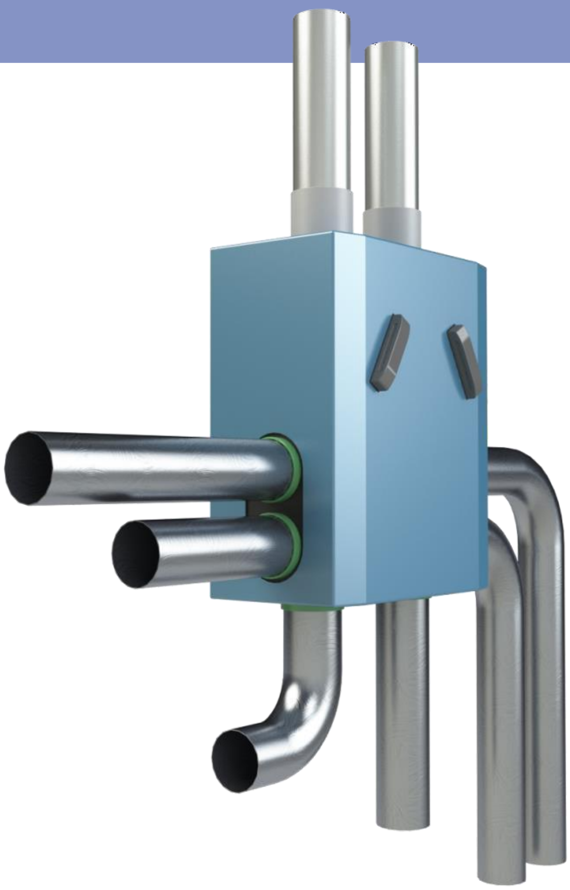
European Commission

Ventilation Units

Ecodesign and Energy Labelling



Review Study

Phase 1.1 and phase 1.2
Technical Analysis and update Preparatory Studies

Draft Interim Report

TASK 4. Technologies

Review study on Regulations EU 1253/2014 (Ecodesign requirements for ventilation units) and EU 1254/2014 (energy labelling of residential ventilation units)

Prepared by
VHK, Delft (NL), for the
European Commission, DG GROW

January 2020

Grow

1. Filter technology

5.1 Introduction

Although ventilation plays a crucial role in maintaining a clean indoor environment, in some cases ventilation systems can also be a source for airborne pollutants as a result of polluted outdoor air, inadequate system design, internal leakage and cross-contamination, etc. Thus, air filtration technology plays a key role in protecting human health by removing indoor and outdoor air pollutions.

Mechanical ventilation (exchanging indoor air with outdoor air using one or more fans), consumes both heating energy and electricity. The use of filters will increase the electricity consumption for ventilation because filters increase the resistance in the flow path of the supply and exhaust air. It is therefore important to try to reduce the additional pressure induced by filters. To give a rough indication: an increase of 50 pascal for filter purposes in the ventilation supply airstream of on average 110 m^3/h in all EU28 dwellings would results in an additional total annual power consumption of around 6.5 TWh[14] (26 kWh/an/hh).

And if parts of the indoor air can also be cleaned by filtration and recirculation (i.e. without exchanging indoor air with outdoor air) this could also contribute to further energy savings without compromising on IAQ, because heating energy is no longer necessary to reheat the fresh outdoor air.

Technical developments related to these two topics will be further discussed here.

5.2 Filtration and pressure drop

Filters may be used for the filtering of both particulate matter (PM) and gas-phase pollutants (VOCs, odours, etc.) that are present in the outdoor- or indoor air. This section 'on filters and pressure drop' only refers to filters that are used for removing PM, because there are no test standards (yet) for gas-phase pollutants and their application for indoor air in buildings still is limited (see further explanation under section 5.3.2).

With around 80%, energy consumption represents the largest share in the total lifecycle cost for filters. Remaining 20% relates to initial investments and disposal (source : https://filterservices.com/pressure-drop-considerations-in-air-filtration/). The pressure drop of the filter is the precursor for the energy consumption.

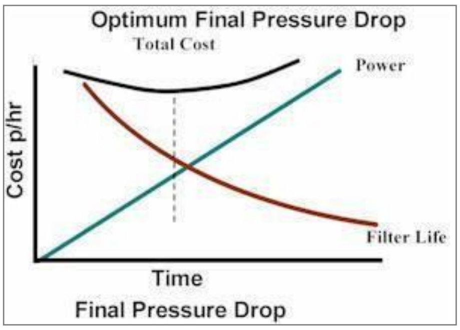


Figure 53. Optimum filter costs

[14] TWh_{deltaP} = (qv*deltaP*hours*No EU28 dwellings)/(eta_{fan}*1000) = 0,03*50*8760*250*10^6/(0.5*1000)=6.57 TWh

Source: R.H. Avery, Optimum Final Pressure Drop, *NAFA Guide to Air Filtration* 3rd Edition, Chapter 13

Figure 53 illustrates the optimal change-out point of an air filter – that point where the pressure drop increases electrical consumption and overtakes the initial cost of the filter.

Obviously, filter pressure drop is not the same for all the existing filter types and filter brands. The same goes for filter pressure drop at end of life. To manifest the differences between filters, Eurovent further developed their Guideline 4/21-2019 regarding the Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes (see also Task 3 report section 1.8.1).

5.2.1 EUROVENT Guideline on Energy Efficiency of Filters

This Eurovent Guideline that was updated in November 2019:

- Implements the EN ISO 16890 classification and testing methods
- Defines energy efficiency evaluation methods
- Defines the energy efficiency of air filters for general ventilation purposes

The aim of this guideline is to assess the yearly energy consumption based on a laboratory test procedure which can be the basis for an energy efficiency classification, to give the user of air filters guidance for the filter selection.

Two important notes to this:

- In order to actually reduce the energy consumption by using more energy efficient filters, it is also required that the speed of the fan can be adjusted accordingly to supply the requested air (if the fan is operated at a fixed speed, lowering the (average) pressure drop of the air filters will result in an increased air volume flow rate; in the worst case scenario, this may even result in a situation where the fan is operated in a region with lower efficiency resulting in an increased overall)
- The method provided in this document is based on laboratory test data with standardized test conditions, which may differ significantly from the individual application in a building ventilation unit. Hence, the yearly energy consumption calculated following this guideline, can only be used as an indicator for the classification system and relates only to the contribution of the air filters involved. The yearly energy consumption in an individual, actual application may differ from this significantly.

The calculation principle used is as follows:

The energy consumption of a fan in an air handling unit can be evaluated as a function of the volume flow rate supplied by the fan, the fan efficiency, the operation time, and the difference of the total pressure (static plus dynamic pressure) after the fan and the static pressure of the ambient air (assuming that the fan sucks in air from a static reservoir). Typically, the volume flow rate supplied by the fan and the pressure difference the fan has to overcome are related to each other by the characteristic fan curve. The efficiency of the fan is a function of the fan speed. The actual fan efficiency also strongly depends on the design and the layout of the fan and can be in the best case as high as 0.80 or even higher, and in the worst case as low as 0.25 or even lower.

The portion of the total yearly energy consumption which is related to the filters' pressure drop can be calculated using the following equation:

$$W = \frac{q_V \cdot \overline{\Delta p} \cdot t}{\eta \cdot 1000}$$

Where we define: q_V = 0.944 m³/s, t = 6000 h/a and η = 0.5

For a detailed description of the test- and rating method, see the latest version of the Eurovent Guideline 4/21-2019 regarding the Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes.

The certification program applies to air filter elements rated as ISO PM1, PM2.5 and PM10 (according to EN ISO 16890) referring to a front size of 592 x 592 mm and nominal airflow rates between 0.24 and 1.5 m^3/s. The filters shall be declared according to one of the following filter groups (see following tables).

Table 8. Energy classes Eurovent Filter Groups
(with Mx = max. dust load, AEC = ann. electricity consumption)

M_X = 200 g (AC Fine)	AEC in kWh/y FOR ePM1					
	ePM_1 and $ePM_{1,\,min} \geq 50\%$					
	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

M_X = 250 g (AC Fine)	AEC in kWh/y FOR ePM2.5					
	$ePM_{2.5}$ and $ePM_{2.5,\,min} \geq 50\%$					
	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 = 400 g (AC Fine)	AEC in kWh/y FOR ePM10					
	$ePM_{10} \geq 50\%$					
	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

Compared to the previous edition, the November 2019-version now includes an Annex 1 in which a method is given for recalculation of energy consumption at air flow rate different that the nominal one (tested). This simple formula was developed based on several tests performed be various manufactures. The formula works well within the Eurovent classification range. The lower deviation of the actual air flow rate from the nominal one, the higher its accuracy.

In their study[15] 'Status on Air Filter Characteristics and Energy Efficiency', the authors analysed a sample of 1800 certified filter test results. The results (see figure below) prove that only a minor portion of certified air filters have proper energy performance and the rest are certified as Classes C, D and E. The authors conclude that the topic filters need more efforts and attention from manufactures to further improve on their filter products.

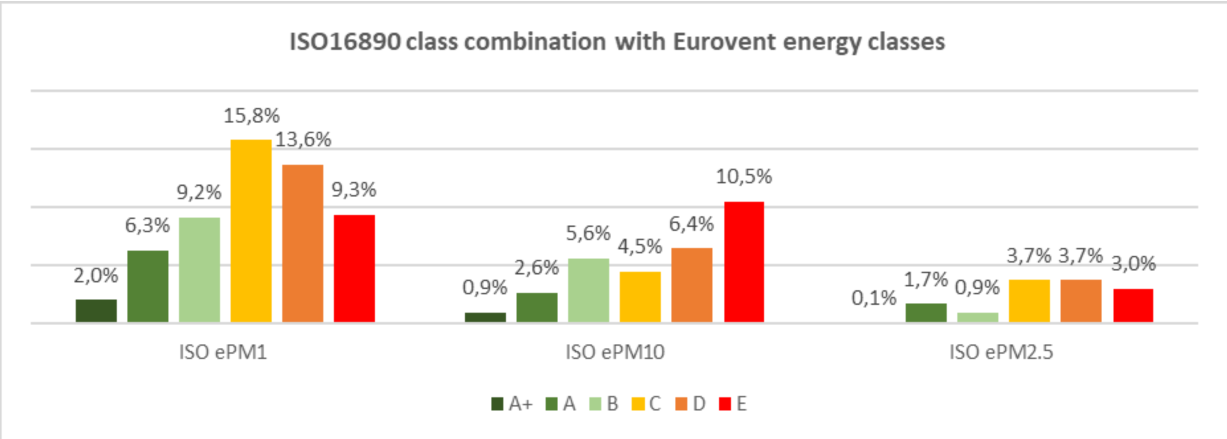


Figure 54. ISO Class rating (ISO 16890) and Eurovent Energy Efficiency Class percentages Source: Vadoudi, K., Kelijian, G., Marinhas, S. (see footnote)

5.2.2 Developments PM-filters and pressure drop

As can be deducted from the previous section, there is still a lot to be gained where the energy performance of filters is concerned. A labelling scheme as developed by Eurovent and its members, can become an important instrument in the pursuit for reduced pressure drops in filter technology.

A technology that is worth mentioning in this context, is the use of electrostatic filters. The EN ISO 16890 allows for the test and assessment of electrostatic filters. The advantage of electrostatic filters over traditional fibre-based filters can be that:

- Due to the working principle the pressure drop can in principle be low (lower) compared to fibre-based filters.
- Pressure drop remains constant or only increases only a little bit with increased dust loading, implying that flow control for the purpose of compensating increased pressure drops are not necessary.
- As a result, the energy consumption due to the filter is constant and does not increase during use.

[15] Vadoudi, K., Kelijian, G., Marinhas, S., Status on Air Filter Characteristics and Energy Efficiency, 40th AIVC Conference, October 2019, Ghent, Belgium.


Figure 55. Example active electronic filter

Source: Expansion Electric

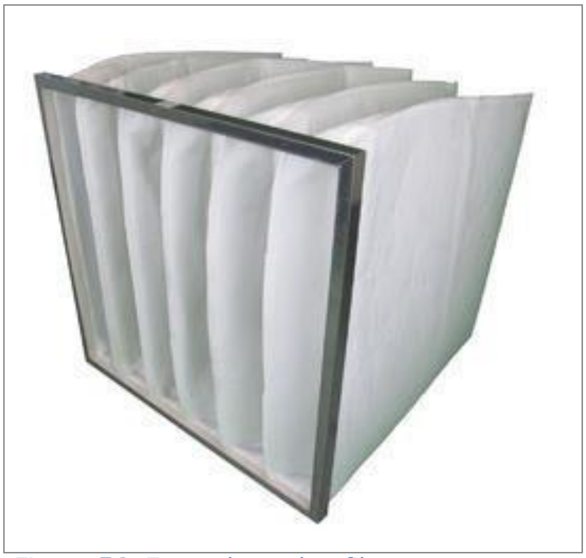


Figure 56. Example pocket filter

Random picture of pocket filter

For comparison, a calculation is made of the annual electricity consumption for an ePM1:70% electrostatic filter with an averaged ΔP of 62 Pa and an ePM1:70% pocket filter with an averaged ΔP of 215 Pa.

Electrostatic filter FE600 ePM1:70%

E = 0.944*62*6000 / (0.5*1000) = 351168/500 = 702 kWh/year

Average Pocket filter ePM1:70%

E = 0.944*215*6000 / (0.5*1000) = 1217760/500 = 2435 kWh/year

Types of electrostatic filters

Two types of electrostatic filters can be distinguished: passive and active electrostatic filters.

The general principle in in the electrostatic filtering systems technology relates to the electrostatic effect that occurs when a polluting particle (dust, smoke, fibres, etc ...) has, on its surface an electric charges (positive and/or negative) that makes it adhere to another surface (filter fibres, walls, curtains, TV and laptop screens, etc..) with equal but opposite charge. If the particle mass is sufficiently small, the electric charge presents on its surface makes it adhere to another opposite electric charge, present on the surface of the mattress filter. By applying this electrostatic effect, high filter efficiencies can be achieved, also for smaller particle sizes.

Passive electrostatic filters

When this phenomenon is enhanced artificially, by electrostatically charging the fibres of a filter, a so-called "passive electrostatic filter" is obtained, which in order to work well must be made with very high electrical resistivity fibres, as for example the rectangular plastic fibres. Its negative aspect is that just the deposit of polluting particles on the filter fibres makes it immediately decrease the ability of pollution's abatement.
Moreover, if the environment is particularly damp, the water contained in the air condenses

on the surface of the fibres and eliminates in a very short time each electric charge, transforming the product into a simple mechanical sieve filter. To overcome this problem the so-called 'buffer' filtering systems were created, in which the filtering means are submerged in an electric field which maintains the attraction power and the pollutants retention. The negative side is in the operation, starting from the fact that it depends on a filter mattress (the so-called buffer) that, even if electrostatically charged, presents the same disadvantages of the mechanical filters.

Active electrostatic filters

Filtration with an active electrostatic system consists of a two-phase system thanks to which it is possible to obtain the precipitation of solid or liquid particles contained in the air flow through the action of an electric field.

The company 'Expansion Electronic' uses the following illustration and accompanying text for explaining the principle of active electrostatic filters:

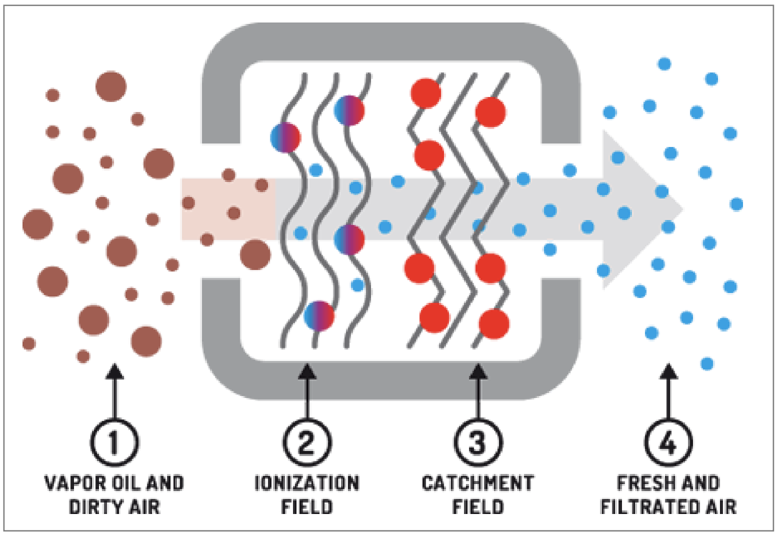


Figure 57. Principle of active electrostatic filter

Source: https://www.expansion-electronic.eu/index.php/en/what-we-do/operating-principle

In a first phase, the air that passes through the FE System electrostatic filter is subjected to the action of an electric field with positive ionization, generated by a powered wire with high electrical voltage placed between two plates connected to ground: that field causes the liberation of positive ions, generating a phenomenon known as "crown discharge". The electrical charges that migrate between the electrode and the grounded surfaces collide with the air particles present in the air flow, giving to them part of their positive electric charge.

In the second phase, the previously loaded gaseous flow crosses the electric field of catchment: this is constituted by positively charged plates and by plates connected to ground, alternately arranged.

Thanks to that shape of the FE System electrostatic filter and to the participation of the electrostatic force, the solid particles contained in the air are attracted to the positively charged catchment plates, since they are negatively charged.

Periodically, depending on the concentration of the pollutants, it is necessary to wash the filter with a particular detergent, in order to guarantee a better performance and a longer life cycle of the product.

In that sense the application of active electrostatic filters, can also help reducing the waste flows of traditional fibre-based filters which need to be replaces regularly and cannot always be cleaned.

5.3 Cleaning and recirculation of indoor air

The requirements for ventilation in most standards and guidelines are based on the assumption that the quality of (clean) outdoor air is acceptable. In various location around the world however, outdoor air quality can be very poor. In such cases, an alternative strategy may be to substitute ventilation-with-outdoor -air, at least in part, with air-cleaning and recirculation. By doing this the energy for heating or cooling the ventilation air and for transporting the air (fan energy) may be saved. For locations where the outdoor air is sufficiently clean, this air-cleaning strategy may also be an alternative additional strategy, provided it can increase the IAQ-performance without impairing the energy performance.

5.3.1 Cleaning indoor air from particulate matter

Indoor PM levels are dependent on several factors amongst which:

- outdoor PM levels,
- infiltration,
- types of ventilation and filtration systems used,
- indoor sources,
- personal activities of occupants.

Main indoor sources of PM are cooking, combustion activities (including burning of candles, use of fireplaces, use of unvented space heaters or kerosene heaters), cigarette smoking and some hobbies.

In homes without smoking or other strong particle sources, indoor PM would be expected to be the same as, or lower than, outdoor levels (source: https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter).

Primary and preferential strategy for reducing indoor generated PM obviously is source control: use efficient cooking hoods, avoid unvented fireplaces or heaters, prohibit smoking indoors.

This strategy always prevails any use of air circulation combined with PM-filters.

5.3.2 Cleaning indoor air from gaseous pollutants

The previous section basically indicates that recirculating and cleaning of indoor air is more about removing or reducing gaseous pollutants (coming from building materials, furniture and decorative products, office equipment, combustion equipment, occupants and their activities) than reducing PM-concentrations.

Opposite to the filtration of particulate matter (PM) however, (for which standards and test methods are already available), the technology of gas-phase air-cleaning is not supported by any standards on how to evaluate its efficiency and effectiveness in removing gaseous pollutants.

To fill this gap in knowledge, the Energy in Buildings and Communities Programme (EBC) of the IEA started a new EBC Annex 78, titled 'Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications'. The duration of this research-project is from 2018 – 2020, and the operating agents are Prof. Bjarne Olesen and Dr. Pawel Wargocki, both from the Technical University of Denmark. Participating countries are Canada, Czech Republic, P.R. China, Denmark, Finland, Italy, Japan, Singapore, USA.

Main objectives of this project are:

- quantify the energy performance of using air cleaning as part of the ventilation requirements,
- analyse how air cleaning can partially substitute for ventilation,
- advance standard testing procedures for air cleaners,
- carry out field studies of the energy performance and indoor air quality in buildings using gas phase air cleaning

(See also https://iea-ebc.org/projects/project?AnnexID=78)

Technical principles for removal of gaseous pollutants

Technology	Mechanism	Advantages	Disadvantages
Ionization	A discharge wire charges incoming particles and VOCs, that collect on oppositely charged plates	– Quiet – Low maintenance – Low pressure drop	– Generates ozone
Adsorption	The gases physically adsorb onto high-surface area medio (activated carbon)	– Potential for high removal efficiency for many gaseous pollutants – No by product formation	– Regular replacement needed – Effectiveness unknown – High pressure drop – Different removal efficiency for different gasses – Test methods limited or lacking
Chemisorption	Gases chemically adsorb onto media coated or impregnated with reactive compounds	– Potential for high removal efficiency for many gaseous pollutants – Chemisorption is an irreversible process (pollutants are permanently captured)	– Regular replacement needed – Effectiveness unknown – High pressure drop – Different removal efficiency for different gasses – Test methods limited or lacking
Catalytic oxidation	(Photo)catalytic oxidation (PCO) in which a high-surface-area medium is coated with titanium dioxide as a catalyst; gases adsorb onto the media and UV lamps activate the titanium oxide which reacts with the adsorbed gases and transforms them	– Can degrade a wide array of gaseous pollutants (e.g. aldehydes, aromatics, alkanes, olefins, halogenated hydrocarbons) – Can be combined with adsorbent media to improve effectiveness	– Can generate harmful by-product (formaldehyde, acetaldehyde, ozone) – No test methods – Relatively low removal efficiency – Lack of studies to validate performance – Catalyst has finite lifespan
Plasma	Electric current is applied to create an electric arc; incoming gases are ionized	– Can have high removal efficiency	– Wide variety of plasma generation types yields

	and bonds are broken to chemically transform the gaseous pollutants	– Can be combined with other air cleaning technologies to improve performance	confusion on how a product actually works – By-products are formed (included particles and gaseous pollutants)
Ozone	Intentional generation of ozone using corona discharge, UV or other method to oxidize odorous compounds and other gases	– Reacts with many indoor gases – Can be combined with adsorbent media to improve effectiveness	– High ozone generation rates – High amounts of by-product formation – Can cause degradation to indoor materials
Ultraviolet	UV-light kills or inactivates airborne microbes	– Can be effective at high intensity and sufficient contact time – Can be used to inactivate microbes on cooling coils and other surfaces	– Can generate ozone – May cause eye injury – High electrical power draw requirements – Inactivates but does not remove microbes

Source: www.epa.gov/iaq