep the bags near full capacity.

High efficiency combined with a low-pressure drop is a feature of PTFE filter media and here, 99.99999% of filtration efficiency with ULPA grade PTFE stretched film is possible.

The pressure drop will increase at this extreme level of filtration, but the PTFE material still outperforms other materials like glass fibre in filtration efficiency and the all-important, energy efficiency

The water repellency of PTFE and its three-dimensional network structure of ultra-fine, nanofibers ensure TEMISH is waterproof and dustproof, with high breathability.

High air permeability results from the millions of micropores per square centimeter of the filter. Air permeability is dependent on the pore size, thickness, and porosity of the membrane, all of which also influence water resistance and dust collection capacity.

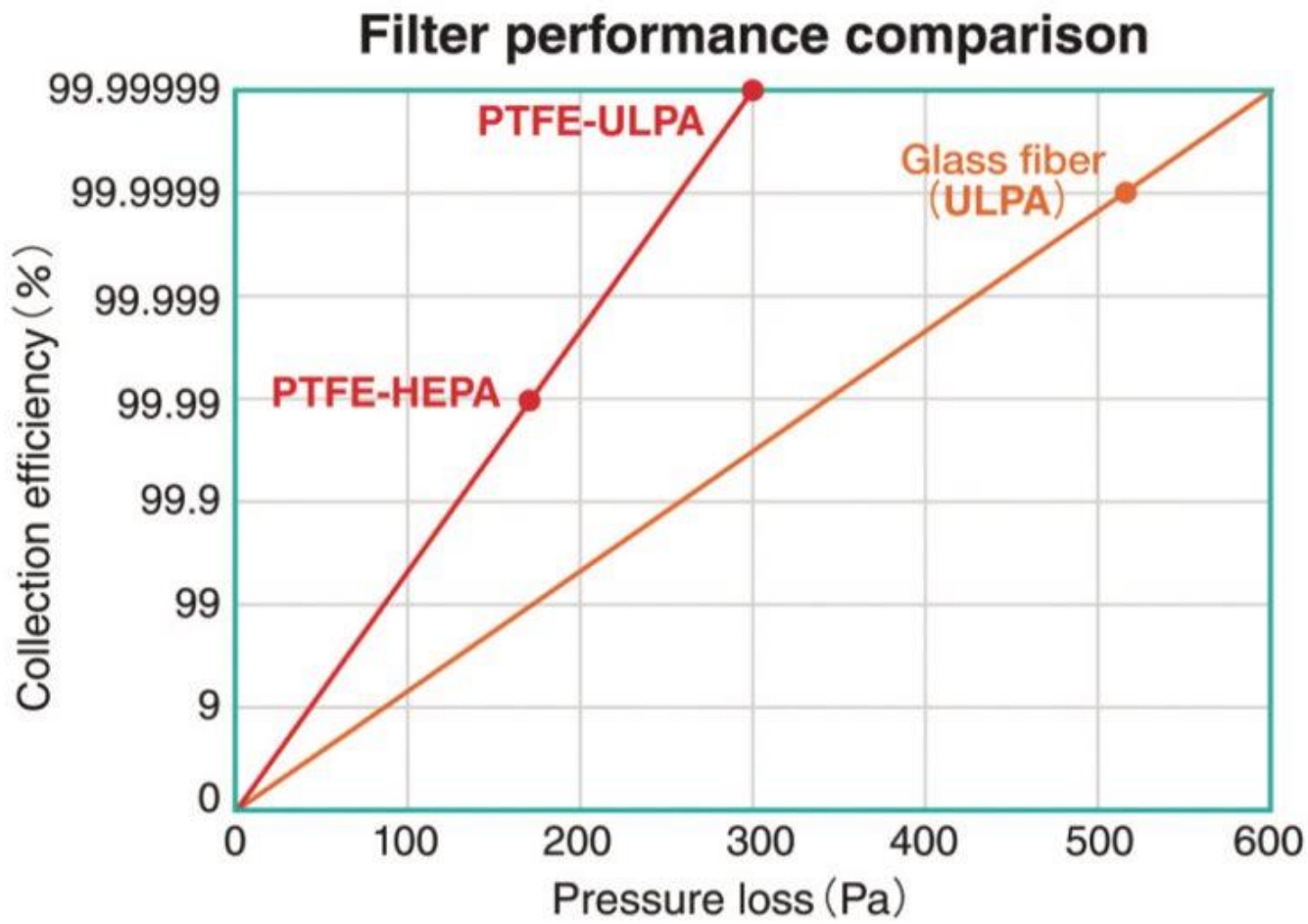
Generally, a higher air permeability tends to lower both water resistance and dust collection efficiency, but this compromise is overcome as a result of the unique and proprietary technology with which the TEMISH is produced.

The PTFE is extruded and calendered, and then either sintered or stretched out to 3-4,000 times its original size in our proprietary processes, depending on the application," explains Brett L. Herrick senior manager of business development for the Americas Growth Division of Nitto, Inc., headquartered in Teaneck, New Jersey. "It is then laminated or further processed with nonwovens, woven fabrics, glass fiber sheets, elastomers or molded plastics. Air goes straight through the membrane, but water won't."

In clean rooms, up to 99.99% filtration efficiency is achievable with TEMISH, and the technology's extremely low pressure drop lowers lifecycle costs. In addition, the inert nature of PTFE means it does not generate harmful off-gases or shed fibers, and it has excellent chemical resistance against acids, alkalis, and organic solvents.

For HEPA-grade performance, the TEMISH membrane is generally sandwiched between two spunbonded nonwovens or can be laminated to a thicker thermally bonded nonwoven. For ULPA grades, a five-layer construction of two TEMISH membranes between layers of 30 GSM spunbond can be employed.

Figure 3.

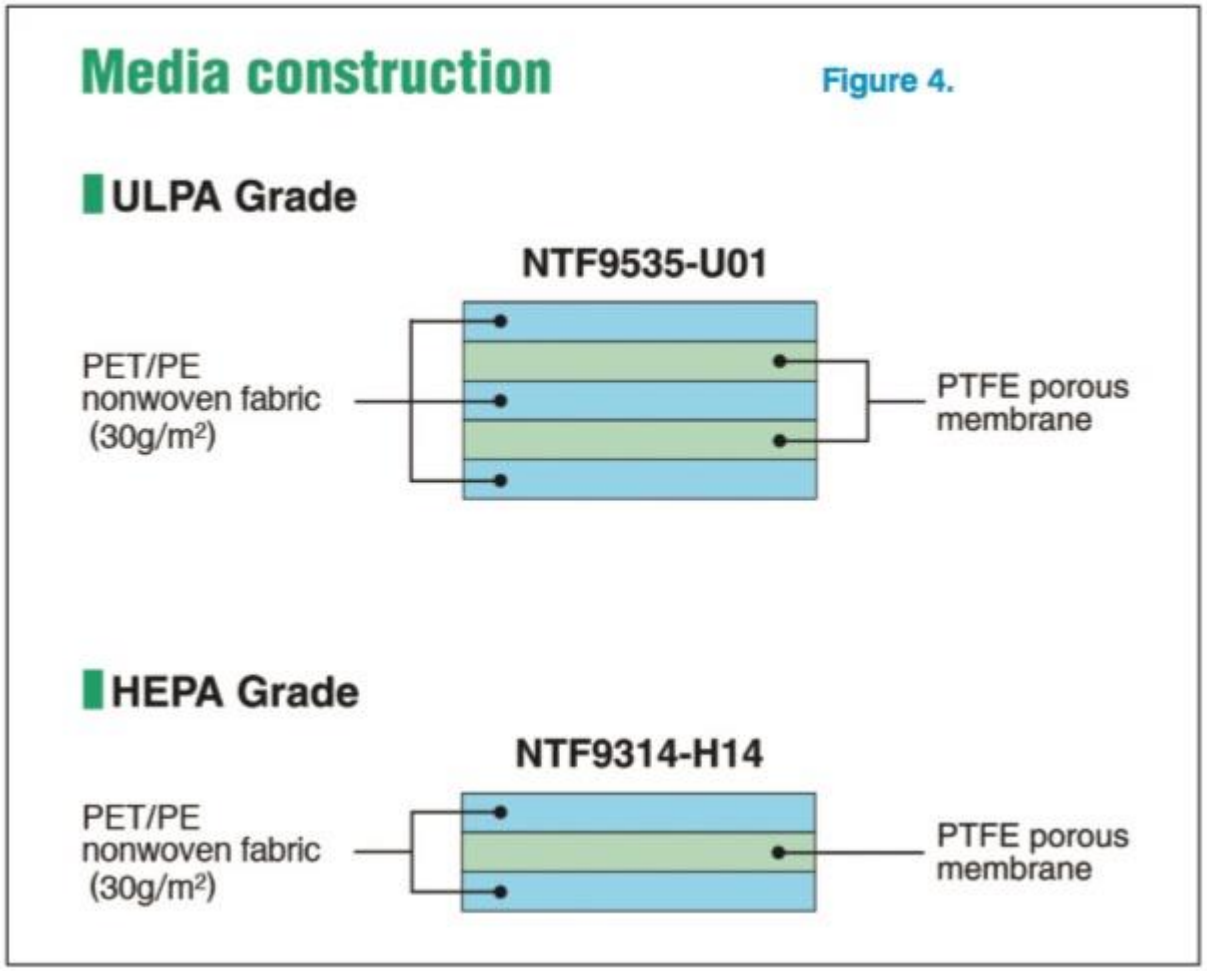


ULPA : Ultra Low Penetration Air Filter
HEPA : High Efficiency Particle Air Filter

Due to low mechanical resistance or outgassing of chemical components, the filtered air could be contaminated by fibres or gases coming from the filter material itself.

The ultrathin PTFE stretched film material is usually reinforced by a non-woven fabric offering excellent mechanical resistance

In combination with the material's natural resistance to acids (such as hydrofluoric acid), alkalis and organic solvents, PTFE drastically reduces the risk of contamination of the cleanroom environment by the filter material



PTFE material shows excellent results when it comes to the outgassing of chemical components

Tests performed by Nitto have shown that there is no trace of bibutyl phthalates, nor methyl ethyl ketone oxime or fluoro alkyl alcohol.

The total amount of outgassing is 461 ppm, which is only 6% of the 7,860 ppm measured with glass fibre material.

TABLE 1: LOW OUTGASSING

unit = ppm

Membrane Name	TEMISH	Glass fibre
Bibutyl Phthalate (DBP)	ND	1100
Methyl Ethyl Ketone Oxime	ND	1000
Methyl Isobutyl Ketone Oxime	ND	210
Fluoro Alkyl Alcohol	ND	1240
Others	461	4310
Total amount of outgassing in $\mu g/m^2$	461	7860

ND = not detectable Method = GC-MS (heating condition 125°C for 1 hour)

Parker Hannifin

- Parker HVAC Filtration, a division of Parker Hannifin Corporation, announced its new line of MICROPLEAT high-efficiency filters designed for HVAC applications. The filters feature a media blend and mini-pleat design to improve particulate removal, dust-holding capacity and efficiency.

- MICROPLEAT filters are available to meet both High Efficiency Particulate Air (HEPA) and Ultra-Low Particulate Air (ULPA) minimum ratings up to 99.97% at 0.3 microns and 99.999% at 0.12 microns. The filters are available in a wide range of materials and configurations to install in all types of housings and framing systems. They are certified to ISO 9001:2015 and C UL listed and offer a wide variety of cell side materials, including wood, galvanized steel, stainless steel, roll-formed aluminum and anodized extruded aluminum.