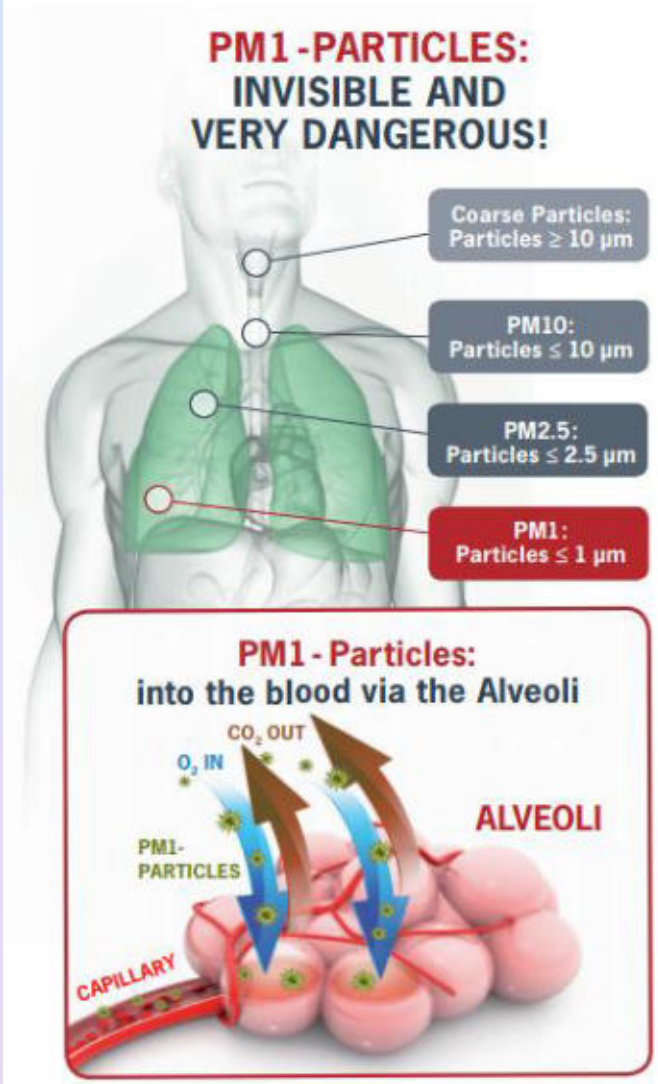
Qualidade do ar ambiente e sistemas de ventilação energeticamente eficientes

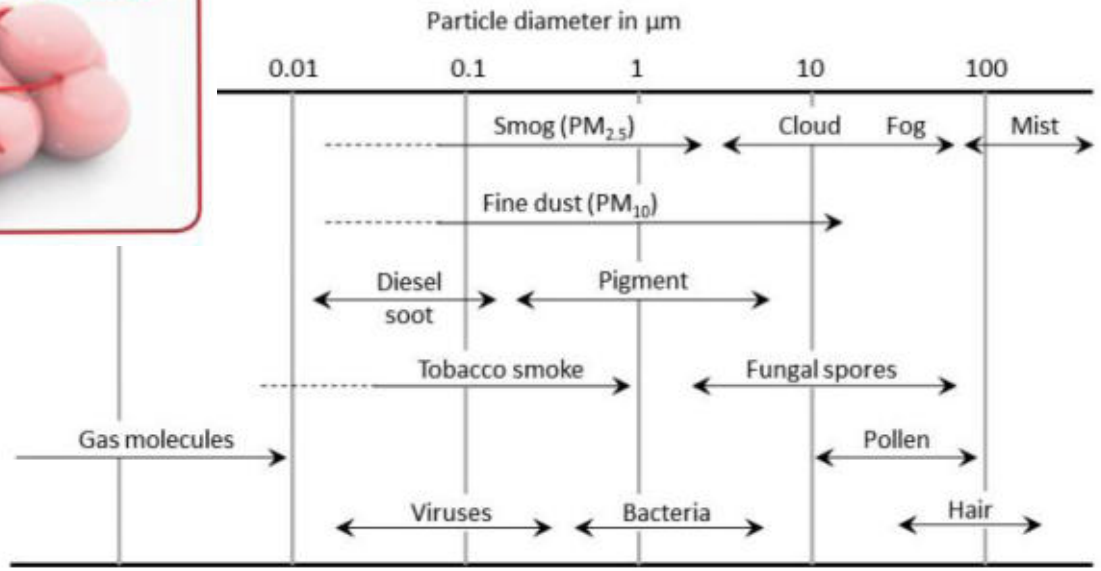
21 Maio 2026

ÍNDICE

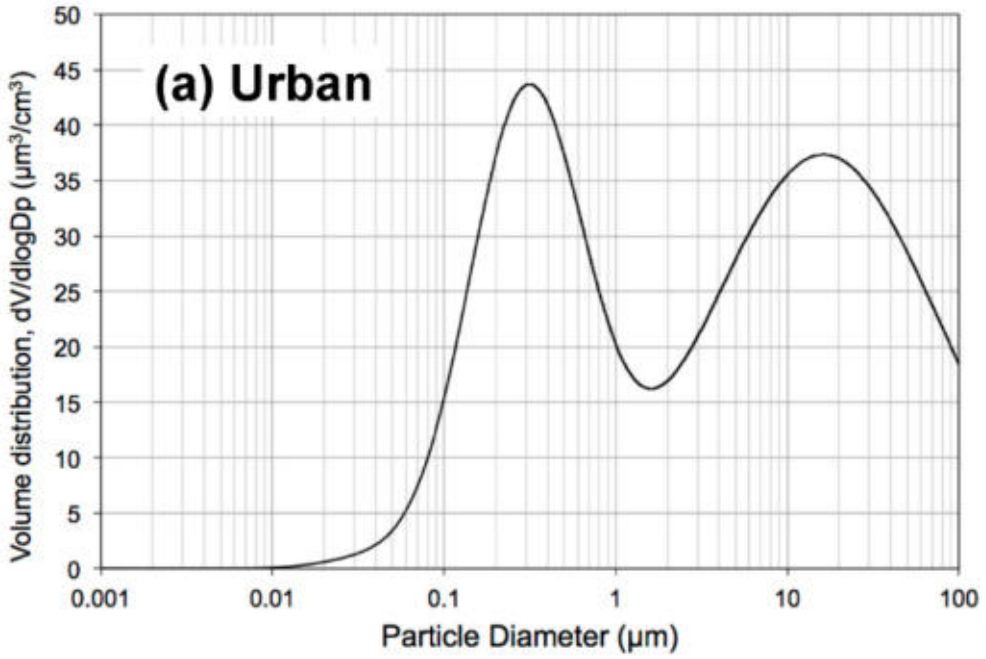
Partículas

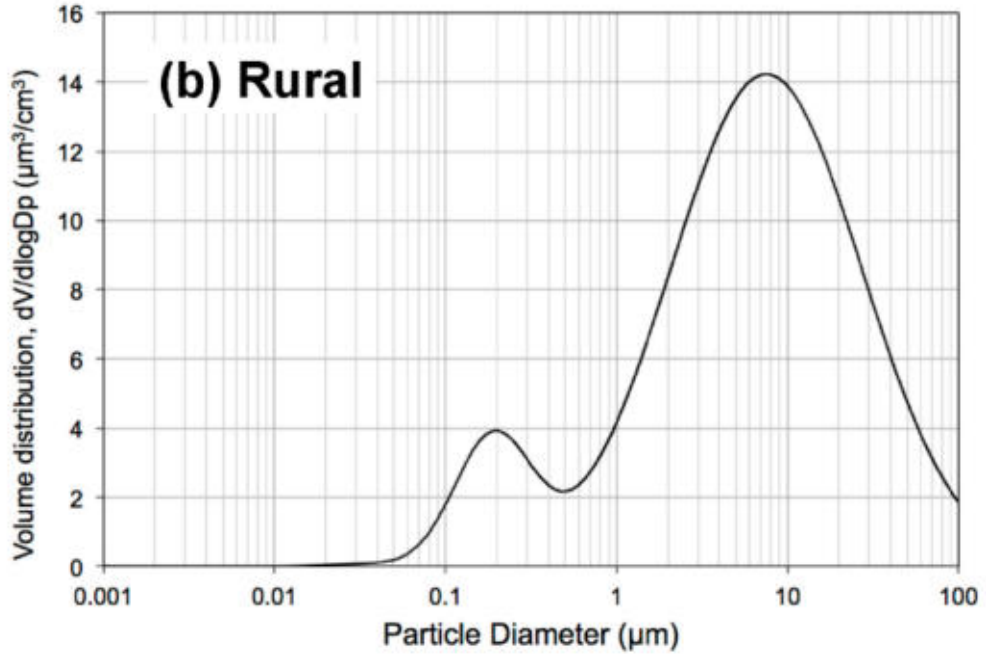
As **PM10** e **PM2.5** são poluentes atmosféricos compostos por partículas minúsculas. As PM10 são inaláveis e ficam retidas nas vias aéreas superiores. As PM2.5 são mais perigosas: penetram profundamente nos pulmões e entram na corrente sanguínea, agravando problemas respiratórios e cardiovasculares.





Ambiente Urbano vs Rural





Fonte: Seinfeld and Pandis (2006) and Jaenicke (1993)

EN 16798-3

Norma europeia projetada para especificar a solução de filtragem correta para edifícios

CATEGORY	DESCRIPTION	TYPICAL ENVIRONMENT
ODA 1	**OUTDOOR AIR, WHICH MAY BE ONLY TEMPORARILY DUSTY** Applies where the World Health Organisation WHO (2021) guidelines are fulfilled (annual mean for $PM_{2.5} \leq 5\ \mu g/m^3$ and $PM_{10} \leq 15\ \mu g/m^3$).	
ODA 2	**OUTDOOR AIR, WITH HIGH CONCENTRATIONS OF PARTICULATE MATTER** Applies where PM concentrations exceed the WHO guidelines by a factor of up to 1.5 (annual mean for $PM_{2.5} \leq 7.5\ \mu g/m^3$ and $PM_{10} \leq 22.5\ \mu g/m^3$).	
ODA 3	**OUTDOOR AIR WITH VERY HIGH CONCENTRATIONS OF PARTICULATE MATTER** Applies where PM concentrations exceed the WHO guidelines by a factor of greater than 1.5 (annual mean for $PM_{2.5} > 7.5\ \mu g/m^3$ and $PM_{10} > 22.5\ \mu g/m^3$).	

Fonte: Camfil

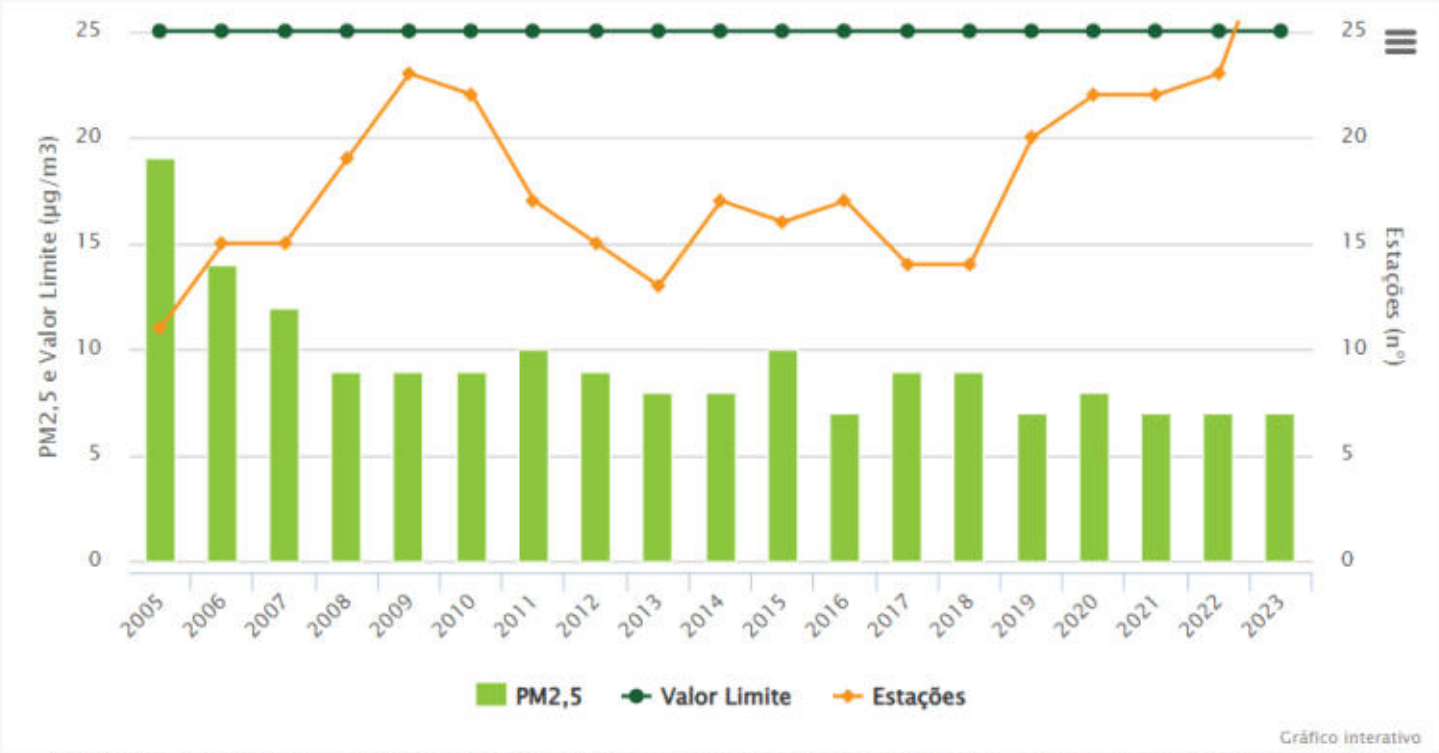
Valores Típicos PM2.5

- Lisboa: ~7-10 $\mu g/m^3$
- Porto: ~8-12 $\mu g/m^3$
- Faro e zonas rurais: ~4-6 $\mu g/m^3$
- Média nacional ~ 7,9 $\mu g/m^3$

EN 16798-3

Dados Portugal

Evolução da concentração média anual de PM2,5 e do número de estações que monitorizam estas partículas



Fonte: APA, CCDR Norte, CCDR Centro, CCDR Lisboa e Vale do Tejo, CCDR Alentejo, CCDR Algarve, DRA Açores, DRA Madeira, 2024

média de qualidade do ar do país 2025

Quão poluído é Portugal?

AQI*
Índice de qualidade do ar
● 44 AQI* US

PM2.5
Partículas finas (≤ 2,5 µm)
● 7.9 µg/m³

A concentração de PM2.5 é atualmente **1.6** vezes o valor da diretriz anual de PM2.5 da Organização Mundial da Saúde.

Fonte: www.iqair.com/pt/portugal

EN 16798-3

Classificações espaços

CATEGORY	GENERAL VENTILATION	
SUP 1		
SUP 2	**ROOMS FOR PERMANENT OCCUPATION** Examples: Offices, kindergardens, hotels, residential buildings, meeting rooms, exhibition halls, conference halls, theaters, cinemas and concert halls.	
SUP 3	**ROOMS WITH TEMPORARY OCCUPATION** Examples: Shopping centers, storage, washing rooms, server rooms and copier rooms.	
SUP 4	**ROOMS WITH SHORT-TERM OCCUPATION** Examples: Restrooms, storage rooms and stairways.	
SUP 5	**ROOMS WITHOUT OCCUPATION** Examples: Data centers, garbage room and underground car parks.	

Fonte: Camfil

EN 16798-3

Filtragem necessária

			SUPPLY AIR				
OUTDOOR AIR			SUP 1* $PM_{2,5} \leq 1,25$ $PM_{10} \leq 3,75$	SUP 2* $PM_{2,5} \leq 2,5$ $PM_{10} \leq 10$	SUP 3** $PM_{2,5} \leq 3,75$ $PM_{10} \leq 11,25$	SUP 4 $PM_{2,5} \leq 5$ $PM_{10} \leq 15$	SUP 5 $PM_{2,5} \leq 7,5$ $PM_{10} \leq 22,5$
CATEGORY	$PM_{2,5}$	PM_{10}	ePM_1	ePM_1	$ePM_{2.5}$	ePM_{10}	ePM_{10}
ODA 1	≤ 5	≤ 15	70%	50%	50%	50%	50%
ODA 2	≤ 7,5	≤ 22,5	80%	70%	70%	80%	50%
ODA 3	≤ 7,5	≤ 22,5	90%	80%	80%	90%	80%

Table 3: Recommended min. ePM_x filtration efficiencies according to EN 16798-3 depending on ODA and SUP (annual mean PM_x values in µg/m³)

*Minimum filtration requirements ISO ePM_1 50% refer to a final filter stage

**Minimum filtration requirements ISO $ePM_{2,5}$ 50% refer to a final filter stage

Fonte: Camfil

France Air
AIRVANCE GROUP

EN 779
Vs
ISO 16890

EN 779-2012	ISO 16-890			
	ISO Grossier	ISO ePM10	ISO ePM2,5	ISO ePM1
G2	50-60%			
G3	50-70%			
G4	60-80%			
M5		50-70%		
M6		60-80%		
F7		80-90%	65-75%	50-65%
F8		90-100%	75-95%	65-90%
F9		90-100%	85-95%	80-90%

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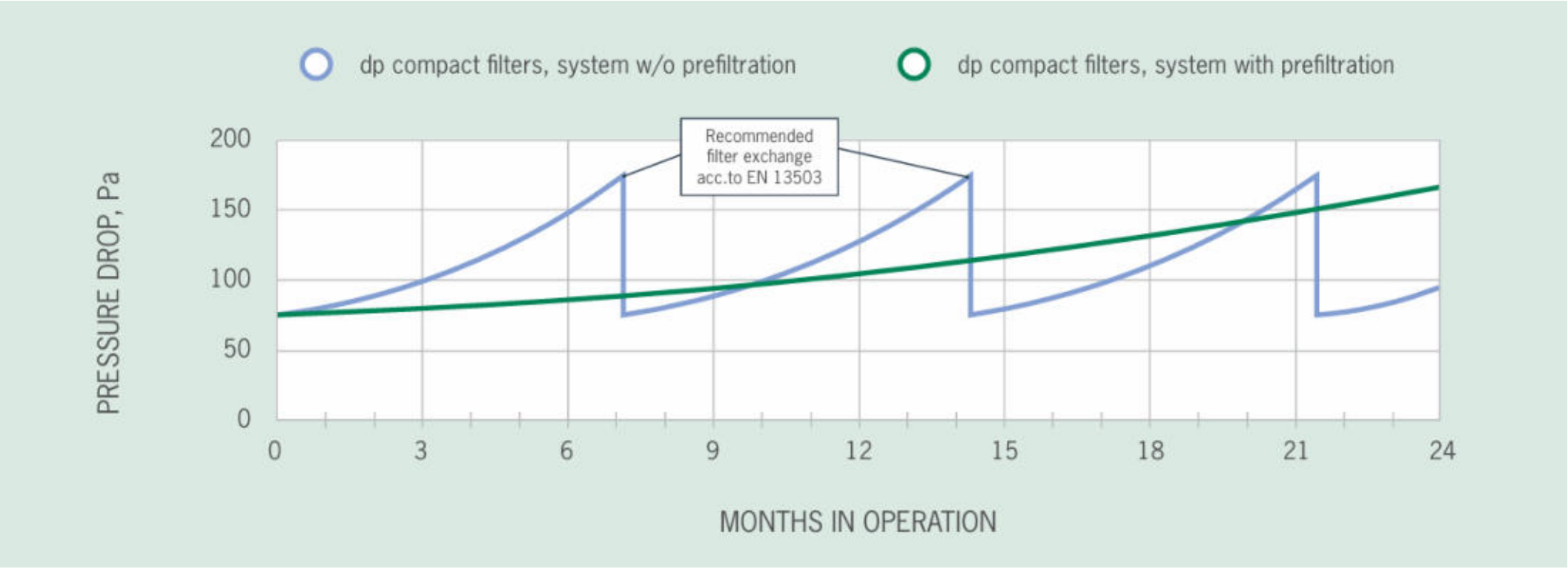
Utilização de pré-filtro

Intervalos de substituição com e sem pré-filtragem



Fonte: Camfil

Utilização de pré-filtro

Recomendação EUROVENT 4/23 (Referida Portaria 138º-I)

Outdoor air quality		Supply air quality				
		SUP 1	SUP 2	SUP 3	SUP 4	SUP 5
ODA 1	Example 1	ePM10 50% + ePM1 60%	ePM1 50%	ePM2,5 50%	ePM10 50%	ePM10 50%
	Example 2	ePM1 70%	-	-	-	-
ODA 2	Example 1	ePM1 50% + ePM1 60%	ePM10 50% + ePM1 60%	ePM1 50%	ePM2,5 50%	ePM10 50%
	Example 2	ePM1 80%	ePM1 70%	ePM2,5 70%	ePM10 80%	-
ODA 3	Example 1	ePM1 50% + ePM1 80%	ePM1 50% + ePM1 60%	ePM10 50% + ePM1 60%	ePM1 50%	ePM2,5 50%
	Example 2	ePM1 90%	ePM1 80%	ePM2,5 80%	ePM10 90%	ePM10 80%

Table 7: examples of filter classes meeting respective ODA/SUP categories requirements

Fonte: Eurovent 4/23

Eficiência filtragem “acumulada”

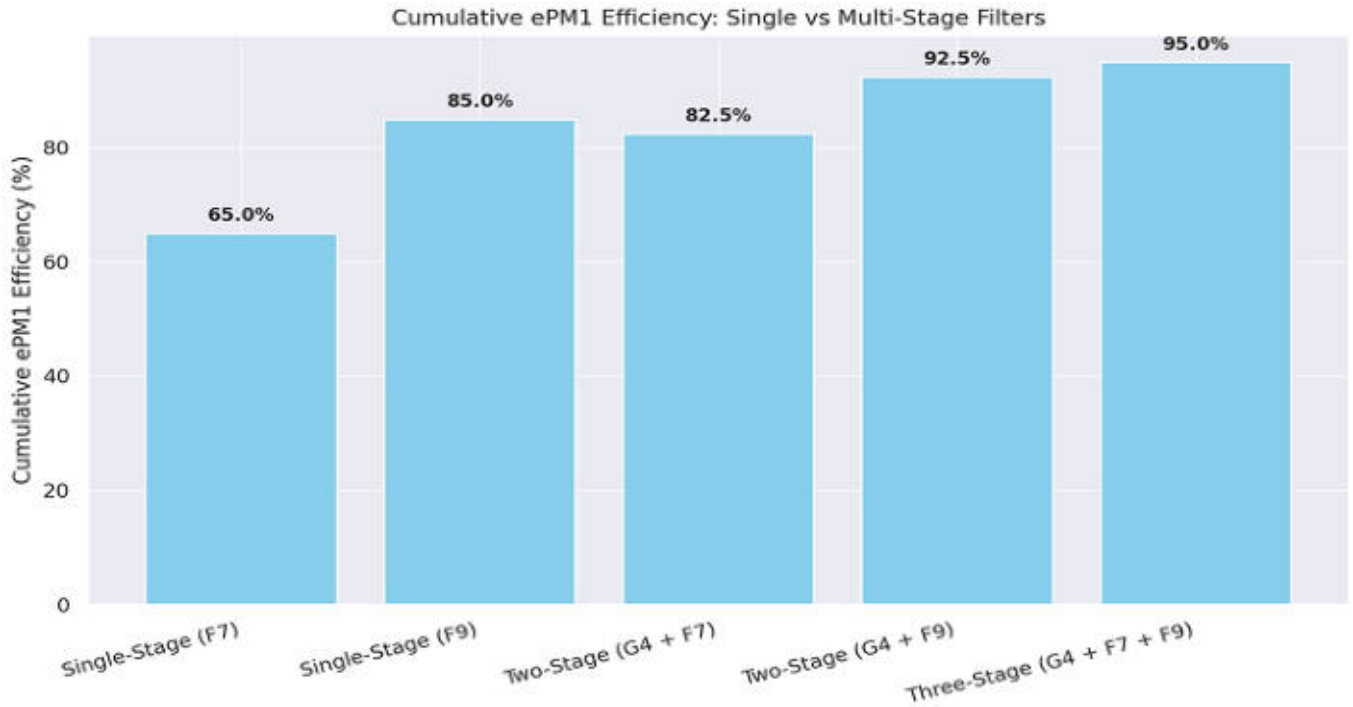


Figure 5: Cumulative ePM1 efficiency

Fonte: https://www.eceuk.com/

To facilitate rough estimations, it is recommended to use the following formula to determine the combined filtration efficiency for respective particle size fractions:

$$ePM_{x,\,cum} = 100 \cdot \left(1 - \left(\left(1 - \frac{ePM_{x,\,s1}}{100}\right) \cdot \left(1 - \frac{ePM_{x,\,s2}}{100}\right) \cdot \ldots \cdot \left(1 - \frac{ePM_{x,\,sn+1}}{100}\right)\right)\right)$$

Where

$ePM_{x,cum}$ is the total cumulated efficiency for x fraction
$ePM_{x,sn+1}$ is the fractional efficiency for each filter stage

This simplified approach assumes the same particle distribution on the inlet to each of the stages. In most cases, it results in minor deviations compared to the EN ISO 16890 methodology, acceptable for engineering calculations accuracy.

However, if high accuracy is required, it is recommended to contact a filter supplier to perform relevant calculations.

Fonte: Eurovent 4/23

Eficiência energética
Filtragem

Caso prático

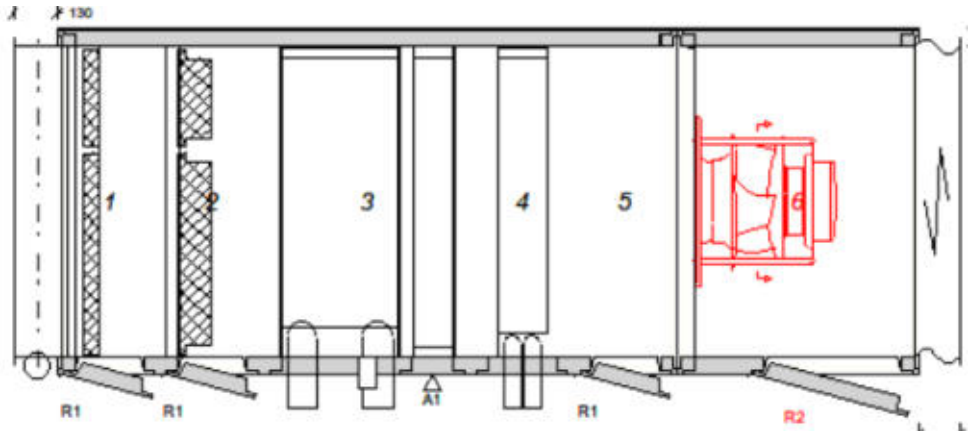
Short filter section

Air volume	6000	m³/h
Filter:	Filter panel M5	
Initial resistance	107	Pa
Initial resistance ERP 1253	147	Pa
Selection resistance	157	Pa
Final pressure difference	207	Pa
Filter surface	9,74	m2
Filter class	5	
Filterbewertung	ISO ePM10 60%	

Short filter section

Air volume	6000	m³/h
Filter:	Filter panel F7	
Initial resistance	125	Pa
Initial resistance ERP 1253	0	Pa
Selection resistance	175	Pa
Final pressure difference	225	Pa
Filter surface	15,90	m2
Filter class	7	
Filterbewertung	ISO ePM1 55%	
Filterabscheidegrade	ePM2,5: 70% ePM10:	

Refer to active power(elec.)	2,084	KW



Eficiência energética
Filtragem

Caso prático

Short bag filter section

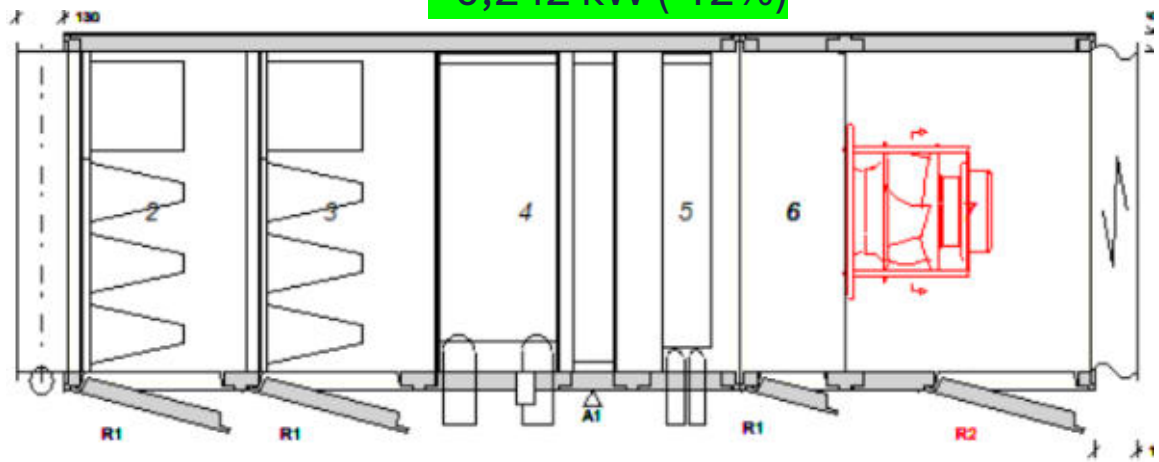
Air volume	6000	m³/h
Filter:	Compact filter V-shape	
Initial resistance	53	Pa
Initial resistance ERP 1253	60	Pa
Selection resistance	103	Pa
Final pressure difference	153	Pa
Filter surface	33,00	m2
Filter class	5	
EnergieVerbrauch	900	kWh
EnergieKlasse	C	
Filterbewertung	ISO ePM10 70%	

Short bag filter section

Air volume	6000	m³/h
Filter:	Compact filter V-shape	
Initial resistance	60	Pa
Initial resistance ERP 1253	0	Pa
Selection resistance	110	Pa
Final pressure difference	160	Pa
Filter surface	33,00	m2
Filter class	7	
EnergieVerbrauch	782	kWh
EnergieKlasse	A+	
Filterbewertung	ISO ePM1 60%	
Filterabscheidegrade	ePM2,5: 65% ePM10:	

Refer to active power(elec.)	1,842	KW

- 0,242 kW (-12%)



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AIRVANCE GROUP

Eficiência energética
Filtragem

Eurovent 21/4

M_x =400g (AC Fine)	AEC in kWh/y FOR ePM_{10}					
	ePM_{10} ≥ 50%					
	A+	A	B	C	D	E
50&55%	450	550	650	750	1100	>1100
60&65%	500	600	700	850	1200	>1200
70&75%	600	700	800	900	1300	>1300
80&85%	700	800	900	1000	1400	>1400
>90%	800	900	1050	1400	1500	>1500

M_x =250g (AC Fine)	AEC in kWh/y FOR $ePM_{2,5}$					
	$ePM_{2,5}$ and $ePM_{2,5,min}$ ≥ 50%					
	A+	A	B	C	D	E
50&55%	700	800	950	1300	1900	>1900
60&65%	750	850	1000	1350	1950	>1950
70&75%	800	900	1050	1400	2000	>2000
80&85%	900	1000	1200	1500	2100	>2100
>90%	1000	1100	1300	1600	2200	>2200

M_x =200g (AC Fine)	AEC in kWh/y FOR ePM_1					
	ePM_1 and $ePM_{1,min}$ ≥ 50%					
	A+	A	B	C	D	E
50&55%	800	900	1050	1400	2000	>2000
60&65%	850	950	1100	1450	2050	>2050
70&75%	950	1100	1250	1550	2150	>2150
80&85%	1050	1250	1450	1800	2400	>2400
>90%	1200	1400	1550	1900	2500	>2500

Le débit de référence — La perte de charges moyenne

$$\text{Consommation énergétique annuelle d'un filtre (kWh/an)} = \frac{Q \times \Delta P \times t}{\eta \times 1000}$$

La durée de fonctionnement

Le rendement du ventilateur

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Eficiência energética
Filtragem

Filtros Electroestáticos

ePM2.5 : 95%

Dim: 610x610
Caudal 3400 m/h

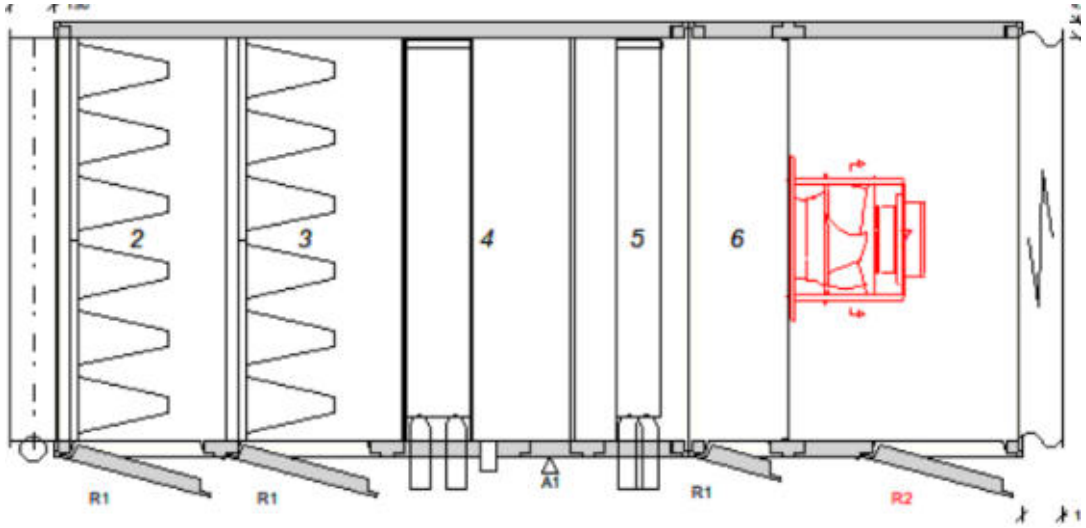
PdC: 17 Pa

Eficiência energética
Velocidade

Caso prático

Air velocity Energy label Eurovent	1,99 m/s		Refer to active power(elec.)	2,084 KW
Air velocity (class in accordance to EN 13053)	2,0 m/s (V3)			
Air velocity Energy label Eurovent	1,49 m/s		Refer to active power(elec.)	1,53 KW
Air velocity (class in accordance to EN 13053)	1,5 m/s (V1)			

- 0,554 kW (-27%)



1000 → 1300mm

France Air
AIRVANCE GROUP

EN 13053

Norma europeia requisitos desempenho UTAs

Classe	Velocidade
V1	≤ 1,6 m/s
V2	1,6 – 1,8 m/s
V3	1,8 – 2,0 m/s
V4	2,0 – 2,2 m/s
V5	2,2 – 2,5 m/s
V6	2,5 – 2,8 m/s
V7	2,8 – 3,2 m/s

Classe	Relação com Pm,ref
P1	≤ 0,85 × Pm,ref
P2	≤ 0,90 × Pm,ref
P3	≤ 0,95 × Pm,ref
P4	≤ 1,00 × Pm,ref
P5	≤ 1,06 × Pm,ref
P6	≤ 1,12 × Pm,ref
P7	> 1,12 × Pm,ref

Classe	Eficiência de recuperação ηe (%)
H1	≥ 71%
H2	≥ 64%
H3	≥ 55%
H4	≥ 45%
H5	≥ 36%
H6	Sem requisitos

$P_{m\,ref} = (\Delta P_{stat} / 450)^{0.925} \cdot (qv + 0{,}08)^{0.95}$

$P_{m\,ref}$ (kW) electric power consumption

ΔP_{stat} (Pa) Static pressure increase

qv (m^3/s) air flow

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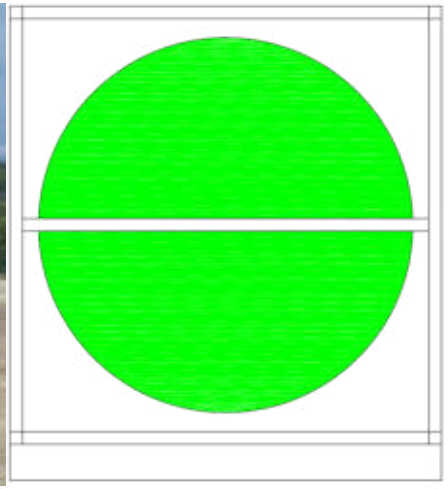
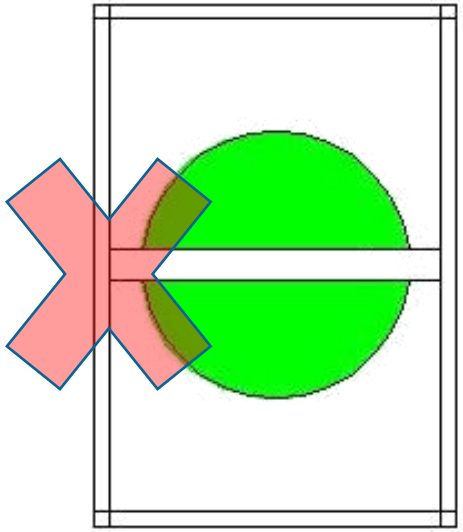
Recuperação Energia





Roda Termica

Optimização Eficiência

Eficiência térmica do recuperador (ES 1253, 2018)					
Tamanho da unidade MAX2	32	42	52	62	72
L (1.7mm)	-	76,8 %	80,1 %	82,0 %	82,8 %
ML (1.6mm)	76,9 %	81,1 %	83,4 %	84,3 %	84,4 %
SL (1.5mm)	81,5 %	84,2 %	85,7 %	86,1 %	86,0 %
Higroscópica- L	73,0 %	77,1 %	80,1 %	81,9 %	83,0 %
Higroscópica-ML	75,6 %	79,4 %	82,2 %	83,4 %	83,7 %
Higroscópica-SL	80,1 %	82,9 %	84,6 %	85,2 %	85,2 %

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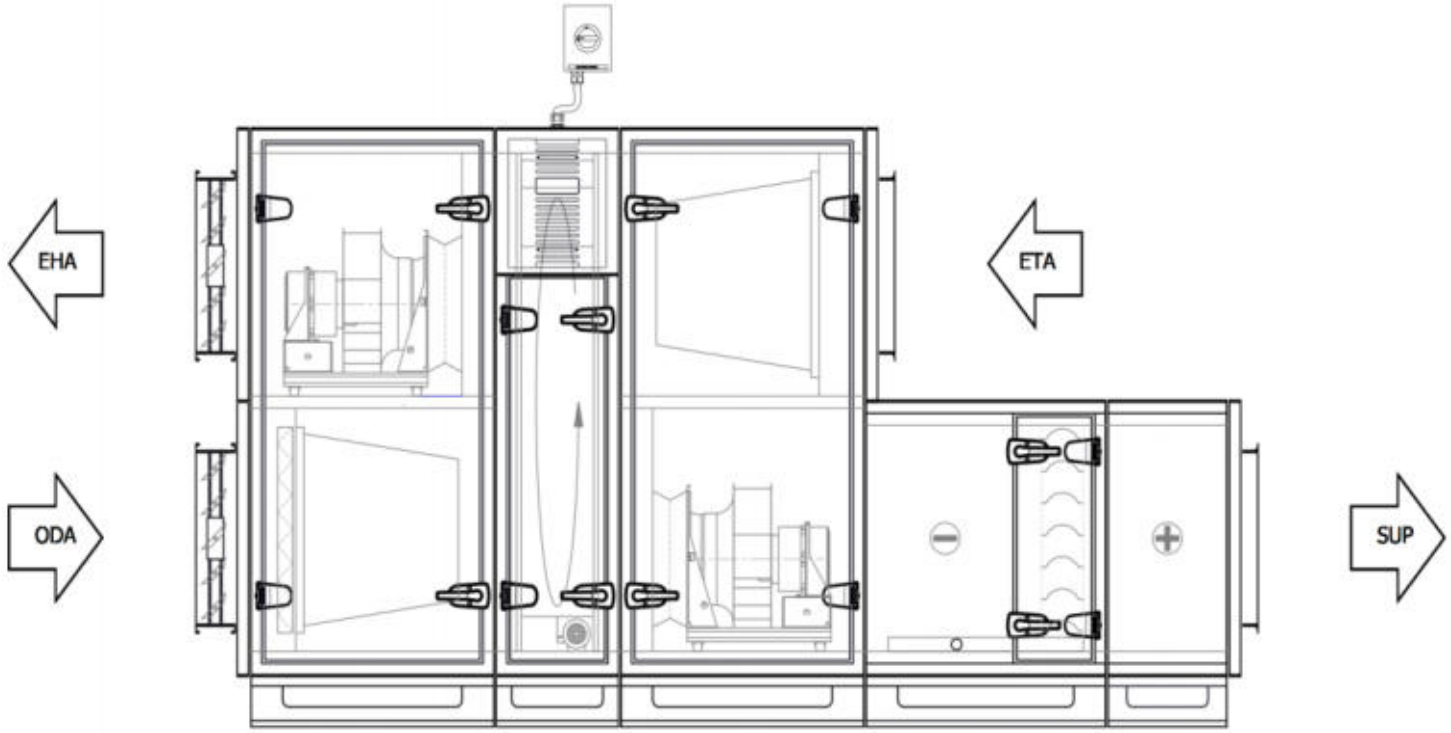
Recuperação Energia

Caso pratico

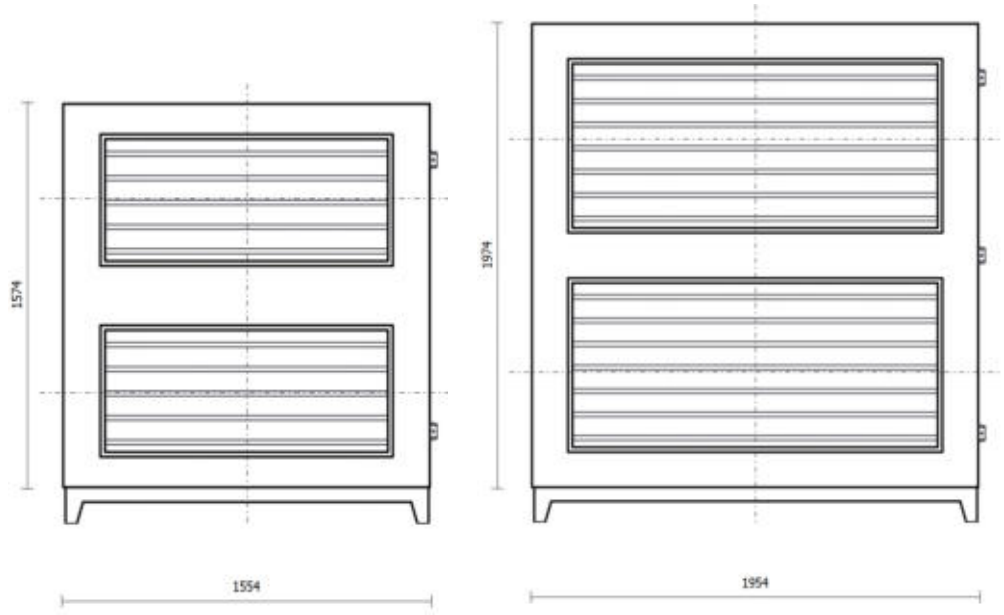


6000 m3/h (insuflação e extração)

Recuperação Energia

Caso pratico

Grupo	Parâmetro	Unidade	UTA 1	UTA 2	
Velocidade	Velocidade frontal	m/s	1,69	1,02	
	Classe (EN13053)	—	V2	V1	
Recuperação	Eficiência sensível	%	79,4	83,4	+4%
	Eficiência latente	%	76,4	88,9	
	Perda de carga recuperador	Pa	209	117	
	Classe recuperação (EN13053)	—	H1	H1	
Insuflação	SFPv	kW/(m³/s)	1,12	0,72	
	Potência absorvida	kW	2,07	1,3	
	Pressão estática	Pa	784	541	
Extração	SFPv	kW/(m³/s)	1	0,67	
	Potência absorvida	kW	1,81	1,19	
	Classe P (EN13053)	—	P1	P1	
	Pressão estática	Pa	668	495	
Global	▽ **Potência absorvida total**	kW	**3,88**	**2,49**	- 36 %



Eficiência Energética

Rede de condutas

Escritórios

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