EVIA initial position on EU 1253 and 1254/2014 Review – Residential aspects

EVIA strongly supports the Ecodesign and energy Labelling Legislation. Both regulations are pushing the market to develop energy efficient products and support the harmonisation of product performance and test methods. Furthermore, they are enhancing the positioning of European Products on export markets. To improve the legislation, EVIA has been discussing the need to consider certain elements for revision of EU 1253 and 1254/2014 on ventilation products, and calls on the European Commission to consider the following aspects in the revision process.

EVIA and its members stand ready to support the European Commission in its efforts to make the legislative framework fit for purpose and hope to continue to contribute to the revision process.

***

1 General Aspects

1.1 Multifunctional ventilation units

EVIA as well as other industry representatives have called the European Commission to include multifunctional bidirectional ventilation units in the revision of the Ecodesign Regulation (EU) 1253/2014 (Ventilation). You can find our position here.

1.2 Use the declaration of intended use as a basis for further specification.

EVIA recommends to use the Declaration of Intended Use (in analogy with the Machine Directive) of the manufacturer to identify the valid ErP regulation for the products. This is a simple way to deal with multi-usage and various applications whilst allowing market surveillance to react in the correct way. Furthermore, manufacturers shall specify the correct way to assess the conformity based on regulations and standards.

Article 2
Definitions

In addition to the definitions set out in Article 2 of Directive 2009/125/EC, the following definitions shall apply for the purpose of this Regulation:

(1) 'Ventilation unit (VU)' means an appliance equipped with at least a fan, motor and casing intended to replace utilised air by fresh air in a building or part of a building;

(2) 'Residential ventilation unit (RVU)' means a ventilation unit where the nominal (maximum) **outside air volume flow does not exceed 1.000 m^3/h and the manufacturer does not declare it as a NRVU;**

(3) 'Non-residential ventilation unit (NRVU)' means a ventilation unit where the nominal (maximum) **outside air volume flow**

a. exceeds 1.000 m^3/h or

b. **does not exceed 1.000 m³/h and the manufacturer declares only for a non-residential ventilation application.**

1.3 All aspects of published FAQ

EVIA suggests that the European Commission refers back to EVIA and Eurovent's Guidance Document which is intended to contribute to a better understanding of EU Regulations 1253 and 1254/2014 and a more uniform and coherent implementation across different sectors and product groups within the EU Common Market.

Residential Ventilation Units

1.4 Climatic zones should be considered in the Label

The thermal aspect of ventilation is based on climatic conditions. The use of average climate only can be misleading.
The principle of SEC calculation for three different climate zones is already implemented in the calculation procedure, but a label schematic has not been developed of all climate zones.

1.5 Information on filters and other IAQ parameters in the label

The additional advantages of better filtration is not yet visible. A filter has a direct impact on SEC value. An information of filter performance shall be added on the label.
Furthermore an information about IAQ controls options shall be given.

1.6 Split the label in different product groups

When considering the current minimum requirements (SEC < -20) there is limited space for unidirectional ventilation units to differentiate in the label class better performing products.
This would lead to a low interest of customer to invest in better performing UVU system especially if we look and the market for refurbishments.

EVIA is requesting a different label for UVU and BVU based on a common calculation scheme in analogy with the boiler.

1.7 Current status of EN 13142, EN 13141 should be considered as the basis of future revisions

These standards have been developed to clarify current regulation and also include further options.

1.7.1 Additional control factor for room by room control CRTL=0.5

The Energy Labelling shall provide a simple and fair comparison between the products within the same group and in relation to other products.

The deletion of the "full local demand control" with the CTRL factor of 0,5 in the development of the current regulation was never understood and lead to a dramatic change of the relation between unidirectional ventilation units (UVU) and bidirectional ventilation units (BVU) which is unfounded.

For that reason, the room by room control option was specified in EN 13142 table A.1 and shall be used for the review.

Table A.3 — Declaration of control factor

Criteria	Grading (optionnal)	Properties	Declaration	Corresponding ecodesign value CTRL	
				Ducted units	Non-ducted units
CTRL Control Factor	N	None	Declaration	1	1
	M	Manual control (no DCV)[a]	Declaration	1	1
	C	Clock control (no DCV)[b]	Declaration	0,95	0,95
	CDC	Central demand control (one sensor)[c d]	Declaration	0,85	—
	LDC	Local demand control (at least two sensors for ducted unit one sensor for non-ducted units)[c e]	Declaration	0,65	0,65
	RDC	Room by room control one sensor in each room[c f]	Declaration	0,5	0,5

[a] Manual control: any control type that does not use demand control.

[b] Clock control: a clocked (daytime-controlled) human interface to control the fan speed/flow rate of the ventilation unit, with at least seven weekday manual settings of the adjustable flow rate for at least two setback periods, i.e. periods in which a reduced or no flow rate applies.

[c] Demand control: a device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts.

[d] Central demand control: a demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor (type O or I) for the whole ventilated building or part of the building at central level.

[e] Local demand control: a demand control for a ventilation unit that continuously regulates the fan speed(s) and two flow rates (for example one sensor related to supply air and one sensor for extract air or 2 sensors related to supply or extract air with dampers) based on more than one sensor (type O or I) for a ducted ventilation unit or one sensor for a non-ducted unit.

[f] Room by room control (not considered in EU 1253/2014): a demand control for a ventilation unit that continuously regulates the fan speed(s) and the air volume flow to/from the rooms in minimum 80 % of the total number of rooms (or area or air volume flow) based on measurements in these rooms.

1.7.2 Filter clogging and kompensation

EVIA proposes to use Annex E of EN 13142 to assess the sensibility of a residential ventilation unit to pressure changes caused by filter clogging.

F.1 General

In a ventilation unit equipped with filters, dust accumulates on the filter media and tends to clog the filter overtime. A regular change of the filter is therefore needed. However, between two filter replacements the progressive clogging of the filter will increase the pressure drop of the filter and may result in a change in the air flow/pressure characteristic of the unit, it may decrease the ventilation air flow and have adverse effects on indoor air quality and on thermal performance of the building. Annex E provides guidance on how to assess the sensitivity of a ventilation unit to this filter clogging effect.

F.2 Definition and calculation of the filter compensation factor

The filter compensation factor (*FC*) is determined by adding an additional pressure drop during the test of the unit. This additional pressure is set to 1,5 times the initial pressure drop of the clean filter and is deemed representative of the clogged filter additional pressure drop.

The *FC* factor is calculated according to Formula (D.1).

$$FC = \frac{(q_{\text{ref}} - q_{\text{vfc}})}{q_{\text{ref}}} \tag{D.1}$$

where

q_{vref} is the reference air flow according to EN 13141-4, EN 13141-6, EN 13141-7, EN 13141-8 or EN 13141-11, with clean filters;

q_{vfc} is the air flow with an additional pressure drop of 1,5 times the initial pressure drop of the filter.

For bidirectional ventilation units, FC shall be determined on both supply and exhaust sides.

F.3 Classification of the filter compensation factor

The classification of the filter compensation factor is given in Table D.1.

Table D.1 — Classification of the filter compensation factor

Type	Class	Filter compensation factor %
Fully compensated	1	≤ 3 %
Not fully compensated	2	≤ 8 %
	3	≤ 12 %
	4	≤ 20 %
	Not classified	> 20 %

F.4 Test method

The test method is the following:

a) The initial pressure drop of the filter ($\Delta p_{initial}$) is measured according to EN ISO 16890 series at reference air flow (q_{vref}).

b) The ventilation unit is set at the reference air flow (regular test) according to the relevant part of the EN 13141 series with clean filters.

c) A pressure drop Δp_{fc} corresponding to 1,5 x $\Delta p_{initial}$ is added at the outside connection of the ventilation unit.

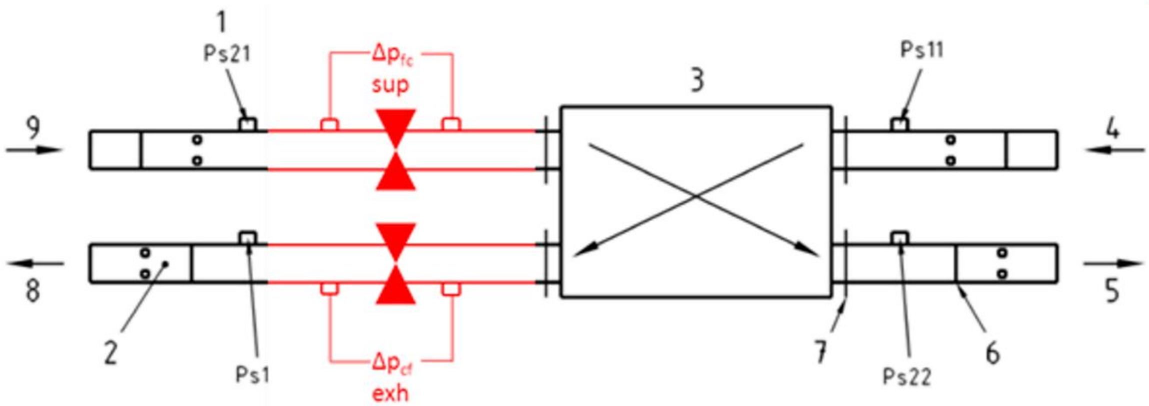
d) The resulting air flow q_{vfc} is measured and reported.

e) The ratio *FC* (filter clogging air flow reduction) is calculated according to D.1and reported.

F.5 Example of test set up for bidirectional ventilation units

The example of test set up for bidirectional ventilation units is based on the test procedure of EN 13141-7 and may be adapted for other standards like EN 13141-4.

The schema of the example test set up for bidirectional ventilation units is given in Figure D.1. The unit (Key 3 of Figure D.1) is equipped with clean filters. Δp_{fc} is set to 1,5 x $\Delta p_{initial}$.



Key

1	pressure measurement
2	temperature and humidity measurement
3	unit under test
4	extract
5	supply
6	perforated plate
7	connection
8	exhaut
9	outdoor air
	additional pressure drop set to Δp_{fc}

Figure D.1 — Schematic of the example test set up for bidirectional ventilation units

1.7.3 SEC calculation considering infiltration

Current definition of MISC factor is wrong and confusing. EVIA is proposing to use the original procedure, already discussed and presented in the first drafts of the current regulation. Annex G of EN 13142 prepared a full set of equations and default values to be used.

Annex G

(informative)

Calculation of an extended SEC considering Infiltration

F.1 General

The current SEC calculation used in EU 1253/2014 and EU 1254/2014 does not consider the impact of the pressure of ventilation systems on the infiltration. This leads to the principle problems when comparing unidirectional ventilation systems (over or underpressure in the building) with balanced system (neutral pressure in the building).

The simplified approach developed in Annex G introduces a parameter for the infiltration to correct the influence of the pressure of ventilation systems on the infiltration.

F.2 Extended SEC calculation

The extended SEC is calculated using Formula (F.1).

$$SEC = \frac{8760}{1000} \times PRI_{\mathrm{el}} \times SPI \times 1,3 \times CTRL^{x} \times MISC - t_{\mathrm{h}} \times \Delta T_{\mathrm{h}} \times \frac{344}{10^{6}} \times PRI_{\mathrm{h}} \times \left(2,2 + INF - 1,3 \times CTRL \times MISC \times (1 - HR)\right) \tag{F.1}$$

The parameter *INF* in Formula (F.1) is defined in Table G.1.

Table G.1 — Infiltration *INF* parameter considering climate impact

Climate	t_h	Δt_h	*INF*	
			Exhaust Supply	Balanced
Cold	6 552	14,5	0,10	0
Average	5 112	9,5	0,18	0
Warm	4 392	5	0,36	0

The current approach of MISC in EU 1253/2014 and EU 1254/2014 does not reflect the real aspects of cascading in dwellings. The modified MISC parameter is defined in Table G.2.

Table G.2 — Modified MISC parameter

Unit	Overflow MISC
Exhaust ventilation unit	1
Supply ventilation unit	1
Balanced ventilation unit (single dwelling)	1
Balanced ventilation unit (single room)	1,5 to 2,0

1.7.4 Frost and defrosting aspects of heat recovery in residential ventilation units

Current correction of defrosting controls and strategies are far to simplified. The revision of the revision shall consider more detailed aspects. Annex F of EN 13142 was provided to consider each detail, typically effects the defrosting and might be used to specify a more targeting correction in the review.

Annex F
(informative)

Calculation of an extended SEC

F.1 Terms, definitions and abbreviated terms

F.1.1 Terms and definitions

E.1.1.1

defrost mode setpoint

outdoor temperature, where the frost protection mode of the ventilation unit switches ON and OFF

Note 1 to entry: In case of different ON and OFF set points (hysteresis), the nominal value is the average of the set points of ON and OFF. The defrost mode set point is defined by the distributor of the unit.

F.1.2 Abbreviated terms

For the purposes of this document, the following abbreviations apply.

SEC	Specific Energy Consumption according Commission Delegated Regulation (EU) No 1254/2014
SEC*	Extended Specific Energy Consumption according the proposal in this document

F.2 Model

F.2.1 General

The model of the SEC is defined on the Commission Delegated Regulation (EU) No 1254/2014. The extended SEC* uses the same pattern but with a more refined calculation and default values.

NOTE The extension from the SEC to the SEC* is based on rules of the Swiss Deklaration Komfortlüftung [6] and in results of a project about defrosting in residential ventilation units [7].

F.2.2 General total energy balance

SEC* is calculated using Formula (E.1).

$$SEC^* = E_{\mathrm{AEC}} - \Delta E_{\mathrm{AHS}} \quad \text{(E.1)}$$

where

*SEC** is the extended specific energy consumption for ventilation per m^2 heated floor area of a dwelling or building, in kWh/(m^2·a);

E_{AEC} is the annual electricity consumption per m^2 heated floor area of a dwelling or building according to 3.2, in kWh/(m^2·a);

ΔE_{AHS} is the annual saving in consumption of energy for heating per m^2 heated floor area of a dwelling or building according to 3.3, in kWh/(m^2·a).

F.2.3 General electric energy balance

E_{AEC} is calculated using Formula (E.2).

$$E_{\mathrm{AEC}} = ta \cdot pef \cdot q_{\mathrm{net}} \cdot MISC \cdot CTRL^{x} \cdot SPI + E_{\mathrm{defr}} \qquad \text{(E.2)}$$

where

E_{AEC} is the annual electricity consumption per m^2 heated floor area, in kWh/(m^2·a);

ta is annual operating hours, in h/a;

pef is the primary energy factor for electric power generation and distribution according to Table A.1;

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

$MISC$ is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;

$CTRL$ is the ventilation control factor according to Table A.1;

x is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics, see Table A.1;

SPI is the specific power input according EN 13142, in kW/(m^3/h);

E_{defr} is the annual electricity consumption per m^2 heated floor area for defrosting according to 3.4, in kWh/(m^2·a).

F.2.4 Heating energy saving

F.2.4.1 Calculation

ΔE_{AHS} is calculated using Formula (E.3).

$$\Delta E_{\mathrm{AHS}} = t_{\mathrm{h}} \cdot \Delta T_{\mathrm{h}} \cdot \eta_{\mathrm{h}}^{-1} \cdot c_{\mathrm{air}} \cdot [q_{\mathrm{ref}} - q_{\mathrm{net}} \cdot CTRL \cdot MISC \cdot (1-\eta_{\mathrm{t}})] - \Delta E_{\mathrm{AH,defr}} \qquad \text{(E.3)}$$

where

ΔE_{AHS} is the annual saving in consumption of energy for heating per m^2 heated floor area, in kWh/(m^2·a);

t_h is the total hours heating season according to Table A.1, in h;

ΔT_h is the average difference in indoor and outdoor temperature over a heating season, minus correction for solar and internal gains according Formula (E.4), in K;

η_h is the average space heating efficiency according to Table A.1;

c_{air} is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);

q_{ref} is the reference natural ventilation rate per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

$CTRL$ is the ventilation control factor according to Table A.1;

$MISC$ is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;

η_t is the thermal efficiency of heat recovery according to Clause 4.

$\Delta E_{AH,defr}$ is the annual heating energy consumption for defrosting per m^2 heated floor area according to Clause 4, in kWh/(m^2·a).

F.2.4.2 Average difference of indoor and outdoor temperature

The average difference of indoor and outdoor temperature over a heating season, minus correction for solar and internal gains is calculated using Formula (E.4).

$$\Delta \mathrm{T}_h = \theta_{I,avg} - \theta_{e,h,avg} - \Delta\theta_{g,h,avg} \tag{E.4}$$

where

$\Delta \mathrm{T}_h$ is the average difference between indoor and outdoor temperature over a heating season, minus correction for solar and internal gains, in K;

$\theta_{I,avg}$ is the average indoor temperature over a heating season (for classification $\theta_{I,avg}$ = 19 K), in °C;

$\theta_{e,h,avg}$ is the average outdoor temperature over a heating season, in °C;

$\Delta\theta_{g,h,avg}$ is the correction for solar and internal gains (for classification $\Delta\theta_{g,h,avg}$ = 3 K), in °C

F.2.4.3 Thermal efficiency of heat recovery for units tested according EN 13141-7

F.2.4.3.1 Units with defined casing insulation

The thermal efficiency of heat recovery is calculated using Formula (E.5).

$$\eta_t = \eta_5 - f_{insu} \tag{E.5}$$

where

η_t is the thermal efficiency of heat recovery;

η_5 is the corrected temperature ratio on supply air side, according to EN 13142:2019;

f_{insu} is the correction value for the casing insulation, according to Table E.1;

The correction value for the casing insulation depends on the thermal resistance *R* of the casing walls, which is calculated using Formula (E.6).

$$R = \sum \frac{d_i}{\lambda_i} \tag{E.6}$$

where

R is the thermal resistance of the casing wall, in m²·K/W;

d_i is the thickness of the layer "*i*", in m;

λ_i is the thermal conductivity of the material of the layer "*i*", in W/(m·K).

Table E.1 — Correction value for the casing insulation f_{insu} for units tested according to EN 13141-7

R m²·K/W	***finsu***
> 1,00	0,00
0,75 to 1,00	0,01
0,50 to 0,74	0,02
< 0,50	0,03

F.2.4.3.2 Units without defined casing insulation

If the correction value for the insulation f_{insu} is not available, the thermal efficiency of heat recovery is calculated according Formula (E.7) and Formula (E.8), depending on the position of the supply ventilators in relation to the heat recovery.

For units with supply ventilator after heat recovery (in air flow direction), Formula (E.7) shall be used.

$$\eta_{\text{t}} = \eta_{\theta,\text{ex}} + \frac{CTRL^{(x-1)} \cdot SPI}{2 \cdot c_{\text{air}} \cdot \Delta T_{\text{h}}} \tag{E.7}$$

For units with supply ventilator before heat recovery (in air flow direction), Formula (E.8) shall be used.

$$\eta_{\text{t}} = \eta_{\theta,\text{ex}} + \left(1 - \frac{\eta_{\theta,\text{su}} + \eta_{\theta,\text{ex}}}{2}\right) \cdot \frac{CTRL^{x} \cdot SPI}{2 \cdot c_{\text{air}} \cdot \Delta T_{\text{h}}} \tag{E.8}$$

where

η_{t}	is the thermal efficiency of heat recovery;
$\eta_{\theta,\mathrm{su}}$	is the temperature ratio on supply air side, according to EN 13141-7 or EN 13141-8;
$\eta_{\theta,\mathrm{ex}}$	is the temperature ratio on exhaust air side, according to EN 13141-7 or EN 13141-8;
$CTRL$	is the ventilation control factor according Table A.1;
x	is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics, see Table A.1;
SPI	is the specific power input according EN 13142, in kW/(m^3/h);
c_{air}	is the specific heat capacity of air at constant pressure and density, in kWh/(m^3·K);
ΔT_{h}	is the average difference in indoor and outdoor temperature over a heating season, minus correction for solar and internal gains according Formula (E.4), in K.

F.2.4.4 Thermal efficiency of heat recovery for units tested according EN 13141-8

The thermal efficiency of heat recovery is calculated according to Formula (E.7) and Formula (E.8), depending on the position of the supply ventilators in relation to the heat recovery.

The temperature ratios are determined according EN 13141-8:2019, test 1.

F.2.5 Annual electricity consumption for defrosting

F.2.5.1 General

Annual electricity consumption for defrosting is calculated using Formula (E.9).

$$E_{\mathrm{defr}} = E_{\Delta\mathrm{p,\,ext,\,defr}} + E_{\Delta\mathrm{p,\,int,\,defr}} + E_{\mathrm{preh}} + E_{\mathrm{pump,\,defr}} \quad \text{(E.9)}$$

where

E_{defr}	is the annual electricity consumption per m^2 heated floor area for defrosting, in kWh/m^2·a;
$E_{\Delta\mathrm{p,\,ext,\,defr}}$	is the annual electricity consumption use due to external pressure losses of external defrosting devices per m^2 heated floor area according to Clause 4, in kWh/m^2·a;
$E_{\Delta\mathrm{p,\,int,\,defr}}$	is the annual electricity consumption due to internal pressure loss during frost growing per m^2 heated floor area according to 3.4.2, in kWh/m^2·a;
E_{preh}	is the annual electricity consumption for an electric preheater per m^2 heated floor area according to Clause 4, in kWh/m^2·a;
$E_{\mathrm{pump,\,defr}}$	is the annual electricity consumption use for defroster pump per m^2 heated floor area according to Clause 4, in kWh/m^2·a.

NOTE For most units, between one and four of the terms in Formula (E.8) are relevant.

F.2.5.2 Annual electricity consumption use due to external pressure losses

The annual electricity consumption due to external pressure losses of the defrosting devices, per m^2 heated floor area is calculated using Formula (E.10).

$$E_{\Delta p,\text{ext, defr}} = ta \cdot pef \cdot q_{\text{net}} \cdot MISC \cdot CTRL^{x} \cdot \Delta p_{\text{ext,defr}} \cdot \eta_{\text{vent}}^{-1} \cdot f_0 \qquad \text{(E.10)}$$

where

$E_{\Delta p,\text{ext, defr}}$	is the annual electricity consumption use due to external pressure losses of external defrosting devices per m^2 heated floor area according to Clause 4, in kWh/m^2·a;
ta	is the annual operating hours, in h/a;
pef	is the primary energy factor for electric power generation and distribution according to Table A.1;
q_{net}	is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);
$MISC$	is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;
$CTRL$	is the ventilation control factor according to Table A.1;
x	is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics, see Table A.1;
$\Delta p_{\text{ext,defr}}$	is the pressure loss of the external defrosting devices, in Pa. If the pressure loss is not defined by the supplier the default values according to Table A.1 shall be used;
η_{vent}	is the ventilator efficiency, depending on the type of blades: — DC or EC motor, forward curved blades: η_{vent} = 0,26; — DC or EC motor, backward curved blades η_{vent} = 0,35;
f_0	is the factor for units conversion, f_0 = 2,78·10^{-7}, in (m^3/h)/(m^3/s) kW/W.

The default values for pressure losses of external defrosting devices are given in Table E.2

Table E.2— Default values for pressure losses of external defrosting devices

Type of defrosting equipment	**Default values** $\Delta p_{ext,defr}$
	Pa
Earth to air heat exchangers	20
Electric preheater	10
Water to air preheater	20
Brine to air preheater	40

F.2.5.3 Annual electricity consumption due to frost growing

Defrost devices can be controlled by temperature of pressure difference in the exhaust air. In this case frost grows in the heat exchanger and increases pressure loss.

The annual electricity consumption due to internal pressure loss during frost periods per m^2 heated floor area is calculated using Formula (E.11).

$$E_{\Delta p,\mathrm{int,defr}} = t_{\mathrm{defr}} \cdot pef \cdot q_{\mathrm{net}} \cdot MISC \cdot CTRL^{x} \cdot \Delta p_{\mathrm{frost}} \cdot \eta_{\mathrm{vent}}^{-1} \cdot f_0 \qquad \text{(E.11)}$$

where

$E_{\Delta p,\mathrm{int,defr}}$	is the annual electricity consumption due to internal pressure loss during frost periods per m^2 heated floor area, in kWh/m^2·a;
t_{defr}	is the annual operating time in defrosting mode according to Table A.1, in h/a;
pef	is the primary energy factor for electric power generation and distribution according to Table A.1;
q_{net}	is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);
$MISC$	is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;
$CTRL$	is the ventilation control factor according to Table A.1;
x	is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics, see Table A.1;
$\Delta p_{\mathrm{frost}}$	is the average additional internal pressure due to frost growing, in Pa. Default value: $\Delta p_{\mathrm{frost}}$ = 45 Pa;
η_{vent}	is the ventilator efficiency, depending on the type of blades: — DC or EC motor, forward curved blades: η_{vent} = 0,26; — DC or EC motor, backward curved blades η_{vent} = 0,35;
f_0	is the factor for units conversion, f_0 = 2,78·10^{-7}, in (m^3/h)/(m^3/s) kW/W.

F.2.5.4 Annual electricity consumption for electric preheater

The energy use for an electric preheater is calculated using Formula (E.12).

$$E_{\mathrm{el,preh}} = t_{\mathrm{defr}} \cdot \Delta T_{\mathrm{defr}} \cdot f_{\mathrm{ctrl,defr}} \cdot c_{\mathrm{air}} \cdot q_{\mathrm{net}} \cdot MISC \cdot CTRL \cdot pef \qquad \text{(E.12)}$$

where

$E_{\mathrm{el,preh}}$	is the annual electricity consumption due to internal pressure loss during frost periods per m^2 heated floor area, in kWh/m^2·a;
t_{defr}	is the annual operating time in defrosting mode according to Table A.1, in h/a;

ΔT_{defr} is the average difference between the outdoor temperature and the defrost mode set point during the defrosting period according to Table A.1, in K;

$f_{\mathrm{ctrl,defr}}$ is the factor of the defrosting control according to Table A.1;

c_{air} is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

$MISC$ is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;

$CTRL$ is the ventilation control factor according Table A.1;

pef is the primary energy factor for electric power generation and distribution according to Table A.1.

F.2.5.5 Electricity consumption for a defroster pump

The annual electricity consumption for a defroster pump per m^2 heated floor area calculated using Formula (E.13).

$$E_{\mathrm{pump,defr}} = P_{\mathrm{pump}} \cdot t_{\mathrm{defr}} \cdot f_{\mathrm{ctrl,defr}} \cdot pef \qquad \text{(E.13)}$$

where

$E_{\mathrm{pump,defr}}$ is the annual electricity consumption for a defroster pump per m^2 heated floor area, in kWh/m^2·a;

P_{pump} is the electrical power input of the defroster pump, in kW;

t_{defr} is the annual operating time in defrosting mode according to Table A.1, in h/a;

$f_{\mathrm{ctrl,defr}}$ is the factor of the defrosting control according to Table A.1;

pef is the primary energy factor for electric power generation and distribution according to Table A.1.

If the supplier of the ventilation unit defines the defroster and the defroster pump, then the electrical power input P_{pump} shall be given by the supplier.

If the pump is not defined, the electrical power input of the defroster pump is calculated using Formula (E.14).

$$P_{\mathrm{pump}} = f_{\mathrm{pump}} \cdot q_{\mathrm{net}} \qquad \text{(E.14)}$$

where

P_{pump} is the electrical power input of the defroster pump, in kW;

f_{pump} is the factor for the type of the defroster with:

— for water based defrosters: $f_{pump} = 3{\cdot}10^{-5}$ kW/(m^3/h);

— for brine defrosters: $f_{pump} = 6{\cdot}10^{-5}$ kW/(m^3/h);

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2).

F.2.5.6 Annual heating energy consumption for defrosting

The annual heating energy consumption for defrosting per m^2 heated floor is calculated using Formula (E.15).

$$\Delta E_{\mathrm{AH,defr}} = \Delta E_{\mathrm{h,preh}} + \Delta E_{\mathrm{by}} + \Delta E_{\mathrm{su}} + \Delta E_{\mathrm{ex}} - \Delta E_{\mathrm{vent}} - \Delta E_{\mathrm{el,preh}} - \Delta E_{\mathrm{earth}} \qquad \text{(E.15)}$$

where

$\Delta E_{\mathrm{AH,defr}}$ is the annual heating energy consumption for defrosting per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

$\Delta E_{\mathrm{h,preh}}$ is the annual heating energy consumption for preheating (by space heating generation) per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

ΔE_{by} is the annual heating energy consumption for bypassing the heat recovery per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

ΔE_{su} is the annual heating energy consumption for lowering of the supply air flow rate per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

ΔE_{ex} is the annual heating energy consumption for increasing of the exhaust air flow rate per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

ΔE_{vent} is the annual heating energy reduction by ventilator heat per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

$\Delta E_{\mathrm{el,preh}}$ is the annual heating energy reduction by an electric preheater per m^2 heated floor area, in kWh/m^2·a;

$\Delta E_{\mathrm{earth}}$ is the annual heating energy reduction by an earth to air heat exchanger per m^2 heated floor area according to Clause 4, in kWh/m^2·a.

NOTE A positive value of $\Delta E_{AH,defr}$ decreases the Specific Energy Consumption (SEC).

F.2.5.7 Annual heating energy consumption for preheating by space heating

The annual heating energy consumption for preheating (by space heating generation) per m^2 heated floor area, is calculated using Formula (E.16).

$$\Delta E_{\mathrm{h,preh}} = t_{\mathrm{defr}} \cdot \Delta T_{\mathrm{defr}} \cdot \eta_{\mathrm{h}}^{-1} \cdot c_{\mathrm{air}} \cdot q_{\mathrm{net}} \cdot MISC \cdot CTRL \cdot f_{\mathrm{ctrl,defr}} \cdot \eta_{\mathrm{t}} \qquad \text{(E.16)}$$

where

$\Delta E_{\text{h,preh}}$ is the annual heating energy consumption for preheating (by space heating generation) per m^2 heated floor area according to Clause 4, in kWh/m^2·a;

t_{defr} is annual operating time in defrosting mode according to Table A.1, in h/a;

ΔT_{defr} is the average difference between the outdoor temperature and the defrost mode set point during the defrosting period according to Table A.1, in K;

η_{h} is the average space heating efficiency according to Table A.1;

c_{air} is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

$MISC$ is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;

$CTRL$ is the ventilation control factor according to Table A.1;

$f_{\text{ctrl,defr}}$ is the factor of the defrosting control according to Table A.1;

η_{t} is the thermal efficiency of heat recovery according to Clause 4.

F.2.5.8 Annual heating energy consumption for preheating for bypassing

The annual heating energy consumption for bypassing the heat recovery per m^2 heated floor area, is calculated using Formula (E.17).

$$\Delta E_{\text{by}} = t_{\text{h}} \cdot \Delta T_{\text{h}} \cdot \eta_{\text{h}}^{-1} \cdot c_{\text{air}} \cdot q_{\text{net}} \cdot MISC \cdot CTRL \cdot \Delta \eta_{\text{t,by}} \tag{E.17}$$

where

ΔE_{by} is the annual heating energy consumption for bypassing the heat recovery per m^2 heated floor area, in kWh/m^2·a;

t_{h} is the total hours heating season according to Table A.1, in h;

ΔT_{h} is the average difference in indoor and outdoor temperature over a heating season, minus correction for solar and internal gains according to Formula (E.4), in K;

η_{h} is the average space heating efficiency according to Table A.1;

c_{air} is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);

q_{net} is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);

$MISC$ is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;

$CTRL$ is the ventilation control factor according to Table A.1;

$\Delta\eta_{t,by}$	is the difference in thermal efficiency of heat recovery with a bypass compared to balanced mass flows according to Table A.1.

F.2.5.9 Annual heating energy consumption for lowering the supply air flow rate

The annual heating energy consumption for lowering of the supply air flow rate per m^2 heated floor area, is calculated using Formula (E.18).

$$\Delta E_{su} = t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot q_{net} \cdot MISC \cdot CTRL \cdot \Delta\eta_{t,low} \quad \text{(E.18)}$$

where

ΔE_{su}	is the annual heating energy consumption for lowering of the supply air flow rate per m^2 heated floor area, in kWh/m^2·a;
t_h	is the total hours heating season according to Table A.1, in h;
ΔT_h	is the average difference in indoor and outdoor temperature over a heating season, minus correction for solar and internal gains according to Formula (E.4), in K;
η_h	is the average space heating efficiency according to Table A.1;
c_{air}	is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);
q_{net}	is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);
$MISC$	is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;
$CTRL$	is the ventilation control factor according to Table A.1;
$\Delta\eta_{t,low}$	is the difference in thermal efficiency of heat recovery with a lowered supply air flow rate compared to balanced mass flows according to Table A.1.

F.2.5.10 Annual heating energy consumption for increasing of the exhaust air flow rate

The annual heating energy consumption for increasing of the exhaust air flow rate per m^2 heated floor area, is calculated using Formula (E.19).

$$\Delta E_{ex} = t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot q_{net} \cdot MISC \cdot CTRL \cdot \Delta\eta_{t,dec} \quad \text{(E.19)}$$

where

ΔE_{ex}	is the annual heating energy consumption for increasing of the exhaust air flow rate per m^2 heated floor area, in kWh/m^2·a;
t_h	is the total hours heating season according to Table A.1, in h;
ΔT_h	is the average difference in indoor and outdoor temperature over a heating season, minus correction for solar and internal gains according to Formula (E.4), in K;

η_{h}	is the average space heating efficiency according to Table A.1;
c_{air}	is the specific heat capacity of air at constant pressure and density according to Table A.1, in kWh/(m^3·K);
q_{net}	is the net ventilation rate demand per m^2 heated floor area according to Table A.1, in m^3/(h·m^2);
$MISC$	is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration according to Table A.1;
$CTRL$	is the ventilation control factor according to Table A.1;
$\Delta\eta_{\mathrm{t,dec}}$	is the difference in thermal efficiency of heat recovery with an increased exhaust air flow rate compared to balanced mass flows according to Table A.1.

F.2.5.11 Annual heating energy reduction by ventilator heat

The annual heating energy reduction by ventilator heat due to additional pressure losses of defrosting depends on the position of the supply air ventilator.

For units with supply ventilator after heat recovery, the annual heating energy reduction by ventilator heat is calculated (in direction of air flow) using Formula (E.20).

$$\Delta E_{\mathrm{vent}} = \frac{E_{\Delta\mathrm{p,ext,defr}} \cdot t_{\mathrm{h}}}{ta \cdot \eta_{\mathrm{h}} \cdot pef} \tag{E.20}$$

For units with supply ventilator before heat recovery, the annual heating energy reduction by ventilator heat is calculated (in direction of air flow) using Formula (E.21).

$$\Delta E_{\mathrm{vent}} = \frac{E_{\Delta\mathrm{p,ext,defr}} \cdot t_{\mathrm{h}}}{ta \cdot \eta_{\mathrm{h}} \cdot pef} \cdot (1 - \eta_{\mathrm{t}}) \tag{E.21}$$

where

ΔE_{vent}	is the annual heating energy reduction by ventilator heat due to additional pressure losses of defrosting per m^2 heated floor area, in kWh/m^2·a;
$E_{\Delta\mathrm{p,ext,defr}}$	is the annual electricity consumption use due to external pressure losses of the defrosting equipment per m^2 heated floor area, in in kWh/m^2·a;
t_{h}	is the total hours heating season according to Table A.1, in h;
ta	is the annual operating hours, in h/a;
η_{h}	is the average space heating efficiency according to Table A.1;
pef	is the primary energy factor for electric power generation and distribution according to Table A.1;
η_{t}	is the thermal efficiency of heat recovery according to Clause 4.

F.2.5.12 Annual heating energy reduction by electric preheater

The annual heating energy reduction by an electric preheater per m2 heated floor area is calculated using Formula (E.22).

$$\Delta E_{\text{el,preh}} = E_{\text{el,preh}} \cdot (1 - \eta_{\text{t}}) \tag{E.22}$$

where

$\Delta E_{\text{el,preh}}$ is the annual heating energy reduction by an electric preheater per m2 heated floor area, in kWh/m2·a;

$E_{\text{el,preh}}$ is the annual electricity consumption for an electric preheater per m2 heated floor area according to Clause 4, in kWh/m2·a;

η_{t} is the thermal efficiency of heat recovery according to Clause 4.

F.2.6 Default values for calculation and classification

For classification of ventilation units the values given in E.2.6 shall be used (see Table E.3 to Table E.10).

Table E.3 — General typology of ventilation units

Type of ventilation units	General typology factor *MISC*
Ducted ventilation units	1,1
Non-ducted ventilation units	1,21

Table E.4 — Ventilation control factor *CTRL*

Type of ventilation control	Ventilation control factor *CTRL*
Manual control (no DCV)	1,00
Clock control (no DCV)	0,95
Central demand control	0,85
Local demand control	0,65

Table E.5 — Exponent x for non-linearity of motor and drive

Type of motor and drive	Exponent for non-linearity x
On/off and single speed	1,0
2-speed	1,2

3-speed	1,5
Variable speed	2,0

Table E.6 — General defaults for SEC calculation

Description	Symbol	Unit	Value
Specific heat capacity of air	*cair*	kWh/(m^3·K)	0,000 344
Net ventilation requirement per m^2 heated floor area	*qnet*	m^3/h·m^2	1,3
Reference natural ventilation rate per m^2 heated floor area	*qref*	m^3/h·m^2	2,2
Annual operating hours	*ta*	h	8 760
Primary energy factor electric power generation and distribution	*pef*	—	2,5
Space heating efficiency	η_h	%	75

Table E.7 — Climate related defaults for definition of the heating season

Climate	Description	Symbol	Unit	Value
Cold	Total hours heating season	t_h	h	6 446
	Average difference indoor and outdoor temperature	ΔT_h	K	14,53
Average	Total hours heating season	t_h	h	4 910
	Average difference indoor and outdoor temperature	ΔT_h	K	10,94
Warm	Total hours heating season	t_h	h	3 590
	Average difference indoor and outdoor temperature	ΔT_h	K	5,21

Table E.8 — Climate related to default values for defrosting

Description	Symbol	Unit	Climate	Defrosting mode setpoint ϑ_{idefr} °C			
				- 2	**- 3**	**- 4**	**- 5**
Operating time in defrosting mode	*tdefr*	h/a	cold	1 814	1 434	1 142	905,5

			average	430,5	303,5	216,5	134
			warm	0	0	0	0
Average difference between the outdoor temperature and defrost mode setpoint during the defrosting period	Δ*T*defr	K	cold	5,15	5,14	5,29	5,32
			average	2,94	2,61	2,48	2,49
			warm	—	—	—	—

Table E.9 — Technology related to default values for defrosting in an average climate

Cat.	**Description**	**Value**	**Unit**	**Defrosting set point °C**				**Note**
				- 2	**- 3**	**- 4**	**- 5**	
N	**None**			Shall be declared like E1				
E	**Electric preheating**							
E1	1 stage, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	4,16	4,46	4,74	5,04	
E2	2 stage, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	2,63	2,78	2,95	3,08	
E3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	*f*ctrl,defr	—	1,00	1,00	1,00	1,00	
E4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	*f*ctrl,defr	—	0,80	0,80	0,80	0,80	
M	**Mixing air**			(Not available yet)				
Cat.	**Description**	**Value**	**Unit**	Temperature ratio η_t				**Note**
				0,6	0,7	0,8	0,9	
L	**Lowering supply air flow rate (or shut off)**							
L1	Ventilator shut off	Δ*η*t,low	—	0,012	0,038	0,057	0,095	
L2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	Δ*η*t,low	—	0,003	0,007	0,013	0,023	
L3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	Δ*η*t,low	—	0,002	0,006	0,011	0,018	
I	**Increasing exhaust air flow rate**							
I1	Ventilator shut off	Δ*η*t,dec	—	0,012	0,038	0,057	0,095	
I2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	Δ*η*t,dec	—	0,009	0,018	0,031	0,045	

Cat.	Description	Value	Unit	Defrosting set point °C				Note
				- 2	- 3	- 4	- 5	
I3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta t,dec$	—	0,007	0,014	0,025	0,036	
B	**Bypass for defrosting**							
B1	Bypass full open	$\Delta\eta t,by$	—	0,012	0,038	0,057	0,095	
B2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta t,by$	—	0,003	0,007	0,013	0,023	
B3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta t,by$	—	0,002	0,006	0,011	0,018	
S	**No freezing risk**							no additional energy use
S1	In warm climate until – 25 °C							
S2	In average climate until – 15 °C							
S3	In cold climate until 0 °C							
X	**External frost protection**							defined by supplier
XE1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	4,16	4,46	4,74	5,04	
XE2	2 stages, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,63	2,78	2,95	3,08	
XE3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
XE4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
XW2	External water based preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	by space heating generation
XB1	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. 1-stage pump	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	heat supply from earth
XB2	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	0,75	0,75	0,75	0,75	heat supply from earth
XG	External earth-to-air heat exchanger							

Table E.10 — Technology related defaults for defrosting in a cold climate

Cat.	Description	Value	Unit	Defrosting set point °C - 2	- 3	- 4	- 5	Note
N	**None**			Shall be declared like E1				
E	**Electric preheating**							
E1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	5,04	4,74	4,46	4,16	
E2	2 stages, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,69	2,64	2,46	2,36	
E3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
E4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
M	**Mixing air**			(Not available yet)				
Cat.	**Description**	**Value**	**Unit**	Temperature ratio η_t 0,6	0,7	0,8	0,9	**Note**
L	**Lowering supply air flow rate (or shut off)**			Not applicable in cold climate				
L1	Ventilator shut off	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
L2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
L3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,low}$	—	NA	NA	NA	NA	
I	**Increasing exhaust air flow rate**			Not applicable in cold climate				
I1	Ventilator shut off	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
I2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
I3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,dec}$	—	NA	NA	NA	NA	
B	**Bypass for defrosting**			Not applicable in cold climate				
B1	Bypass full open	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	
B2	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	

Cat.	Description	Value	Unit	Defrosting set point °C - 2	- 3	- 4	- 5	Note
B3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$\Delta\eta_{t,by}$	—	NA	NA	NA	NA	
S	**No freezing risk**							no additional energy use
S1	In warm climate until – 25 °C							
S2	In average climate until – 15 °C							
S3	In cold climate until 0 °C							
X	**External frost protection**							defined by supplier
XE1	1 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	5,04	4,74	4,46	4,16	
XE2	2 stage, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	2,69	2,64	2,46	2,36	
XE3	Stepless variable, controlled by outdoor temperature inlet in ventilation unit	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	
XE4	Stepless variable, controlled by outdoor temperature inlet in ventilation unit and additional temperature or pressure sensor in exhaust air	$f_{ctrl,defr}$	—	0,80	0,80	0,80	0,80	
XW2	External water based preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	0,75	0,75	0,75	0,75	by space heating generation
XB1	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. 1-stage pump	$f_{ctrl,defr}$	—	1,00	1,00	1,00	1,00	heat supply from earth
XB2	External brine air preheater, controlled by outdoor temperature inlet in ventilation unit. Stepless variable controlled pump	$f_{ctrl,defr}$	—	0,75	0,75	0,75	0,75	heat supply from earth
XG	External earth-to-air heat exchanger							

About EVIA

The European Ventilation Industry Association (EVIA)'s mission is to represent the views and interests of the ventilation industry and serve as a platform between all the relevant European stakeholders involved in the ventilation sector, such as decision-makers at the EU level as well as our partners in EU Member States. Our membership is composed of more than 35 member companies and 6 national associations across Europe, realising an annual turnover of over 7 billion euros and employing more than 45,000 people in Europe.

EVIA aims to promote highly energy efficient ventilation applications across Europe, with high consideration for health and comfort aspects. Fresh and good indoor air quality is a critical element of comfort and contributes to keeping people healthy in buildings.