Service Contract to DG Enterprise

Sustainable Industrial Policy –
Building on the Ecodesign Directive –
Energy-Using Product Group Analysis/2

Lot 6: Air-conditioning and ventilation systems

Final Report Task 1
Product Definition, Standards and Legislation Ventilation Systems
for non residential and collective residential applications

Prepared by VHK, with Armines and BRE
14 June 2012

Main contractor: ARMINES, France
Project leader: Philippe RIVIERE

PARTICIPANTS
Jérôme ADNOT, Dominique MARCHIO, Pascal STABAT, Philippe RIVIERE
ARMINES, France
René KEMNA, Rob VAN HOLSTEIJN, Martijn VAN ELBURG, William LI, Roy VAN DEN BOORN
VHK, The Netherlands
Roger HITCHIN, Christine POUT
BRE, UK

Legal disclaimer
The sole responsibility for the content of this report lies with the authors. It does not necessarily represent the opinion of the European Community. The European Commission is not responsible for any use that may be made of the information contained therein.
Notice:
This report has been prepared by the authors to the best of their ability and knowledge. The authors do not assume liability for any damage, material or immaterial, that may arise from the use of the report or the information contained therein.
## Contents

1 **INTRODUCTION** 6  
1.1 **Scope** 6  
1.2 **Subtasks** 9  
1.2.1 **Reporting** 10  

2 **SUBTASK 1.1 - PRODUCT CLASSIFICATION AND DEFINITION** 11  
2.1 **Introduction** 11  
2.2 **Definition of Ventilation** 11  
2.3 **Types of Ventilation / Air-exchange** 11  
2.4 **Product Scope for Ventilation Systems** 12  
2.5 **Definitions** 17  
2.6 **Classifications** 22  

3 **SUBTASK 1.2 - MEASUREMENT AND OTHER STANDARDS** 32  
3.1 **Subtask 1.2.1 - Standards at European Community Level** 32  
3.1.1 **EN 15251 Criteria Indoor Environment** 33  
3.1.2 **EN 13779 Performance requirements non-residential ventilation** 38  
3.1.3 **CEN/TR 14788 Design and dimensions residential ventilation** 47  
3.1.4 **EN 15665 Performance criteria residential ventilation** 53  
3.1.5 **EN 15242 Calculation ventilation rates** 58  
3.1.6 **EN 15241 Calculation ventilation energy loss, commercial buildings** 63  
3.1.7 **EN 13465 Calculation air flow rates in dwellings.** 68  
3.1.8 **prEN 13142 Performance components/products residential ventilation** 69  
3.1.9 **EN 13053 Air handling units, rating and performance** 70  
3.1.10 **EN 308 Performance testing air-to-air heat recovery devices** 76  
3.1.11 **EN ISO 13348 Industrial fans, tolerances** 77  
3.1.12 **ISO 12759 Fan efficiency** 77  
3.1.13 **EN 13141-4 Performance testing residential fans** 79  
3.1.14 **EN 13141-6 Performance exhaust ventilation system packages in single dwellings** 80  
3.1.15 **prEN 13141-7 Performance mechanical supply & exhaust units (incl. HR) dwellings** 80  
3.1.16 **EN 13141-8 Performance mechanical supply & exhaust units (incl. HR) for rooms** 81  
3.1.17 **EN 1886 Mechanical performance air handling units** 82  
3.1.18 **EN ISO 5801 Industrial fans, performance testing** 82  
3.1.19 **EN ISO 3741, 3744, 3746, 5136 Acoustics** 82
3.1.20  EN 779, EN 1822 Air filters performance  
3.1.21  EN 14134 Installation checks residential ventilation  
3.1.23  EN 1507, EN 12237 Ductwork (not in scope)  
3.2  SUBTASK 1.2.2 - STANDARDS AT MEMBER STATE LEVEL  
3.3  SUBTASK 1.2.3 – THIRD COUNTRY STANDARDS  
3.4  DISCUSSION AND GUIDANCE  

4  SUBTASK 1.3 - EXISTING LEGISLATION  
4.1  SUBTASK 1.3.1 - LEGISLATION AND AGREEMENTS AT EUROPEAN COMMUNITY LEVEL  
4.1.1  Ecodesign Directive for Energy-related Products 2009/125/EC (recast)  
4.1.2  Ecodesign Fan Regulation  
4.1.3  Ecodesign Electric Motor Regulation No. 640/2009  
4.1.5  Energy Labelling Directive 2010/30/EU (recast)  
4.1.6  European Union Ecolabel Regulation 66/2010  
4.1.7  Construction Products Regulation 305/2011/EU (recast)  
4.1.8  LVD - Low Voltage Directive 2006/95/EC  
4.1.9  EMC-D - Electromagnetic Compatibility 2004/108/EC  
4.1.10  MD - Machinery Directive 2006/42/EC  
4.1.11  Packaging Directive 2004/12/EC  
4.1.12  WEEE Directive 2002/96/EC  
4.1.13  RoHS Directive 2011/65/EU (recast of 2002/95/EC)  
4.1.14  Existing voluntary agreements  
4.1.15  Eurovent Certification  
4.2  SUBTASK 1.3.2 - LEGISLATION AT MEMBER STATE LEVEL  
4.2.1  Finland  
4.2.2  France  
4.2.3  Germany  
4.2.4  Ireland  
4.2.5  Netherlands  
4.2.6  Poland  
4.2.7  Portugal  
4.2.8  Spain  
4.2.9  United Kingdom  
4.3  SUBTASK 1.3.3 - THIRD COUNTRY LEGISLATION
4.3.1 USA 129
4.4 DISCUSSION AND GUIDANCE 146

5 SCOPE AND SAVING POTENTIAL FOR COLLECTIVE & NON-RESIDENTIAL VENTILATION SYSTEMS (FIRST ESTIMATE) 147

REFERENCES 150
LIST OF FIGURES 154
LIST OF TABLES 154
ACRONYMS 158
1 Introduction

1.1 Scope

This is the draft report for Task 1 on the Ventilation Systems, as part of the preparatory study on Air Conditioning and Ventilation Systems in the context of the Ecodesign Directive: ‘ENTR Lot 6 – Air Conditioning and Ventilation Systems.

This study is being carried out for the European Commission (DG ENTR). The consortium responsible for the study is Armines (lead contractor), BRE and VHK. Subcontractor for the underlying report is VHK. The Task 1 report on Air Conditioning Systems is issued separately. Wherever there is an overlap, data between the two reports are harmonized.

The scope of this task, in accordance with the tender specifications1, is to “classify and define the energy-using products covered by the lot and [provide a] "level playing field" for ecodesign. The product classification and definition should be relevant from a technical, functional, economic and environmental point of view, so that it can be used as a basis for the whole study. It is important to define the products as placed on the Community market. The product classification and definition have to be agreed with the Commission, after having consulted the stakeholders, and should be confirmed throughout the other tasks of the study. Standards and existing legislation for the defined energy-using products should be investigated.”

The products covered in this report are mechanical ventilation units with an electric power input per individual fan larger than 125 W. The main reason for the 125 W limit is that the product group would thus be complementary to the Ecodesign study on Domestic2 Ventilation [DG ENER lot 103], which deals with units up to and including 125 W individual fan power, and thus the combination of the two studies would cover the whole field of study. Furthermore, the 125 W limit is the lower limit in the Ecodesign Fan Regulation 327/2011 (see Chapter 4). Finally, the 125 W limit is used in Eurostat production and trade statistics, probably to give an approximate idea of data related to fans normally used in a domestic setting and fans mostly used in a non-domestic environment.

The function of the mechanical ventilation units is the exchange between relatively clean outdoor air and polluted indoor air of a buildings to create a healthy Indoor Air Quality (IAQ) for its inhabitants and building construction. The mechanical ventilation in the scope is achieved by

- a single-fan central ‘exhaust’ unit (CEXH), realizing mechanical air extraction from the building (or mechanical air supply to the building), whereby the air supply (or exhaust) is realized by separate natural ventilation openings in the building shell4, or
- a double-fan ‘balanced’ unit, providing both the air exhaust and air supply mechanically.

---

1 European Commission, Tender specifications ENTR/2009/035, which are the basis for the study.
2 Note that the adjectives ‘domestic’ (relating to use in private households and more popular in English literature) and ‘residential’ (related to the use in buildings intended for private households and more popular in American literature) are used in this report as being synonymous. The preference for using one or the other adjective is primarily dictated by the use of the adjective in the original source.
3 Latest status: Commission Working Document Dec. 2010 for written consultation. All relevant documents, including reactions to the written consultation, can be found on the Commission’s CIRCA website or can be consulted through public websites like http://www.eceee.org/Eco_design/products/domestic_ventilation.
4 A.k.a. “rooftop fans” / “boxed fans” / exhaust ventilation units are incorporated in LOT 11 preparatory study on fans.
The balanced units can be subdivided between *air handling units* (AHUs) and *central heat recovery ventilation units* (CHRV). AHUs are balanced units, with or without heat recovery, that are pre-disposed to also contain a section with one or more cooling and/or heating heat exchangers (a.k.a. ‘coils’). CHRVs are balanced units dedicated to heat recovery ventilation only.

Technical ventilation (e.g. mining, hospital operating rooms, high-temperature applications) is also not included in the scope of this preparatory study.

The products in the scope of the study are relatively large, given the lower limit of 125 W, and thus are used predominantly in *non-domestic or collective domestic applications*. Two-thirds of commercial buildings and half of the public administration buildings rely on mechanical ventilation, which has become indispensable in any modern, air-tight and thus energy-efficient building.

The units are usually *centralized*, meaning that they serve several individual rooms/zones of the building through a *ductwork with silencers, dividers and terminal units*. The ductwork and related components are not in the product scope of the study.

The interaction between ventilation and airconditioning systems is limited. Most of the space cooling (and air heating) in today’s modern buildings is taken care of by water-based systems (‘chillers’ and ‘fan coil units’) or refrigerant-based products.

The AHUs provide pre-cooling of the ventilation air and thus take care of only a relatively small part of the cooling load. The energy for pre-cooling (pre-heating) does not come from the AHU itself, but is provided by an external source, such as a chiller (boiler). Pre-cooling and pre-heating energy consumption thus appears in the energy balance of heating and cooling products in the Air Conditioning part of the DG ENTR Lot 6 study and in the DG ENER Lot 1 (CH boilers) and Lot 21 (air heating) preparatory studies. The energy use of the AHU attributable to the pre-cooling or pre-heating function comes from the extra pressure drop over the heat exchanger (the ‘coil’) that makes the fan motor work a little harder.

The energy efficiency of individual fans (incl. motor & drive), inside a ventilation unit will be part of Ecodesign measures for ‘fans’ in the power range above 125W following DG ENTR Lot 11. The assessment of the electricity consumption of a fan integrated in a ventilation unit adds several important dimensions, relating to e.g. internal pressure drop of the components, effectiveness in responding to ventilation demand and optimisation of controls in general.

In an exhaust unit --consisting of casing, fan, fan controller and possibly one or more sensors-- the aerodynamic design, the fan’s operating mode (e.g. fan speed) and the intelligence of the controller have a significant impact. In a balanced unit, shown below, also the pressure drop of individual components like filters, heat recovery unit and coils are major contributors to the electricity use of the ventilation unit. Humidifiers and dehumidifiers are not covered by the product scope.
The figure below provides the demarcation of the study scope with respect of Ecodesign measures in force/under preparation as well as the air-conditioning part of the study.

**Figure 1-2. Study scope with respect of related measures and studies**
1.2 Subtasks

The technical tender specifications for the Task 1 subtasks are:

Subtask 1.1 - Product classification and definition

The classification and definition of the products should be based notably on the following categorisations:
- Prodcom category or categories (Eurostat);
- Categories according to EN- or ISO-standard(s);
- Other product-specific categories (e.g. labelling, sector-specific categories), if not defined by the above. (stipulate)

Prodcom should be the first basis for defining the products (see also subtask 2.1).

If the product classification and definition relevant from a technical, economic and environmental point of view does not match directly with one or several Prodcom categories, the study should detail how it is translated into parts of Prodcom categories or the other categories mentioned above.

If products do not match with Prodcom categories, the standalone or packaged products placed on the European internal market, to which a CE mark is/could be affixed, should be defined. This may result in several Prodcom or otherwise categorised products relevant for the lot.

The above existing categorisations are a starting point for classifying and defining the products and can be completed by other relevant criteria, according notably to the functionality of the product, its environmental characteristics and the structure of the market where the product is placed. In particular, the classification and definition of the products should be linked to the assessment of primary product performance parameter (the "functional unit").

If needed, on the basis of functional performance characteristics and not on the basis of technology, a further segmentation can be applied on the basis of secondary product performance parameters.

Subtask 1.2 – Measurement and other standards

This task should identify the relevant measurement and other standards for the products. It can be subdivided in three parts:

subtask 1.2.1 - Standards at European Community level
Identify and shortly describe
- the harmonised measurement standards;
- and additional sector-specific directions for product-measurement;

regarding the measurement procedures for:
- the primary and secondary functional performance parameters mentioned above;
- resources use and emissions during product-life;

---

5 A product is placed on the Community market when it is made available for the first time. This is considered to take place when a product is transferred from the stage of manufacture with the intention of distribution or use on the Community market.

6 The functional unit is the quantified performance of a product for use as a reference unit.
- safety (gas, oil, electricity, EMC, stability of the product, etc.);
- product quality;
- noise and vibrations (if applicable).

Identify and shortly describe

- any other standard relevant for the products regarding the technical, economic, environmental and ecodesign analysis carried out in this study.

This analysis should prepare the ground, together with the following tasks, for evaluating the needs and generic requirements for standards to be developed in task 7.1.

**subtask 1.2.2 - Standards at Member State level**
This section deals with the subjects as above, but now for standards that have been indicated by stakeholders (NGOs, industry, users) as being relevant for the products at Member State level.

**subtask 1.2.3 - Third Country Standards**
This section again deals with the subjects as above, but now for standards in Third Countries (extra-EU) that have been indicated by stakeholders as being relevant for the product group.

**Subtask 1.3 - Existing legislation**
This subtask should identify and analyse the relevant legislation for the products. It can be subdivided in three parts:

**subtask 1.3.1 - Legislation and Agreements at European Community level**
Apart from the obvious environmental legislation such as the IPPC Directive, this could be building legislation (EPBD and CPD), regulations on health and labour conditions, labelling directives, product safety, EMC etc., including relevant standards interpreting such instruments. Also EU Voluntary Agreements and already existing ecodesign regulations for the sector’s products or related products need to be identified.

**subtask 1.3.2 - Legislation at Member State level**
This section deals with the subjects as above, but now for legislation that has been indicated by stakeholders as being relevant for the products at Member State level.

**subtask 1.3.3 - Third Country Legislation**
This section again deals with the subjects as above, but now for legislation and measures in Third Countries (extra-EU) that have been indicated by stakeholders as being relevant for the product group.

**1.2.1 Reporting**
The Task 1 report follows the structure of the subtasks, i.e. chapters 2, 3 and 4 relate to subtasks 1.1, 1.2 and 1.3. The separate Chapter 5 represents the first screening as stipulated in the tender specifications on the environmental impact and potential for improvement of the products as referred to in Article 15 of the Ecodesign Directive.
2 Subtask 1.1 - Product classification and definition

2.1 Introduction

As is elaborated in subtask 2.1 (Task 2 report), official statistics on the production, sales and trade for ‘ventilation units’ or ‘ventilation systems’ do not exist. Eurostat (Prodcom, External trade) and the national statistics offices classify ventilation units/systems either as ‘fans’, characterized by their technical typology (axial, centrifugal, etc.) or a size characteristic (>125 W/<125 W; >300 Pa/<300 Pa), or as ‘Air conditioning machines not containing a refrigeration unit; central station air handling units; Variable Air Volume (VAV) boxes and terminals, constant volume units and fan coil units’ (Prodcom 28251270).

For ‘fans’ this means a complete mix-up of ventilation units intended for end-users with OEM-fans intended to be built into boilers (combustion fans), chillers (e.g. condenser fans), laundry driers, ovens, fan-coils, etc.. For the Prodcom 28251270 category the ventilation devices (AHU’s) are mixed up with large quantities of non-ventilation devices (most fan-coils, terminals, etc.).

As a consequence, this subtask 1.1 will focus on the definitions and categorization as found in various EN- and ISO standards.

2.2 Definition of Ventilation

The term “Ventilation” refers to the process of exchanging indoor air by fresh outdoor air in human occupied space for the purpose of obtaining an acceptable Indoor Air Quality (IAQ).

Or - formulated in more ‘pollutant-related’ terms – ventilation is the process of exchanging air for the following purposes:

a. provision of air for occupants respiration
b. control of internal humidity
c. dilution and/or removal of background pollutants (metabolic CO2, vapours, odours, emission from building-, furnishing- and cleaning materials)
d. dilution and/or removal of specific pollutants from identifiable local sources: toilet and cooking odours, water vapour from bathing / cooking / washers & driers, tobacco smoke, combustion products from fuel burning appliances
e. provision of air for fuel burning appliances and dilution of related emissions

2.3 Types of ventilation / air-exchange

There are three different mechanisms through which the indoor air is exchanged by outdoor air:

1. Infiltration: air exchange through leakages in building envelope (to be measured acc. EN 13829). The infiltration rate is determined by the air tightness of the building envelope and the pressure difference over the building. Infiltration is an uncontrollable air exchange process.
2. **Ventilation**: purpose provided air exchange between the inside and the outside of a building, through the (for this purpose specifically designed and installed) ventilation system by means of a range of natural and/or mechanical devices. Depending on type of ventilation system, the air-exchange rate is more or less controllable.

3. **Airing**: air exchange induced by opening windows (also referred to as *Purge ventilation* (UK), *Stoßlüften* (DE), *Spuiventilatie* (NL)).

Looking at the history of ventilation systems\(^7\), the IAQ in older buildings mainly depend on infiltration and airing. The *purpose provided air-exchange* through ventilation systems became necessary, when people could no longer rely on infiltration alone as the key parameter for achieving an acceptable IAQ.

Due to energy conservation and EPBD-legislation, new buildings have an increased air tightness. Infiltration can no longer guarantee acceptable indoor air qualities. But also in refurbished buildings, where additional insulation and increased air tightness are applied, indoor air quality levels can no longer be guaranteed. Additional ventilation systems are necessary to secure – on a long term basis - the requested indoor air quality levels in all the occupied rooms of the building.

### 2.4 Product scope for ventilation systems

A preliminary definition of the ventilation products that are in the scope of the underlying study are given in Chapter 1.1, in as much as could be concluded from the Terms of Reference for the contract and general engineering knowledge.

The final wording of product definitions and boundaries of the scope of the study and possible measures is an iterative process. The preparatory study makes recommendations, based on the definitions in the Terms of Reference for the underlying contract, the definitions in standards (see par. 2.5 and Chapter 3), definitions used in legislation (Chapter 4), in official statistics sources (see Task 2 report) and the inputs from stakeholders during –amongst others—the three stakeholder meetings which has been included in the various task reports. After the preparatory study, again on the basis of new consultations with stakeholders, Commission services and additional analyses, the Commission will propose draft definitions. But ultimately no definition is final until it is laid down in legislation.

The following is a more technical description of the various products involved. Contrary to natural ventilation systems, the mechanical ventilation systems use a mechanically powered device (ventilation unit containing one or more fans) as core component to initiate the air transport necessary for the requested air-exchange. These mechanical ventilation units are the key subject of this study. Note that the descriptions have been aligned with the wording used for DG ENER Lot 10 on Domestic Ventilation.

---

\(^7\) In the context if this study, when we talk about ventilation systems, we refer to systems according to the 2nd mechanism: “purpose provided air exchange through a - for this purpose specially designed and installed -ventilation system”. 
**Energy-related Products included**

**Small extraction fan (local exhaust).** Wall, window, ceiling fan for wet rooms (toilet, bathroom, kitchen). Manually, humidity and/or timer-controlled. Equipped with housing to accommodate mounting and possibly connection to simple ducting.⁸

Small extraction fans are not further analysed in ENTR lot 6.

**Rooftop/boxed ventilation units (central exhaust or central supply).** Extraction or supply fan unit mounted on top of the roof (‘rooftop’) or indoors (‘boxed fan’, including duct fans), dimensioned for air extraction/supply from/to a large zone (industry, warehouse, corridor of office) or a stack of dwellings in multi-family buildings. Usually delivered as single package unit, equipped with

- housing to accommodate mounting and possibly connection to ductwork;
- provisions to avoid penetration from precipitation (rooftop unit only, IP rating >IP 4X);
- electronics: CPU, possibly sensors, connector block (wired) or receiver(s);
- drive (on-off, multispeed or continuously variable);
- motor (AC or DC);
- fan (centrifugal, axial or mixed flow).

In addition the following separate items may be part of the product put on the market:

- wired or wireless, manual or automatic (timer, occupancy, gas and/or humidity sensor-driven) means of IAQ controls;
- VAV terminals in multi-duct systems (incl. transmitters/receivers to/from unit CPU), to realize local demand-side ventilation;
- Electrically operated, humidity operated or outside pressure operated inlet/outlet grids (incl. transmitters/receivers to/from unit Central Processing Unit CPU), to realize local (per room) ventilation;

---

**Exhaust rooftop/boxed ventilation units** are of the type mechanical exhaust and natural supply (through openings or grids in windows). Supply rooftop/boxed ventilation units are rare in most parts of the EU (exception UK) in comfort ventilation applications. They are used in positive pressure systems, i.e. mechanical supply and natural supply. Supply units are similar in built and components to exhaust units, but typically are more indoors (‘boxed’) and may be equipped with filters. Capacities range from 200 to 10 000 m³/h @ 150-200 Pa external pressure and overall efficiencies 15-25%. Power ranges from 50W to 3 kW electric. The market below 125 W falls into the scope of DG ENER Lot 10 (Domestic Ventilation). The fans>125W inside the rooftop/boxed units are in the scope of DG ENER Lot 11 (Industrial fans). The motors >750W could at some stage of unit production have been in the scope of Regulation on motors, but—as opposed to the planned fan measures—for integrated direct-drive fan-motors there is no obligation for rooftop/boxed fan manufacturers to prove compliance. For belt-driven motors, which are rare, it is easy to disassemble the unit and here the Motor Regulation does apply.

---

⁸ Typically equipped with AC-motors (on-off, 2 or 3 speed). Axial fan type. Capacities 30-150 m³/h@100Pa with overall efficiency 10-15%. Typical used as auxiliary local ventilation to supplement mainly natural ventilation (‘System A’). Almost completely in the scope of DG ENER Lot 10 on Domestic Ventilation for capacities up to 125 W nameplate (nominal) power.
Rooftop/boxed ventilation units > 125 W/fan are analysed in ENTR Lot 6

Local heat recovery ventilation (LHRV) unit: Single package balanced room ventilation unit with inlet and outlet through the façade of the building/dwelling. Ductless through-the-wall version or version with small ducts, combined with heat/cooling emitter. The latter can be built against façade or integrated in floor, ceiling or façade boarding. Nominal capacity typically 100 m³/h at 75-100 Pa. Range between 50 and 150 m³/h.

The product contains components as the rooftop fan, but uses

- 2 fans instead of 1 (‘balanced’);
- a heat exchanger (usually counter-flow, efficacy 80-90%);
- filters on both exhaust side (coarse filter G4 to keep heat exchanger clean) and supply side (e.g. fine-filter F5-F7);
- special valve solutions on outdoor inlet and outdoor side;
- integrated local sensors;
- soft- or hardware anti-condense and anti-frost solutions.

The product is optimized to be compact and silent. New product group aiming both at new built and —especially—retrofit/renovation purposes. Requires additional local fans in wet rooms for incidental ventilation. As it is a new product group, the quality varies greatly between models. Recirculation (inlet air taken from the air outlet) may be problematic with ductless through-the-wall units. For high-rise buildings (>6 to 8 floors) less suitable without special measures (double façade, collector pipes, etc.). Resistance to extreme wind loads on the façade in some through the wall versions. Even though it is a product both for residential and non-residential use, its nominal ventilation power consumption is far below 125 W per unit and thus fully in the scope of DG ENER Lot 10 (Domest Ventilation), at least for measures dealing with the LHRV as a component.
Local heat recovery ventilation (LHRV) units are not further analysed in ENTR lot 6.

**Central heat recovery ventilation (CHRV) unit:** Dedicated ‘ventilation only’ single package unit, usually located in utility or service area under or on top of roof and designed to operate with indoor ductwork for supply (to living and sleeping area) and exhaust (from wet rooms). It contains the same components as the LHRV unit, but because of its location it will usually be equipped with solutions for condensate collection and abdution (instead of avoidance) as well active anti-frost protection and possibly preheat of supply air. As with LHRV the dominant heat exchanger for heat recovery is a counterflow heat exchanger with efficacies of 80-90%.

Additional options for local (per room/zone) ventilation with this central unit include VAV terminals and means for local IAQ control.

---

**CHRV units for individual dwellings are typically 250-300 m³/h at 200 Pa and will be in the scope of DG ENER Lot 10 on the grounds of their nominal electric power <125 W per unit (at least for the energy efficient solutions). For small and medium-sized non-residential applications capacity varies between 400 and 4000 m³/h at 200-300 Pa total pressure drop (internal and external) and nominal power will be in the range 125W-3.5 kW. The dominant heat exchanger for heat recovery is a counterflow heat exchanger with efficacies of 80-90%. By definition not equipped for combination with air cooling or heating, i.e. they do not contain, nor can they be extended to contain heat exchangers for chillers and/or boilers. CHRV-units are typically associated with a balance mechanical exhaust and supply system. Most unit sales (>80%) go into individual dwellings (out of scope of Lot 6), but popularity of the larger units in small commercial and public (school) buildings is growing.**

Central heat recovery ventilation (CHRV) units > 125 W are analysed in ENTR lot 6.

**Air Handling Unit (AHU):** Factory made encased assembly consisting of sections containing a fan or fans and other necessary equipment to perform one or more of the following functions: air supply, air exhaust, filtration, heat recovery. Additional functions may be integrated (heating, cooling, circulation, (de)humidifying, mixing). The formal difference with CHRV is that an AHU can be—and in 95% of cases is—combined with a heating and/or cooling function.

The ‘additional functions’ mentioned will not be assessed in the context of its ventilation function, but will be assessed in the context of its air-conditioning function.

AHU’s are modular. Fans, Heat recovery unit, heat exchanger units, etc. are separate module and can also be tested separately.
Heat recovery units are different from CHRV units in the sense that cross-flow (efficacy 50%) and rotary wheels (60-70%) are the dominant types of heat exchangers.

AHU capacity ranges typically from 1000 to 100 000 m³/hr. at external pressure 200-1000 Pa. Average capacity is around 8-9000 m³/hr with German manufacturers more specialized in larger units (average 14 000 m³/hr) and other countries using relatively smaller AHU's (average 5000 m³/hr).

![Image of AHUs with heat recovery](image)

**Figure 1-5**. Upper left: Very large (100 000 m³/h) AHU with heat recovery (project Gemini/Kamen, Howatherm). Upper right: Rooftop AHU with heat recovery (Hoval). Below: heat exchangers for waste heat recovery. Below left: Cross-flow plate heat exchanger. Below right: Rotary wheel (Hoval).

**Air handling units are analysed in ENTR lot 6.**

Obviously, these energy using ventilation products are not the only products necessary to build a full and proper functioning ventilation system. Additional components like ducts, orifices, air transfer devices, ventilation grids etc. are generally used to build a complete mechanical ventilation system.

**Not included**

Not included in this Task 1 assessment on ventilation are the sections of air handling units that deal with other (non-ventilation) functions, such as humidifiers, cooling and heating sections. They are discussed in the air conditioning section.

**Energy performance scope**

The energy performance of these mechanical ventilation units will be assessed on the basis of their ventilation function. This means that this study will not only look at the electrical performance of these units, but also at the air exchange performance and the thermal energy content of the air exchange (either heating or cooling) in relation to the requested IAQ. As far as the other (passive)

---

9 NB: There is actually a separate ENTR lot 6 and ENER lot 21 consultation of stakeholders on the scope of "Air handling units". In case that the consultation would result in consideration of cooling or heating functions of "Air handling units", next to the ventilation function, ENTR lot 6 will be updated accordingly.
components of the ventilation system have an influence on the air exchange performance, default values will be defined for these parameters to ensure a neutral and objective comparison.

Other Environmental Performance Scope
The study team assumes that the main environmental impact of ventilation systems is their energy consumption, either direct electricity from fan motors or the energy required to balance for heat and cool losses from the building shell. Following the requirements of the Ecodesign Directive, the study will also quantify the other environmental impacts.\(^{10}\)

2.5 Definitions
This paragraph gives an overview of ventilation definitions found in existing EN-product and building standards. As such, it can serve as a summary of generally accepted terms, definitions and classifications that are used in the EU standards that are further discussed in subtask 1.2. Note that this overview of definitions that are found in standards; definitions that are not found in standards are not provided.

These terms, definitions and classifications will be used throughout this study.

Definitions of ventilation systems

*Ventilation system*
Combination of appliances designed to supply interior spaces with outdoor air and to extract polluted indoor air

*Natural ventilation system*
Ventilation system which relies on pressure differences without the aid of powered air movement components. These pressure difference mechanism are:

*Stack effect*
Movement of air or gas in a vertical enclosure (e.g. duct, chimney, building) induced by density difference between the air or gas in the enclosure and the ambient atmosphere (due to temperature differences).

*Cross ventilation*
Natural ventilation in which air flow mainly results from wind pressure effects on the building facades and in which stack effect in the building is of less importance.

*Fan assisted exhaust air ventilation*
Ventilation which employs powered air movement components (fans) in the exhaust air side only

*Fans assisted supply air ventilation*
Ventilation which employs powered air movement components in the supply air side only

---

\(^{10}\) The thermal energy content related to air exchanges caused by Infiltration and Airing are not in the scope of this study. They are subject to EPBD-legislation.
**Fan assisted balanced ventilation**

Ventilation which employs powered air movement components in both the supply and the exhaust air sides in order to achieve a design flow rate/pressure ratio

**Demand controlled ventilation**

Ventilation systems where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicators for the need of ventilation

**Ventilation flow rate**

Volume flow rate at which ventilation air is supplied and removed

**Air handling unit (AHU)**

Factory made encased assembly consisting of sections containing a fan or fans and other necessary equipment to perform one or more of the following functions: air supply, air exhaust, filtration, heat recovery. Additional functions may be integrated (heating, cooling, circulation, (de)humidifying, mixing), but these functions will not be assessed in the context of its ventilation function. (These additional functions will be assessed in the context of its air-conditioning function).

**Definitions of performance parameters**

**Ventilation effectiveness (source EN13779**)

Ventilation effectiveness is the relation between the pollution concentrations in the supply air, the extract air and the indoor air in the breathing zone (within the occupied zone). It is defined as

\[ \varepsilon_v = \frac{C_{ETA} - C_{SUP}}{C_{IDA} - C_{SUP}} \]

where:

- \( \varepsilon_v \) is the ventilation effectiveness
- \( C_{ETA} \) is the pollution concentration in the extract air in mg/m³
- \( C_{IDA} \) the pollution concentration in the indoor air (breathing zone) in mg/m³
- \( C_{SUP} \) is the pollution concentration in the supply air in mg/m³

**Maximum and minimum air volume flow (source EN 13142**)

For central mechanical ventilation units with or without heat recovery (to be used with ducts), the maximum air volume flow of the mechanical ventilation unit is the maximum flow at a reference

---


pressure difference (e.g. \( \Delta P = 100 \text{ Pa} \) for single dwellings), that can be achieved with integrated and/or separately co-supplied controls (at standard air conditions: 20°C and 101325 Pa).

The minimum air volume flow is the minimum flow that can be achieved with integrated and/or separately co-supplied controls (at standard air conditions: 20°C and 101325 Pa).

For room based mechanical ventilation units the maximum and minimum are the volume flows that can be achieved with the unit when installed according manufacturer instructions (with wall-ducts and grills) with the integrated and/or separately co-supplied controls (at standard air conditions: 20°C and 101.325 Pa).

**Reference air volume flow** (source EN 13142)

Reference air volume flow is 70% of the maximum air volume flow (at standard air conditions: 20°C and 101.325 Pa).

**Specific Power Input (SPI)** (source EN 13142)

The Specific Power Input for mechanical ventilation units is the power input at reference air volume flow and reference pressure difference and includes the electrical demand for fans, controls (including remote controls) and (if integrated) any heat pump.

In formula: \[ SPI = \frac{P_E}{q_{v,\text{ref}}} \]

**Standby Power Consumption in Fan-off Mode**

Standby power consumption in fan-off mode is the power consumption in the mode during which the fans are not working, but the controls and any sensors are active in order to monitor the functional parameters and determine a possible switch-on of the fans.

**Standby Power Consumption in switched-off Mode**

Standby power consumption in off mode is the power consumption in the mode during which the unit is switched off manually or with any remote control system. Switching the unit on again is only possible with the same remote or manual action.

**Acoustics**

Sound power levels of mechanical ventilation units shall be given at declared maximum air volume flow and reference air volume flow. Depending on the type of product the following noise level data may be requested:

**Casing radiated sound power level** (source En 13142)

Noise radiated through the casing at maximum and reference air volume flow must be measured according to EN 13141-6 13 (for exhaust only central mechanical ventilation units) or EN 13141-7 14 (for central mechanical ventilation units with heat recovery) or EN 13141-8 15 (for room based mechanical ventilation unit with heat recovery)

**Duct radiated sound power level** (source En 13142)

---


15 EN 13141-8:2006, Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of unducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room. March 2006 (currently being revised, Nov. 2010). See also Chapter 3.1.
The noise radiated from the duct connected to the central mechanical ventilation unit (exhaust only, or balanced with heat recovery / with default length) at maximum and reference air volume flow, shall be measured according to EN 13141-7

**Sound transmitting resistance (Dn,e,w)** *(source En 13142)*

The sound transmitting resistance $D_{n,e,w}$ for room based mechanical ventilation units with heat recovery at reference air volume flow shall be measured according to EN ISO 10140:2010\(^\text{16}\).

### ADDITIONAL PERFORMANCE PARAMETERS FOR MECHANICAL VENTILATION UNITS WITH HEAT RECOVERY AND FILTERS

In principle leakage and mixing parameters mentioned below are, if their influence is significant, relevant in the context of this study, because not only do they influence the product performance (the actual exchange with fresh air), but also they constitute a potential loophole in the assessment of the energy consumption (measurement of pressure drops, flow rates and air temperatures).

**External leakage**

Leakage to or from the air flowing inside the casing of the unit to or from the surrounding air, to be tested according to EN13141-7 and -8

**Internal leakage**

Leakage inside the unit between the exhaust and the supply air flows, to be tested according to EN13141-7 and -8.

**Mixing or short circuiting**

Mixing of the two air flows external to the unit under test, between discharge and intake ports at both indoor and outdoor terminal ports, to be tested according to EN13141-8

**Filter bypass leakage**

Air flow around filter cells, i.e. air that does not pass through the filter —as intended—but passes through the possible space between the filter and the filter holder or between filter holder and casing, to be tested according to EN13141-7 and -8

**Humidity Ratio**

Difference of water content between inlet and outlet of one of the air flows, divided by the difference of water content between the inlets of both air flows, to be tested according to EN13141-7 and -8.

**Temperature ratio**

Temperature difference between inlet and outlet of one of the air flows, divided by the temperature difference between the inlets of both airflows (to be tested according to EN13141-7 and -8)

---

Definitions of room types

**Activity room**
Room used for activities such as cooking, washing and bathing which is characterized by relatively high pollutant emission (which may be intermittent), e.g. kitchen, bathroom, laundry/utility room, WC.

**Low pollution room**
Room used for dwelling purposes which is characterized by relatively low pollution emission, e.g. a bedroom, living room, dining room, study, but not a space used only for storage

**Common space**
Corridor, stairway or atrium used for access to a dwelling or dwellings
2.6 Classifications

Classification of types of air (according to EN 13779:2007)

Table 1-1. EN classification of type of air

<table>
<thead>
<tr>
<th>Type of air</th>
<th>Abbreviation</th>
<th>Colour</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air</td>
<td>ODA</td>
<td>Green</td>
<td>Air entering the system or opening from outdoors before any air treatment</td>
</tr>
<tr>
<td>Supply air</td>
<td>SUP</td>
<td>Blue</td>
<td>Airflow entering the treated room, or air entering the system after any treatment</td>
</tr>
<tr>
<td>Indoor air</td>
<td>IDA</td>
<td>Grey</td>
<td>Air in the treated room or zone</td>
</tr>
<tr>
<td>Extract air</td>
<td>ETA</td>
<td>Yellow</td>
<td>The airflow leaving the treated room</td>
</tr>
<tr>
<td>Exhaust air</td>
<td>EHA</td>
<td>Brown</td>
<td>Airflow discharges to the atmosphere</td>
</tr>
<tr>
<td>Transferred air</td>
<td>TRA</td>
<td>Grey</td>
<td>Indoor air which passes from the treated room to another treated room</td>
</tr>
<tr>
<td>Secondary air</td>
<td>SEC</td>
<td>Orange</td>
<td>Airflow taken from a room and returned to the same room after any treatment</td>
</tr>
<tr>
<td>Leakage</td>
<td>LEA</td>
<td>grey</td>
<td>Unintended airflow through leakage paths in the system</td>
</tr>
</tbody>
</table>

Classification of extract air (ETA) and exhaust air (EHA) (according to EN 13779:2007)

Table 1-2. EN classification of extract and exhaust air

<table>
<thead>
<tr>
<th>Category</th>
<th>Pollutin level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA1</td>
<td>EHA1</td>
<td>Low Air from rooms where the main emission sources are the building materials and structures, and air from occupied rooms where the main emission sources are human metabolism and building materials and structures. Rooms where smoking is allowed are excluded.</td>
</tr>
<tr>
<td>ETA2</td>
<td>EHA2</td>
<td>Moderate Air from occupied rooms, which contain more impurities than category 1 from the same sources and/or also from human activities. Rooms which shall otherwise fall in category ETA1 but where smoking is allowed.</td>
</tr>
<tr>
<td>ETA3</td>
<td>EHA3</td>
<td>High Air from rooms where emitted moisture, processes, chemicals etc. Substantially reduce the quality of the air.</td>
</tr>
<tr>
<td>ETA4</td>
<td>EHA4</td>
<td>Very high Air which contains odours and impurities in significantly higher concentrations than those allowed for indoor air in occupied zones.</td>
</tr>
</tbody>
</table>
Classification of outdoor air (ODA) (according to EN 13779:2007)

Table 1-3 . EN classification of outdoor air

<table>
<thead>
<tr>
<th>Category</th>
<th>Pollution level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODA1</td>
<td>Low</td>
<td>Pure air which may be only temporarily dusty (e.g. pollen). ODA1 applies where the WHO (1999) guidelines and any National air quality standards or regulations for outdoor air are fulfilled.</td>
</tr>
<tr>
<td>ODA2</td>
<td>High</td>
<td>Outdoor air with high concentrations of particulate matter and/or gaseous pollutants. ODA2 applies where pollutant concentrations exceed the WHO guidelines or any national air quality standard or regulations for outdoor air by a factor of up to 1.5</td>
</tr>
<tr>
<td>ODA3</td>
<td>Very high</td>
<td>Outdoor air with very concentrations of particulate matter and/or gaseous pollutants. ODA3 applies where pollutant concentrations exceed the WHO guidelines or any national air quality standard or regulations for outdoor air by a factor greater than 1.5</td>
</tr>
</tbody>
</table>

Classification of indoor air quality (IDA) for residential buildings (according to EN 13779 and EN15215 17)

Table 1-4 . EN classification of indoor air quality

<table>
<thead>
<tr>
<th>Category</th>
<th>IAQ level</th>
<th>Related default CO2 value acc. EN15251</th>
<th>Related recommended default ventilation rates acc. EN15251 either per person or per m² floor area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Corresponding CO2 concentration above outdoors [ppm]</td>
<td>Airflow [l/s/p]</td>
</tr>
<tr>
<td>IDA1</td>
<td>High</td>
<td>350</td>
<td>10</td>
</tr>
<tr>
<td>IDA2</td>
<td>Medium</td>
<td>500</td>
<td>7</td>
</tr>
<tr>
<td>IDA3</td>
<td>Moderate</td>
<td>800</td>
<td>4</td>
</tr>
<tr>
<td>IDA4</td>
<td>Low</td>
<td>&gt;800</td>
<td></td>
</tr>
</tbody>
</table>

Categories of heat exchangers

Category I heat exchangers

Recuperative heat exchangers (e.g. air-to-air plate or tube heat exchangers)

Recuperative heat exchangers are designed to transfer thermal energy (sensible or total) from one air stream to another without moving parts. Heat transfer surfaces are in form of plates or tubes. This heat exchanger may have parallel flow, cross flow or counter flow construction or a

17 EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics. June 2007
combination of these. Plate and tube heat exchangers with vapour diffusion (e.g. cellulose) are also in this category.

**Category II heat exchangers**

Regenerative heat exchangers (e.g. rotary or reciprocating heat exchangers).

A rotary heat exchanger is a device incorporating a rotating “thermal wheel” for the purpose of transferring energy (sensible or total) from one air stream to the other. It incorporates material allowing latent heat transfer, a drive mechanism, a casing or frame, and includes any seals which are provided to retard bypassing and leakage or air from one stream to the other. Regenerative heat exchangers have varying degrees of moisture recovery, depending on the material used (e.g. condensation non hygroscopic rotor-, hygroscopic rotor-, and sorption rotor- heat exchangers)

**Classification leakage rates**

There are two test methods for rating leakages: pressure testing and tracer gas testing. The pressure method applies to Category I type heat exchanger units and the tracer gas method applies to the Category II type heat exchangers.

a. Leakage classification *mechanical ventilation units with heat recovery for single dwellings*

a.1) According to the pressurisation test method (EN 13141-7)

<table>
<thead>
<tr>
<th>Class*</th>
<th>Pressurisation test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal Leakage (at 100 Pa)</td>
<td>External Leakage (at 250 Pa)</td>
</tr>
<tr>
<td>A1</td>
<td>≤ 2%</td>
<td>≤ 2%</td>
</tr>
<tr>
<td>A2</td>
<td>≤ 5%</td>
<td>≤ 5%</td>
</tr>
<tr>
<td>A3</td>
<td>≤ 10%</td>
<td>≤ 10%</td>
</tr>
<tr>
<td>Not classified</td>
<td>&gt; 10%</td>
<td>&gt; 10%</td>
</tr>
</tbody>
</table>

* Class is determined on the bases of the highest leakage value

a.2) According to the tracer gas method (EN 13141-7)

<table>
<thead>
<tr>
<th>Class</th>
<th>Chamber method</th>
<th>In-duct method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Recirculated fraction in supply air</td>
<td>Class*</td>
</tr>
<tr>
<td>B1</td>
<td>≤ 1%</td>
<td>C1</td>
</tr>
<tr>
<td>B2</td>
<td>≤ 2%</td>
<td>C2</td>
</tr>
<tr>
<td>B3</td>
<td>≤ 6%</td>
<td>C3</td>
</tr>
<tr>
<td>Not classified</td>
<td>&gt; 6%</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

* Class is determined on the bases of the highest leakage value

b. Leakage classification *mechanical ventilation units with heat recovery for single rooms*

Leakage rates to be tested according to En 13141-8
Table 1-7. EN leakage classification EN 13141-8

<table>
<thead>
<tr>
<th>Class*</th>
<th>Internal Leakage (at 20 Pa)</th>
<th>External Leakage (at 50 Pa)</th>
<th>Mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>≤ 2%</td>
<td>≤ 2%</td>
<td>≤ 2%</td>
</tr>
<tr>
<td>U2</td>
<td>≤ 5%</td>
<td>≤ 5%</td>
<td>≤ 5%</td>
</tr>
<tr>
<td>U3</td>
<td>≤ 10%</td>
<td>≤ 10%</td>
<td>≤ 10%</td>
</tr>
<tr>
<td>U4</td>
<td>≤ 15%</td>
<td>≤ 15%</td>
<td>≤ 15%</td>
</tr>
<tr>
<td>U5</td>
<td>≤ 20%</td>
<td>≤ 20%</td>
<td>≤ 20%</td>
</tr>
<tr>
<td>U6</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
</tr>
</tbody>
</table>

* Class is determined on the basis of the highest leakage value.

Classification of filter bypass leakage

Filter bypass leakage to be tested according EN 1886 ¹⁸(at 200 Pa). Due to the fact that filter bypass leakage measurements can be a difficult task to perform, it is also possible to give a classification on the basis of a visual inspection of the design details.

Table 1-8. EN filter bypass leakage classification EN 13141-8

<table>
<thead>
<tr>
<th>Class</th>
<th>Leakage rate</th>
<th>Proof</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBL 1</td>
<td>&lt; 2%</td>
<td>Measured EN 1886 (at 200 Pa)</td>
<td></td>
</tr>
<tr>
<td>FBL 2</td>
<td>&lt; 4%</td>
<td>Measured EN 1886 (at 200 Pa)</td>
<td></td>
</tr>
<tr>
<td>FBL 3</td>
<td>&lt; 6%</td>
<td>Measured EN 1886 (at 200 Pa)</td>
<td></td>
</tr>
<tr>
<td>FBL 4</td>
<td>Approved</td>
<td>Visual inspection 1. Design &amp; construction of air filter and frames allow easy assembly and tight fit 2. Tight fit shall not be affected under the impact of humidity</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
<td>Not classified</td>
<td></td>
</tr>
</tbody>
</table>

Filter classification

a. Mechanical coarse filters shall be tested according to EN 779 ¹⁹ and classified accordingly.

Table 1-9. EN coarse filter classification

<table>
<thead>
<tr>
<th>Key particle size</th>
<th>Classification acc. EN779</th>
<th>Examples of matter retained per filter class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse &gt; 1 μm</td>
<td>G1 EU1</td>
<td>Leaves, insects, textile fibres, human hairs, sand, fly ash, water droplets</td>
</tr>
<tr>
<td></td>
<td>G2 EU2</td>
<td>Beach sand, plant spores, pollen, fog</td>
</tr>
<tr>
<td></td>
<td>G3 EU3</td>
<td></td>
</tr>
</tbody>
</table>


¹⁹ EN 779 :2003, Particulate air filters for general ventilation - Determination of the filtration performance.(currently under review; latest publication prEN 779 :2011, which amongst others renames F5-F7 classes)
b. Mechanical fine filters shall be tested according to EN-1822\textsuperscript{20} and classified accordingly.

<table>
<thead>
<tr>
<th>Key particle size</th>
<th>Classification acc. EN1822-1</th>
<th>Examples of matter retained per filter class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine: 0.4 (\mu)m</td>
<td>G4 EU4</td>
<td>Spores, cement dust (coarse fraction), sediment dust</td>
</tr>
<tr>
<td></td>
<td>F5 EU5</td>
<td>Bigger bacteria, germs or carrier particles, PM10</td>
</tr>
<tr>
<td></td>
<td>F6 EU6</td>
<td>Agglomerated soot, lung damaging dust (PM2.5), cement dust</td>
</tr>
<tr>
<td></td>
<td>F7 EU7</td>
<td>Tobacco smoke (coarse fraction), oil smokes, bacteria</td>
</tr>
</tbody>
</table>

\textbf{Table 1-10 . EN fine filter classification}

\textbf{HEPA 0.3 \(\mu\)m}
- H10 EU10: Germs, tobacco smoke, metallurgical fumes, viruses, radioactive particles, carbon black
- H11 EU11: Oil fumes, metallurgical fumes, sea salt nuclei, viruses, radioactive particles, all air suspended PM
- H12 EU12: Filter cleanroom ISO 4, operating theatres etc.
- H13 EU13: Filter cleanroom ISO 3
- H14 EU14: Filter cleanroom ISO 2
  - U15 EU15: Filter cleanroom ISO 1
  - U16 EU16: Filter cleanroom ISO 2
  - U17 EU17: Filter cleanroom ISO 3
  - U18 EU18: Filter cleanroom ISO 4

\textbf{ULPA 0.12}
- H10 EU10: Germs, tobacco smoke, metallurgical fumes, viruses, radioactive particles, carbon black
- H11 EU11: Oil fumes, metallurgical fumes, sea salt nuclei, viruses, radioactive particles, all air suspended PM
- H12 EU12: Filter cleanroom ISO 4, operating theatres etc.
- H13 EU13: Filter cleanroom ISO 3
- H14 EU14: Filter cleanroom ISO 2
  - U15 EU15: Filter cleanroom ISO 1
  - U16 EU16: Filter cleanroom ISO 2
  - U17 EU17: Filter cleanroom ISO 3
  - U18 EU18: Filter cleanroom ISO 4

\textbf{c. Electrostatic filters shall be tested for their filter effectiveness by measuring the particle removal efficiency at the maximum volume flow rate and related reference pressure drop of the mechanical ventilation unit. Test method and results must be reported.}

\textbf{d. Gas adsorption filters (or activated carbon filters) shall be tested according EN ISO 10121-1 and 2\textsuperscript{21}, and classified accordingly.}

\textsuperscript{20} EN 1822:2009, High efficiency air filters (EPA, HEPA and ULPA) – Parts 1 to 5 (Part 1 : Determination of the filtration performance). See also Chapter 3.1.

\textsuperscript{21} ISO 10121-1 and -2: 2010, Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation, Parts 1 and 2 (under development 2010). See also Chapter 3.1.
**Classification of Specific Power Input (according to EN 13142)**

Table 1-11. EN classification of SPI values (residential units)

<table>
<thead>
<tr>
<th>Class</th>
<th>Dedicated mechanical ventilation Exhaust- or supply units</th>
<th>Combined mechanical exhaust and supply ventilation units with heat recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single room * [W/m³/h]</td>
<td>Dwelling * [W/m³/h]</td>
</tr>
<tr>
<td>SPI 1</td>
<td>≤ 0.10</td>
<td>≤ 0.10</td>
</tr>
<tr>
<td>SPI 2</td>
<td>≤ 0.15</td>
<td>≤ 0.15</td>
</tr>
<tr>
<td>SPI 3</td>
<td>≤ 0.20</td>
<td>≤ 0.20</td>
</tr>
<tr>
<td>SPI 4</td>
<td>≤ 0.25</td>
<td>≤ 0.25</td>
</tr>
<tr>
<td>SPI 5</td>
<td>≤ 0.30</td>
<td>≤ 0.30</td>
</tr>
<tr>
<td>SPI 6</td>
<td>≤ 0.35</td>
<td>≤ 0.35</td>
</tr>
<tr>
<td>SPI 7</td>
<td>&gt; 0.35</td>
<td>&gt; 0.35</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

* figures to be discussed with CEN/TC ad hoc WG on classification (revision 13142)

**Classification of specific fan power, per fan (according to EN 13799)**

Table 1-12. EN classification of SFP values (non-residential)

<table>
<thead>
<tr>
<th>Category</th>
<th>( P_{SFP} ) in ( W/(m^3/s) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFP 1</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>SFP 2</td>
<td>500 – 750</td>
</tr>
<tr>
<td>SFP 3</td>
<td>750 – 1.250</td>
</tr>
<tr>
<td>SFP 4</td>
<td>1.250 – 2.000</td>
</tr>
<tr>
<td>SFP 5</td>
<td>2.000 – 3.000</td>
</tr>
<tr>
<td>SFP 6</td>
<td>3.000 – 4.500</td>
</tr>
<tr>
<td>SFP 7</td>
<td>&gt; 4.500</td>
</tr>
</tbody>
</table>

The specific fan power SFP depends on the pressure drop, the efficiency of the fan and the design of the motor and the drive system.

**Classification of heat recovery thermal efficiency/ temperature ratio (according to EN 13142)**

Classification of the temperature ratio on the supply side of the unit measured at reference- air volume flow and pressure difference and at nominal temperature difference (\( \Delta T = 13 \) K).

(measured according to EN13141-7 /-8, relating to residential units)
Table 1-13. EN classification of thermal efficiency/ temperature ratio for HR units (EN 13141-7/-8)

<table>
<thead>
<tr>
<th>Class</th>
<th>Temperature ratio (measured on supply side at reference air volume flow and nominal ΔT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≥ 90%</td>
</tr>
<tr>
<td>2</td>
<td>80 – 89%</td>
</tr>
<tr>
<td>3</td>
<td>70 – 79%</td>
</tr>
<tr>
<td>4</td>
<td>60 – 69%</td>
</tr>
<tr>
<td>5</td>
<td>50 – 59%</td>
</tr>
<tr>
<td>6</td>
<td>&lt; 50 %</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

Classification of heat recovery energy efficiency, non residential (according to EN 13053\textsuperscript{22})

The table below gives the energy efficiency $\eta_e$ at balance mass flow (1:1) as a basis for the H1 to H6 classification. The underlying thermal efficiency $\eta_t$, pressure drop of the Heat Recovery System $\Delta p_{HRS}$ and the electric coefficient of performance $\varepsilon$. Note that thermal efficiency is to be determined according to EN 308 at 25 °C exhaust and 5 °C supply air temperature (db). (ΔT = 20 K). Furthermore the energy efficiency—as opposed to the thermal efficiency—also takes into account the electricity consumption caused by the pressure drop of the heat exchanger.

Table 1-14. EN classification of energy efficiency for HR units (EN 13053)

<table>
<thead>
<tr>
<th>EN 13503 Class</th>
<th>energy efficiency $\eta_e$ (in %)</th>
<th>$\eta_t$ (in %)</th>
<th>$\Delta p_{HRS}$ in Pa</th>
<th>$\varepsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>71</td>
<td>75</td>
<td>2 x 280</td>
<td>19.5</td>
</tr>
<tr>
<td>H2</td>
<td>64</td>
<td>67</td>
<td>2 x 230</td>
<td>21.2</td>
</tr>
<tr>
<td>H3</td>
<td>55</td>
<td>57</td>
<td>2 x 170</td>
<td>24.2</td>
</tr>
<tr>
<td>H4</td>
<td>45</td>
<td>47</td>
<td>2 x 125</td>
<td>27.3</td>
</tr>
<tr>
<td>H5</td>
<td>36</td>
<td>37</td>
<td>2 x 100</td>
<td>26.9</td>
</tr>
<tr>
<td>H6</td>
<td>No requirement</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note that the efficiencies mentioned above apply to thermal efficiency under ‘dry conditions’.

Classification of humidity ratio (according to EN 13142)

(measured acc. EN13141-7 /-8, residential units)

Classification of the humidity ratio on the supply side of the unit, measured at reference- air volume flow and pressure difference and at nominal temperature difference (ΔT = 13 K)

(measured according EN13141-7 /-8)

### Table 1-15. EN classification of humidity ratio for HR units

<table>
<thead>
<tr>
<th>Class</th>
<th>Humidity ratio (measured on supply side at reference air volume flow and nominal ΔT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>≥ 90%</td>
</tr>
<tr>
<td>II</td>
<td>80 – 89%</td>
</tr>
<tr>
<td>III</td>
<td>70 – 79%</td>
</tr>
<tr>
<td>IV</td>
<td>60 – 69%</td>
</tr>
<tr>
<td>V</td>
<td>50 – 59%</td>
</tr>
<tr>
<td>VI</td>
<td>&lt; 50%</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

### Classification of power consumption in standby modes (according EN 13142)

**Table 1-16. EN classification of standby power for residential ventilation units**

<table>
<thead>
<tr>
<th>Class</th>
<th>Standby power consumption in fan-off mode</th>
<th>Standby power consumption in switched-off mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≤ 2 W</td>
<td>≤ 0.5 W</td>
</tr>
<tr>
<td>2</td>
<td>≤ 5 W</td>
<td>≤ 1 W</td>
</tr>
<tr>
<td>3</td>
<td>≤ 10 W</td>
<td>≤ 2 W</td>
</tr>
<tr>
<td>4</td>
<td>≤ 15 W</td>
<td>≤ 5 W</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 15 W</td>
<td>&gt; 5 W</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

### Classification of (face) air velocity inside the casing (according to EN 13053)

**Table 1-17 — Classes of average air velocity levels inside the casing**

<table>
<thead>
<tr>
<th>Class</th>
<th>air velocity in m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class V1</td>
<td>maximum 1.6</td>
</tr>
<tr>
<td>Class V2</td>
<td>&gt; 1.6 to 1.8</td>
</tr>
<tr>
<td>Class V3</td>
<td>&gt; 1.8 to 2.0</td>
</tr>
<tr>
<td>Class V4</td>
<td>&gt; 2.0 to 2.2</td>
</tr>
<tr>
<td>Class V5</td>
<td>&gt; 2.2 to 2.5</td>
</tr>
<tr>
<td>Class V6</td>
<td>&gt; 2.5 to 2.8</td>
</tr>
<tr>
<td>Class V7</td>
<td>&gt; 2.8 to 3.2</td>
</tr>
<tr>
<td>Class V8</td>
<td>&gt; 3.2 to 3.6</td>
</tr>
<tr>
<td>Class V9</td>
<td>&gt; 3.6</td>
</tr>
</tbody>
</table>

NOTE The air velocity in the unit has a large influence on energy consumption. The velocities are calculated for air velocity in AHU cross-section. The velocity is based on the face area of filter section of a unit, or if no filter is installed, it is based on the face area of the fan section.
## Classification of control types

Table 1-18 . EN classification of control types for ventilation units

<table>
<thead>
<tr>
<th>Control types</th>
<th>Parameter</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate Variations FRV</td>
<td>FRV 1</td>
<td>Fixed flow (no variation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRV 2</td>
<td>Multiple preset flow rates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRV 3</td>
<td>Variable flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Flow Rate Control FRC</td>
<td>FRC 1</td>
<td>None (no control or operation possible; runs constantly)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC 2</td>
<td>Manual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC 3</td>
<td>Time controlled (runs according a given time schedule)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC 4</td>
<td>Occupancy control (switched on/off or high/low on the basis of occupancy)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC 5</td>
<td>Presence control (flow rate controlled on basis of number of people)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC 6</td>
<td>IAQ sensor control (flow rate controlled on basis of IAQ sensors (CO2, VOC RV))</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Flow Balance Control FBC</td>
<td>FBC 1</td>
<td>No flow balance control</td>
<td></td>
</tr>
<tr>
<td>(only for units with heat recovery)</td>
<td>FBC 2</td>
<td>Flows are manually balanced</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FBC 3</td>
<td>Fan speed control (on basis of rpm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FBC 4</td>
<td>Dynamic flow control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Bypass Options BPO</td>
<td>BPO 1</td>
<td>No bypass option</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BPO 2</td>
<td>On or off</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BPO 3</td>
<td>Partly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BPO 4</td>
<td>By pass with Variable flow rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Bypass Flow rate Control BFC</td>
<td>BFC 1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BFC 2</td>
<td>Manual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BFC 3</td>
<td>Time controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BFC 4</td>
<td>Temperature controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BFC 5</td>
<td>Humidity controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Type of Frost Protection TFP</td>
<td>TFP 1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 2</td>
<td>Electric preheating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 3</td>
<td>Mixing air</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 4</td>
<td>Lowering air supply flow rate (or shut off)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 5</td>
<td>Increasing exhaust air flow rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 6</td>
<td>Bypass for defrosting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TFP 7</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
<tr>
<td>Combination with Fireplace</td>
<td>CRF</td>
<td>Suited for combination with room air dependent fireplace. Declaring this means that the system takes into account national and local building and combustion regulation on this topic.</td>
<td></td>
</tr>
<tr>
<td>Filter Indicator Type FIT</td>
<td>FIT 1</td>
<td>Time controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FIT 2</td>
<td>Pressure controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FIT 3</td>
<td>Optical control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FIT 4</td>
<td>Air volume controlled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Not classified</td>
<td></td>
</tr>
</tbody>
</table>

## Classification of sound power levels

Classification of “casing radiated sound power level” and “in-duct radiated sound power level” at declared maximum air volume flow, determined according EN13141 -7/ -8; classification according EN 13142.
### Table 1-19. EN classification of sound power levels for ventilation units

<table>
<thead>
<tr>
<th>Class</th>
<th>Casing radiated sound power level [dB(A)]</th>
<th>In-duct radiated sound power level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applicable for mechanical ventilation units for dwellings and single room</td>
<td>Applicable for mechanical ventilation units for dwellings (centralized systems)</td>
</tr>
<tr>
<td>1</td>
<td>&lt; 35</td>
<td>&lt; 35</td>
</tr>
<tr>
<td>2</td>
<td>35 – 40</td>
<td>35 – 40</td>
</tr>
<tr>
<td>3</td>
<td>40 – 45</td>
<td>40 – 45</td>
</tr>
<tr>
<td>4</td>
<td>45 – 55</td>
<td>45 – 55</td>
</tr>
<tr>
<td>5</td>
<td>55 – 65</td>
<td>55 – 65</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 65</td>
<td>&gt; 65</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

### Classification of sound-damping performance (sound transmitting resistance) $D_{n,e,w}$

Classification of sound-damping performance (sound transmitting resistance) $D_{n,e,w}$ for single room mechanical ventilation units, measured at reference air volume flow with a unit installed according manufacturer installation instructions and measured according EN ISO 10140:2010.

Classification according to EN 13142

### Table 1-20. EN classification of sound transmitting resistance for ventilation units

<table>
<thead>
<tr>
<th>Class</th>
<th>sound-damping performance (sound transmitting resistance) $D_{n,e,w}$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≥ 55</td>
</tr>
<tr>
<td>2</td>
<td>≥ 50</td>
</tr>
<tr>
<td>3</td>
<td>≥ 45</td>
</tr>
<tr>
<td>4</td>
<td>≥ 40</td>
</tr>
<tr>
<td>5</td>
<td>&lt; 40</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
</tr>
</tbody>
</table>
3 Subtask 1.2 - Measurement and other standards

3.1 Subtask 1.2.1 - Standards at European Community level

This part summarizes and gives detail of the most relevant existing standards for ventilation systems. The table below gives an overview of the standards discussed.

<table>
<thead>
<tr>
<th>Purpose of EN standard</th>
<th>Building type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential</td>
</tr>
<tr>
<td>Criteria for Indoor Environment</td>
<td>EN 15251: 2007</td>
</tr>
<tr>
<td>Determining performance criteria residential ventilation systems</td>
<td>EN 15665 : 2009</td>
</tr>
<tr>
<td>Calculation Ventilation rates</td>
<td>EN 15242 : 2007</td>
</tr>
<tr>
<td>Calculation Ventilation energy</td>
<td>EN 15241 : 2007</td>
</tr>
<tr>
<td>Rating and performance characteristics</td>
<td>prEN 13142 (rev V7) on components/products for residential ventilation</td>
</tr>
<tr>
<td>Inspection of installed systems</td>
<td>EN 14134</td>
</tr>
<tr>
<td></td>
<td>EN 12599 : 2000 (for AC : 2002) (standard is under revision)</td>
</tr>
</tbody>
</table>
3.1.1 EN 15251 Criteria Indoor Environment

**Full title:** EN 15251:2007 *Indoor environmental input parameters for design and assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics.* June 2007

This European Standard describes the indoor environmental parameters which have an impact on the energy performance of buildings, being: *indoor air quality, thermal environment, lighting* and *acoustics.* As such, this standard:

- specifies how to establish indoor environmental input parameters for building system design and energy performance calculations
- specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements
- specifies criteria for measurements that can be used if required to measure compliance by inspection
- specifies how different categories of criteria for indoor environment *can be* used (but is does not require certain criteria to be used; this is up to national regulations or individual project specifications)
- does not include criteria for local discomfort factors (like draught, radiant temperature asymmetry, vertical temperature gradient and floor surface temperatures).

This standard is applicable mainly in non-industrial buildings where criteria for indoor environment are set by human occupancy and where production processes does not have a major impact on indoor environment. The standard is thus applicable to the following building types:

- single family houses
- apartment buildings
- offices
- educational buildings
- health care buildings
- hotels and restaurants
- sports facilities
- wholesale and retail trade service buildings

This standard is important because it gives a detailed description of what is considered an acceptable or good indoor air quality (IAQ) and how it can be achieved. Where most of the national building codes go no further than descriptions like “the ventilation system must be able to achieve an IAQ that is not detrimental to the health of the inhabitants”, followed by requirements to the installed air exchange capacity of the ventilation system, this standard is a first European Standard that specifies the actual IAQ goal that is behind the requested air exchanges. For the purpose of Ecodesign Legislation and related energy declaration this is crucial because – as formulated in the introduction of this standard – “an energy declaration without a declaration related to the IAQ makes no sense”

**Informative Annex B**

Informative Annex B of this standard gives methods for specifying ventilation rates for IAQ-classes and different types of buildings.
Section B.1 of this Annex gives recommended design ventilation rates for non-residential buildings.

Section B.2 of the Annex describes the recommended design ventilation rates for residential buildings.

The following tables give an overview of the recommended ventilation rates for different IAQ-categories.

**Recommended ventilation rates non residential buildings**

Table 1-22 Examples of recommended ventilation rates for non-residential buildings for three categories of pollution from buildings itself. Rates are given per person (for diluting bio effluents from people) and per m² floor area (for dilution of buildings emissions) (acc. Table B.3 of annex B).

<table>
<thead>
<tr>
<th>IAQ category</th>
<th>Airflow for dilution bio effluents</th>
<th>Airflow for dilution building emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airflow per person l/s/pp</td>
<td>Very low polluting building l/s/m²</td>
</tr>
<tr>
<td>I</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>0.35</td>
</tr>
<tr>
<td>III</td>
<td>4</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 1-23 Examples of recommended ventilation rates for different types of non-residential buildings with default occupancy density for three categories of pollution from buildings itself. If smoking is allowed the last column gives the additional required ventilation rates (acc. Table B.2 of annex B).

<table>
<thead>
<tr>
<th>Type of building or space</th>
<th>IAQ category</th>
<th>Floor area in m²/pp</th>
<th>qP</th>
<th>qB</th>
<th>qtot</th>
<th>qB</th>
<th>qtot</th>
<th>qB</th>
<th>qtot</th>
<th>Add when smoking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single office</td>
<td>I</td>
<td>10</td>
<td>1.0</td>
<td>0.5</td>
<td>1.5</td>
<td>1.0</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>10</td>
<td>0.7</td>
<td>0.3</td>
<td>1.0</td>
<td>0.7</td>
<td>1.4</td>
<td>1.4</td>
<td>2.1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>10</td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
<td>0.4</td>
<td>0.8</td>
<td>0.8</td>
<td>1.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Land-scaped office</td>
<td>I</td>
<td>15</td>
<td>0.7</td>
<td>0.5</td>
<td>1.2</td>
<td>1.0</td>
<td>1.7</td>
<td>2.0</td>
<td>2.7</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>15</td>
<td>0.5</td>
<td>0.3</td>
<td>0.8</td>
<td>0.7</td>
<td>1.2</td>
<td>1.4</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>15</td>
<td>0.3</td>
<td>0.2</td>
<td>0.5</td>
<td>0.4</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Conference room</td>
<td>I</td>
<td>2</td>
<td>5.0</td>
<td>0.5</td>
<td>5.5</td>
<td>1.0</td>
<td>6.0</td>
<td>2.0</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2</td>
<td>3.5</td>
<td>0.3</td>
<td>3.8</td>
<td>0.7</td>
<td>4.2</td>
<td>1.4</td>
<td>4.9</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>2</td>
<td>2.0</td>
<td>0.2</td>
<td>2.2</td>
<td>0.4</td>
<td>2.4</td>
<td>0.8</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Auditorium</td>
<td>I</td>
<td>0.75</td>
<td>15</td>
<td>0.5</td>
<td>15.5</td>
<td>1.0</td>
<td>16</td>
<td>2.0</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>0.75</td>
<td>10.5</td>
<td>0.3</td>
<td>10.8</td>
<td>0.7</td>
<td>11.2</td>
<td>1.4</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>0.75</td>
<td>6.0</td>
<td>0.2</td>
<td>6.2</td>
<td>0.4</td>
<td>6.4</td>
<td>0.8</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Restaurant</td>
<td>I</td>
<td>1.5</td>
<td>7.0</td>
<td>0.5</td>
<td>7.5</td>
<td>1.0</td>
<td>8.0</td>
<td>2.0</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>1.5</td>
<td>4.9</td>
<td>0.3</td>
<td>5.2</td>
<td>0.7</td>
<td>5.6</td>
<td>1.4</td>
<td>6.3</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>1.5</td>
<td>2.8</td>
<td>0.2</td>
<td>3.0</td>
<td>0.4</td>
<td>3.2</td>
<td>0.8</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Class room</td>
<td>I</td>
<td>2.0</td>
<td>5.0</td>
<td>0.5</td>
<td>5.5</td>
<td>1.0</td>
<td>6.0</td>
<td>2.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2.0</td>
<td>3.5</td>
<td>0.3</td>
<td>3.8</td>
<td>0.7</td>
<td>4.2</td>
<td>1.4</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>2.0</td>
<td>2.0</td>
<td>0.2</td>
<td>2.2</td>
<td>0.4</td>
<td>2.4</td>
<td>0.8</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>
where \(qp\) = ventilation rate for occupancy (bio effluents) in [l/s/m²]

\(qB\) = ventilation rate for emissions from building in [l/s/m²]

\(q\text{tot}\) = total ventilation rate of the room in [l/s/m²]

**Explanation**

The values in the table are based on complete mixing in the room (concentration of pollutants is equal in exhaust and in occupied zone). Ventilation rates can be adjusted according to the ventilation efficiency if the performance of air distribution differs from complete mixing and can be reliably proven (EN 13779). The ventilation required for smoking is based on the assumption that 20% of the occupants are smokers and smoke 1.2 cigarettes per hour. For a higher rate of smoking, the ventilation rates should be increased proportionally. The ventilation rates for smoking are based on comfort, not on health criteria.

**Low-polluting building**

A building is called low-polluting or very low-polluting, when the majority of building materials used for finishing the interior surfaces meet the national of international criteria of low-polluting or very low-polluting materials. See the example in Annex C of this standard.

**CO\(_2\) concentrations**

The required ventilation rates can also be calculated based on a mass balance equation for the CO\(_2\) concentration (acc EN 13779) taking into account the outdoor CO\(_2\) concentration. Recommended criteria for the CO\(_2\) – calculation are given in table 1.2.2.3 (see below). The listed CO\(_2\) values can also be used for demand controlled ventilation. If the ventilation rate is controlled automatically (DCV) the maximum design ventilation rate has to correspond to the calculated maximum concentration of pollutant.

**Table 1-24 Examples of recommended CO2 concentrations above outdoor concentrations for energy calculations and demand control (acc. Table B.4 of annex B)**

<table>
<thead>
<tr>
<th>IAQ category</th>
<th>Corresponding CO2 concentration above outdoors in PPM for energy calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>350</td>
</tr>
<tr>
<td>II</td>
<td>500</td>
</tr>
<tr>
<td>III</td>
<td>800</td>
</tr>
<tr>
<td>IV</td>
<td>&gt; 800</td>
</tr>
</tbody>
</table>
Recommended ventilation rates residential buildings

The recommendations in annex B for residential ventilations relate to both the direction of the ventilation air flow and the ventilation rate.

Air flow direction

It is recommended that all habitable rooms of a dwelling (living room, bedrooms, study etc.) are directly supplied with fresh air from outside, and that polluted air in wet room or utility rooms (bathroom, kitchen, toilets) are directly expelled to the outdoor atmosphere. Common spaces (corridor, staircase, etc) may be ventilated with overflow air from the habitable rooms, meaning that air is transferred from the living spaces to the common spaces and then expelled through the wet or utility rooms. This ultimately means that the supply air for the wet rooms is the exhaust air from the habitable rooms, after having passed the common spaces.

(Some national regulation consider the overall ventilation rate in the building (air changes per hour or ach.), while others emphasize the minimum fresh air supply into the habitable rooms. This addition allows for a better control of the indoor air quality in the rooms where the real occupation is).

Recommended Air flow rates (in case of overflow principle)

Table 1-25 Example of ventilation rates for residences (assuming complete mixing and at continuous operation of ventilation during occupied hours) (acc. Table B.5 of annex B)

<table>
<thead>
<tr>
<th>Category</th>
<th>Total air exchange rate house</th>
<th>Air exchange rate habitable rooms (living, bedrooms, study)</th>
<th>Related exhaust airflow from wet rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per m² dwelling</td>
<td>Per person (at ceiling height of 2.5m)</td>
<td>Per m²</td>
</tr>
<tr>
<td>I</td>
<td>0.49 m²</td>
<td>0.7 m³</td>
<td>1.0 m³</td>
</tr>
<tr>
<td>II</td>
<td>0.42 m²</td>
<td>0.6 m³</td>
<td>1.0 m³</td>
</tr>
<tr>
<td>III</td>
<td>0.35 m²</td>
<td>0.5 m³</td>
<td>0.6 m³</td>
</tr>
</tbody>
</table>

Example of procedure for determining ventilation rates

1. Calculate total ventilation rate dwelling based on
   a. Total floor area dwelling (column 1)
   b. Number of occupants or total surface of all habitable rooms (column 2 or 3)
2. Select the higher value from above a) of b) for the total ventilation rate of the dwelling
3. Adjust the exhaust air flows from the kitchen, bathroom and toilets (column 4) accordingly
4. Outdoor air should be supplied primarily to habitable rooms

Recommended ventilation rates during un-occupied hours

For Non-Residential Buildings, an outdoor air flow equivalent to 2 air volumes of the ventilated space shall be delivered to the space before occupancy (e.g. if the ventilation rate is 2 ach, the ventilation...
is started one hour before the occupancy). Infiltration can be calculated as a part of this ventilation (leakage assumptions must be described).

Instead of pre-start of the ventilation system, buildings can be ventilated during unoccupied periods with lower ventilation rates than during occupied hours. The minimum ventilation rate shall be defined based on building type and pollution load of the spaces. A minimum value of 0.1 to 0.2 l/s/m² is recommended if national requirements are not available.

For *residential buildings* a ventilation rate between 0.05 and 0.1 l/s/m² is recommended if no value is given on a national level.

*Recommended criteria for (de-)humidification*

If humidification or dehumidification is used, the values in the table below are recommended as design values. Usually (de-)humidification is needed only in special buildings like museums, some health care facilities, process control, paper industry etc.. Note that RH is Relative Humidity.

**Table 1-26  Example of recommended design criteria for the humidity in occupied spaces if (de-)humidification systems are installed (acc table B.6 annex B)**

<table>
<thead>
<tr>
<th>Type of building/space</th>
<th>Category</th>
<th>Design limit value RH for dehumidification in [%]</th>
<th>Design limit value RH for humidification in [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaces where humidity criteria are set by human occupancy <em>(Special spaces (e.g. museums) may require other limits)</em></td>
<td>I</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>&gt;70</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

**Informative Annex E**

For the design of ventilation systems, the required maximum allowable sound levels shall be specified in the design documents based on national requirements. If these are not available the recommended values listed in this standard (Annex E) may be applied if appropriate. Noise from the ventilation (or HVAC-) system may disturb the occupants and prevent the intended use. The noise in a space can be evaluated using A-weighted equivalent sound pressure, in decibel dB(A).

The table below is based on noise from service equipment and not on outside noise. These figures should be used to limit the sound pressure level from mechanical equipment and to set sound insulation requirements for the noise from adjacent rooms and buildings.

**Table 1-27  . Examples of recommended design A-weighted sound pressure levels (EN 15251, Table E.1, annex E)**

<table>
<thead>
<tr>
<th>Building</th>
<th>Type of space</th>
<th>Sound pressure level [dB(A)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typical range</td>
</tr>
<tr>
<td>Residential</td>
<td>Living room</td>
<td>25 to 40</td>
</tr>
<tr>
<td></td>
<td>Bed room</td>
<td>20 to 35</td>
</tr>
<tr>
<td>Child care institutions</td>
<td>Nursery schools</td>
<td>30 to 45</td>
</tr>
<tr>
<td></td>
<td>Day nurseries</td>
<td>30 to 45</td>
</tr>
<tr>
<td>Places of assembly</td>
<td>Auditoriums</td>
<td>30 to 35</td>
</tr>
<tr>
<td></td>
<td>Libraries</td>
<td>28 to 35</td>
</tr>
<tr>
<td></td>
<td>Cinemas</td>
<td>30 to 35</td>
</tr>
<tr>
<td></td>
<td>Court rooms</td>
<td>30 to 40</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Noise Levels</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Museums</td>
<td>28 to 35</td>
<td>30</td>
</tr>
<tr>
<td>Commercial</td>
<td>Retail shops</td>
<td>35 to 50</td>
</tr>
<tr>
<td></td>
<td>Department stores</td>
<td>40 to 50</td>
</tr>
<tr>
<td></td>
<td>Supermarkets</td>
<td>40 to 50</td>
</tr>
<tr>
<td></td>
<td>Computer rooms, large</td>
<td>40 to 60</td>
</tr>
<tr>
<td></td>
<td>Computer rooms small</td>
<td>40 to 50</td>
</tr>
<tr>
<td>Hospitals</td>
<td>Corridors</td>
<td>35 to 45</td>
</tr>
<tr>
<td></td>
<td>Operating theatres</td>
<td>30 to 48</td>
</tr>
<tr>
<td></td>
<td>Wards</td>
<td>25 to 35</td>
</tr>
<tr>
<td></td>
<td>Bed rooms night time</td>
<td>20 to 35</td>
</tr>
<tr>
<td></td>
<td>Bed rooms daytime</td>
<td>25 to 40</td>
</tr>
<tr>
<td>Hotels</td>
<td>Lobbies</td>
<td>30 to 45</td>
</tr>
<tr>
<td></td>
<td>Reception rooms</td>
<td>30 to 45</td>
</tr>
<tr>
<td></td>
<td>Hotel rooms night time</td>
<td>25 to 35</td>
</tr>
<tr>
<td></td>
<td>Hotel rooms daytime</td>
<td>30 to 40</td>
</tr>
<tr>
<td>Offices</td>
<td>Small offices</td>
<td>30 to 40</td>
</tr>
<tr>
<td></td>
<td>Conference rooms</td>
<td>30 to 40</td>
</tr>
<tr>
<td></td>
<td>Landscaped offices</td>
<td>35 to 45</td>
</tr>
<tr>
<td></td>
<td>Office cubicles</td>
<td>35 to 45</td>
</tr>
<tr>
<td>Restaurants</td>
<td>Cafeterias</td>
<td>35 to 50</td>
</tr>
<tr>
<td></td>
<td>Restaurants</td>
<td>35 to 50</td>
</tr>
<tr>
<td></td>
<td>Kitchens</td>
<td>40 to 60</td>
</tr>
<tr>
<td>Schools</td>
<td>Classrooms</td>
<td>30 to 40</td>
</tr>
<tr>
<td></td>
<td>Corridors</td>
<td>35 to 50</td>
</tr>
<tr>
<td></td>
<td>Gymnasiums</td>
<td>35 to 45</td>
</tr>
<tr>
<td></td>
<td>Teacher rooms</td>
<td>30 to 40</td>
</tr>
<tr>
<td>Sport</td>
<td>Covered sport stadiums</td>
<td>35 to 50</td>
</tr>
<tr>
<td></td>
<td>Swimming baths</td>
<td>40 to 50</td>
</tr>
<tr>
<td>General</td>
<td>Toilets</td>
<td>40 to 50</td>
</tr>
<tr>
<td></td>
<td>Cloakrooms</td>
<td>40 to 50</td>
</tr>
</tbody>
</table>

Please note that the noise levels relate to the noise measured in building spaces, not to the sound pressure measured directly at the ventilation unit.

**3.1.2 EN 13779 Performance requirements non-residential ventilation**

**Full title:** EN 13799: 2007, Ventilation for non-residential buildings; Performance requirements for ventilation and room-conditioning systems. May 2007

This standard provides guidance especially for designers, building owners and users, on ventilation, air-conditioning and room conditioning systems in order to achieve a comfortable and healthy indoor environment in all seasons with acceptable installation and running costs. The standard focuses on the system-aspects for typical applications and covers the following:

1. Aspects important to achieve and maintain a good energy performance in the systems, without any negative impact on the quality of the internal environment
2. Relevant parameters of the indoor environment
3. Definitions of data design assumptions and performances

(Natural ventilation systems are not covered by this standard).
The standard applies to the design and implementation of mechanical ventilation and room conditioning systems for non-residential buildings subject to human occupancy (excluding applications like industrial processes). It focuses on the definitions of the various parameters that are relevant for such systems.

Where EN 15251 gives general guidance related to indoor environmental design criteria, this standard focuses on the design criteria for mechanical ventilation and room conditioning systems for non-residential buildings. As such it contains more detailed design criteria for the ventilation systems that are topic of this study.

Chapter 5 of this standard describes what type of information & design specifications are necessary to be able to design a proper ventilation and/or air-conditioning system.

Chapter 6 deals with classification of the various design parameters, making is more easy to specify what quality is requested for the different IAQ- and system performance parameters.

Finally chapter 7 explains how these performance parameters can be met and on what design assumptions it is founded. (Most of these classifications and design assumptions are also described in paragraph 1.1.3 of this report)

**Informative Annex A**

Informative Annex A of this standard contains “Guidelines for Good Practice”. This annex reveals a lot of detailed and practical information useful for the design of mechanical ventilation and/or air-conditioning systems for buildings subject to human occupancy. The Guideline for Good Practice gives guidance concerning the following topics:

**A.2 Intake and exhaust openings**

This paragraph of the annex contains guidelines for:
- classification of the extract or exhaust air (ETA1, ETA2, ETA3 and ETA4)
- the location of air intake openings
- the location of the exhaust openings (airflow rate, air velocity, distance to adjacent buildings, etc)
- distance between intake and exhaust openings (among others: dilution factor \( f \leq 0.01 \), with
  \[
  f = \sqrt{\frac{q_v}{C_1 l + C_2 \Delta h}}
  \]

  where:
  - \( f \) = dilution factor
  - \( q_v \) = discharge airflow rate in [l/s]
  - \( l \) = length of a direct line between inlet and outlet provision in [m]
  - \( \Delta h \) = difference in height between inlet and outlet provision in [m]
  - \( C_1, C_2 \) = dilution coefficients, depending on situation

**A.3 Outdoor air quality considerations and the use of air filters**

A.3.1 Contains proposal for a method on how to classify the outdoor air quality (see table with examples of key air pollutants and their guideline values)
Table 1-28 . Key outdoor air pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging time</th>
<th>Guideline value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur dioxide SO$_2$</td>
<td>24 h</td>
<td>125 μg/m$^3$</td>
<td>WHO 1999</td>
</tr>
<tr>
<td>Sulphur dioxide SO$_2$</td>
<td>1 year</td>
<td>50 μg/m$^3$</td>
<td>WHO 1999</td>
</tr>
<tr>
<td>Ozone O$_3$</td>
<td>8 h</td>
<td>120 μg/m$^3$</td>
<td>WHO 1999</td>
</tr>
<tr>
<td>Nitrogen dioxide NO$_2$</td>
<td>1 year</td>
<td>40 μg/m$^3$</td>
<td>WHO 1999</td>
</tr>
<tr>
<td>Nitrogen dioxide NO$_2$</td>
<td>1 h</td>
<td>200 μg/m$^3$</td>
<td>WHO 1999</td>
</tr>
<tr>
<td>Paticulate matter PM$_{10}$</td>
<td>24 h</td>
<td>50 μg/m$^3$ (max 35 days exceeding)</td>
<td>99/30/EC</td>
</tr>
<tr>
<td>Paticulate matter PM$_{10}$</td>
<td>1 year</td>
<td>40 μg/m$^3$</td>
<td>99/30/EC</td>
</tr>
</tbody>
</table>

Step 1. Determine key pollutants

Step 2  Search for available actual and periodical measurement data of outdoor AQ (see http://air-climate.eionet.europa.eu/databases/airbase/ )

Step 3. Classify pertaining outdoor air

A.3.2  Gives recommendations for the filter classes to be used on the basis of the actual outdoor AQ and the requested indoor AQ.

Table 1-29 . Recommended minimum filter classes

<table>
<thead>
<tr>
<th>Outdoor Air Quality</th>
<th>Indoor Air Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IDA 1 (High)</td>
</tr>
<tr>
<td>ODA 1 (pure air)</td>
<td>F9</td>
</tr>
<tr>
<td>ODA 2 (dust)</td>
<td>F7 + F9</td>
</tr>
<tr>
<td>ODA 3 (very high conc. of dust or gases)</td>
<td>F7 + GF + F9</td>
</tr>
</tbody>
</table>

GF = Gas Filter (Carbon filter and/or chemical filter)

A.4  Heat recovery: pressure conditions to avoid contaminant transfer

This part of the annex gives information on the preferred arrangement of fans in a mechanical ventilation unit with heat recovery, for the purpose of achieving the right pressure conditions in the unit to avoid contaminant transfer from the extract air channel to the supply air channel.

A.5  Removal of extract air

This paragraph gives guidelines on how extract air should be removed from a building depending the extract air qualities. Ducts should be designed and maintained in accordance with EN 12097, and removed from the building in accordance with the following requirements:

Table 1-30 . Recommendations on removal of extract air

<table>
<thead>
<tr>
<th>ETA category</th>
<th>Ducts</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA 1</td>
<td>Extract are can be collected into a common ducts</td>
</tr>
<tr>
<td>ETA 2</td>
<td>Extract are can be collected into a common ducts</td>
</tr>
</tbody>
</table>
Paragraph A.5 also recommends extract air rates from kitchens and hygiene rooms in case no national guidelines are available.

Table 1-31 . Design values for air extract rates

<table>
<thead>
<tr>
<th>Kind of use</th>
<th>Typical range</th>
<th>Default value for design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>simple use (e.g. kitchen for hot drinks)</td>
<td>&gt; 20 l/s</td>
<td>30 l/s</td>
</tr>
<tr>
<td>professional use</td>
<td>To be determined in situ</td>
<td>To be determined in situ</td>
</tr>
<tr>
<td>Toilet/Washroom*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per closet or urinal</td>
<td>&gt; 6.7 l/s</td>
<td>15 l/s</td>
</tr>
<tr>
<td>per floor area</td>
<td>&gt; 1.4 l/s</td>
<td>3 l/s</td>
</tr>
</tbody>
</table>

* In use for at least 50% of the time. With shorter running times higher rates are needed. Lower values are possible with direct air extract at the closet (typical value: 3 to 1 l/s per closet or urinal)

A.6 Re-use of extract air and the use of transfer air.

In case the ventilation system is combined with an air- heating of cooling system, recirculation of air is an important design parameter. Based on the classification of exhaust and extract air, the following re-use of the air is recommended:

Table 1-32 . Design values for air extract rates

<table>
<thead>
<tr>
<th>ETA category</th>
<th>Comment concerning the possible re-use of the air</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA 1</td>
<td>This air is suitable for recirculation and transfer air</td>
</tr>
<tr>
<td>ETA 2</td>
<td>This air is not suitable for recirculation, but it can be used for transfer air into toilets, wash rooms, garages and other similar places</td>
</tr>
<tr>
<td>ETA 3</td>
<td>This air is not suitable for recirculation or transfer air</td>
</tr>
<tr>
<td>ETA 4</td>
<td>This air is not suitable for recirculation or transfer air</td>
</tr>
</tbody>
</table>

A.7 Thermal insulation of the system

Guideline: All ducts, pipes and units with a significant temperature difference between the medium and the surrounding should be insulated against heat transfer, in a way that:
- condensation does not occur in the construction itself nor on the surface
- the insulation is protected against damage
- proper cleaning of ducts is still possible
- production and disposal causes as little harm to the environment as possible
A.8 Air-tightness of the system

This paragraph gives guidance to the design, the classification and testing of the air tightness of the ventilation system.

The air-tightness class of a ventilation system should be selected so that neither infiltration into an installation operating at negative pressure, nor exfiltration from an installation operating at positive pressure, exceeds a defined percentage of the total system flow rate under operating conditions (this percentage should normally be less than 2%, corresponding class B according to EN 12237 and EN 1507).

Guidance for estimating leakage rates and its influence on air flows and energy consumption is presented in EN 15242 and EN 15241.

A.9 Airtightness of the building

The air tightness of the building should be suitable for the kind of ventilation system installed.

Buildings with balanced ventilation systems (mechanical supply and extract air) should be as airtight as possible with a $n_{50}$ value below 1.0 /h for high buildings (above 3 stories) and below 2.0 /h in case of low buildings. The method to measure $n_{50}$-values is specified in ISO 9972 or EN13829. The values given here describe the overall air tightness of the building structure. Accordingly all windows, doors and intentional openings as well as supply and extract air vents should be closed during such measurements.

A.10 Pressure conditions within the system and the building

The relative pressure within the building, the different spaces and the ventilation system should be designed so that spreading of odours and impurities in unallowable concentrations is prevented.

In the Building

In situations with no special requirements or emissions, ventilation systems should be designed for neutral pressure conditions in the building. The pressure difference from indoors to outdoors or between rooms should not exceed 20 Pa.

In areas where expected outdoor pollution is high (ODA2 to ODA3) or in areas where under pressure can cause increased concentration of e.g. radon, the under pressure indoors should be designed to a minimum. Alternatively the building should be designed for slight overpressure (in severe climates it must be checked that internal overpressure doesn’t cause moisture damage).

High-rise buildings should be divided into separate ventilation zones with a specified maximum height. The vertical distance (D) between the lowest and the highest intake in the same zone should not exceed the following:

$$D_{\text{max}} = 600 / (\vartheta_a - \vartheta_{\text{out;min}})$$

, where

- $D_{\text{max}}$ = the maximal vertical distance in [m]
- $\vartheta_a$ = the air temperature in the room in [$^\circ$C]
- $\vartheta_{\text{out;min}}$ = is the design outdoor temperature for winter condition in [$^\circ$C]
Alternatively, the systems can be equipped with constant flow dampers or similar devices, which automatically compensate for the stack effect.

In the Air Handling Unit (AHU)

Pressure drops for filters and filter sections, for dampers, damper sections and mixing sections in air handling units should be specified in accordance with EN 13053. For systems with variable airflow, additional requirements are specified for a) maximum variation for pressure difference and the ratio of exhaust and supply airflows, and b) pressure monitoring.

The influence of variations of pressure drop on the airflows, due to pollution (e.g. dust accumulation) or different damper positions, should be determined and estimated. No significant changes in the airflows (generally not more than ± 10% of the total supply or exhaust airflow) or to the pressure conditions in the building should be allowed due to changes in the pressure drops in the AHU and the system.

A.11 Demand controlled ventilation

Practical experience shows that adapting the ventilation to the actual requirements can very often substantially reduce the energy consumption.

In situations with variable demand, the ventilation system can be operated in such a way that given criteria in the room are met. In rooms for the occupancy of people, the following sensors can be adopted for ventilation control according actual demand:

- movement sensors
- counting sensors
- CO₂ sensors
- mixed gas sensors
- infrared sensors

In rooms with known emissions, the concentration of the most important pollutant can be used as input signal. Further information and references are available in prEN 15232.

But also more simple methods are available to adjust the ventilation according demand, amongst which:

- manual switch
- combination with light switch
- time controlled switch
- switch at the window

A.12 Low power consumption

The specific fan power SFP depends on the pressure drop, the efficiency of the fan and the design of the motor. The pressure drop of components in the system should be as low as practicable to meet the performance requirements of the system.

In the table below examples of pressure drops are given; these figures may be used as default values if such data is not available (real product data is of course preferred).

Annex D of this standard EN13779 gives further guidance for assessing the power efficiency of fans and air handling units.
### Table 1-33 : Examples for pressure drops for specific components in air handling systems (acc. table A.8 of EN13779)

<table>
<thead>
<tr>
<th>Component</th>
<th>Pressure losses in [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Ductwork supply</td>
<td>200</td>
</tr>
<tr>
<td>Ductwork exhaust</td>
<td>100</td>
</tr>
<tr>
<td>Heating coil</td>
<td>40</td>
</tr>
<tr>
<td>Cooling coil</td>
<td>100</td>
</tr>
<tr>
<td>Heat recovery unit H3</td>
<td>100</td>
</tr>
<tr>
<td>Heat recovery unit H2 – H1</td>
<td>200</td>
</tr>
<tr>
<td>Humidifier</td>
<td>50</td>
</tr>
<tr>
<td>Air washer</td>
<td>100</td>
</tr>
<tr>
<td>Air filter F5 – F7 per section</td>
<td>100</td>
</tr>
<tr>
<td>Air filter F8 – F9 per section</td>
<td>150</td>
</tr>
<tr>
<td>HEPA* filter</td>
<td>400</td>
</tr>
<tr>
<td>Gas filter</td>
<td>100</td>
</tr>
<tr>
<td>Silencer</td>
<td>30</td>
</tr>
<tr>
<td>Terminal device</td>
<td>30</td>
</tr>
<tr>
<td>Air inlet and outlet</td>
<td>20</td>
</tr>
</tbody>
</table>

Class H1 – H3 according to EN 13053
Final pressure drop before replacement

*HEPA is High-Efficiency Particulate Air (filter)

### A.13 Space requirements for components and systems

This paragraph gives initial guidance for the space requirements necessary to facilitate easy cleaning, maintenance and repair operations.

### A.14 Hygienic and technical aspects to installation and maintenance

All components installed in a ventilation system and room conditioning system should be suitable, i.e. corrosion resistant, easy to clean, accessible and hygienically unobjectionable. Moreover, they should not encourage the growth of micro-organisms.

The basic requirements for ductwork components to facilitate maintenance are given in EN12097. But this standard also applied to all ductwork components and other equipment of ventilation systems.

### A.15 Ventilation rates for indoor air

This paragraph gives guidelines for minimum ventilation rates.
Table 1-34 . Rates of outdoor or transferred air per unit floor area (net area) for rooms not designed for human occupancy

<table>
<thead>
<tr>
<th>IDA Category</th>
<th>Rate of outdoor or transferred air in [ l/s/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical range</td>
</tr>
<tr>
<td>IDA 1 *)</td>
<td>*)</td>
</tr>
<tr>
<td>IDA 2 &gt; 0.7</td>
<td>&gt; 0.7</td>
</tr>
<tr>
<td>IDA 3 0.35 – 0.7</td>
<td>0.55</td>
</tr>
<tr>
<td>IDA 4 &lt; 0.35</td>
<td>&lt; 0.35</td>
</tr>
</tbody>
</table>

*) For IDA 1 this method is not sufficient

Outdoor air rates by CO₂ level

CO₂ levels may be used for the design of a demand controlled system. Typical ranges and default values are in the table below

Table 1-35 . CO₂-levels in rooms

<table>
<thead>
<tr>
<th>IDA Category</th>
<th>CO₂ level above level of outdoor air in [ppm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical range</td>
</tr>
<tr>
<td>IDA 1</td>
<td>≤ 400</td>
</tr>
<tr>
<td>IDA 2</td>
<td>400 - 600</td>
</tr>
<tr>
<td>IDA 3</td>
<td>600 – 1000</td>
</tr>
<tr>
<td>IDA 4</td>
<td>&gt; 1000</td>
</tr>
</tbody>
</table>

See also paragraph 1.1.5.4

Outdoor air rates per person

The table below presents recommended minimum air rates per person.

Table 1-36 . Rates of outdoor air per person CO₂-levels in rooms

<table>
<thead>
<tr>
<th>IDA Category</th>
<th>Rate of outdoor air per person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-smoking area</td>
</tr>
<tr>
<td></td>
<td>Typical range</td>
</tr>
<tr>
<td>IDA 1</td>
<td>&gt;15</td>
</tr>
<tr>
<td>IDA 2</td>
<td>10 – 15</td>
</tr>
<tr>
<td>IDA 3</td>
<td>6 – 10</td>
</tr>
<tr>
<td>IDA 4</td>
<td>&lt; 6</td>
</tr>
</tbody>
</table>

A.16 Acoustic environment

See Table 1.2.2-6 “Examples of recommended design A-weighted sound pressure levels”
A.17 Internal loads
This paragraph gives information about the heat load caused by persons, lighting and equipment. For the design of HVAC Systems it is essential to clearly define realistic internal loads with their time schedule.

An overestimation of internal loads may result in unnecessary high investment and running costs, whilst an underestimation may result in too high room temperatures in the cooling season.

Informative Annex D
This annex describes a method for assessing the electric power consumption of fans and air handling units (AHU) in ventilation systems for buildings.

D.2 SFP of an entire building
The SFP for an entire building is defined as follows: “The combined amount of electric power, consumed by all he fans in the air distribution system divided by the total airflow rate through the building under design load conditions in [W/m³/s]:

\[
SFP = \frac{(P_{sf} + P_{ef})}{q_{max}}
\]

where

\[
SFP = \text{specific fan power demand in [W/m³/s]}
\]

\[
P_{sf} = \text{the total fan power of the supply air fans at the design air flow rate in [W]}
\]

\[
P_{ef} = \text{the total fan power of the extract air fans at the design air flow rate in [W]}
\]

\[
q_{max} = \text{the design airflow rate through the building, which should be the extract air flow in [m³/s]}
\]

Design load condition is the condition when the filter drop is the average of the clean filter and recommended maximum (dirty filter) pressure drops. Also the pressure drops for other components (heat exchanger, cooling coil, humidifier) is the mean of start- and end values.

D.3 SFP of individual air handling units or fans (SPF_E)
To enable the designers of building projects to quickly determine whether a given air handling unit will comply with the requirements on power efficiency, a SPF_E for the individual fan or AHU has been defined.

In a constant air volume flow system, the demands on SPF_E shall be met at the design airflow and at design external pressure drop (pressure drop in ducting). In a variable air volume flow system, the demands on SPF_E shall be met at the partial air flow and the related external pressure drop. If data on partial air flow rate and related external pressure is not specified, 65% of the maximum design airflow rate and external pressure will be used.

The specific fan power, SPF_E is the total amount of electric power in W, supplied to the fans in the AHU, divided by the largest of either supply air or extract air flow rates (i.e. not the outdoor air or the exhaust air flow rates) expressed in [m³/s] under design load conditions.
D.3.2 SFP of heat recovery AHU:

\[ SFP_E = \frac{P_{sfm} + P_{efm}}{q_{max}} \]

Where

- \( SFP_E \) = specific fan power of a heat recovery AHU in [W/m³/s]
- \( P_{sfm} \) = the total fan power of the supply air fans at the design air flow rate in [W]
- \( P_{efm} \) = the total fan power of the extract air fans at the design air flow rate in [W]
- \( q_{max} \) = the design airflow rate through the AHU (largest of supply or extract air flow rate) in [m³/s]

D.3.3 SFP of separate supply air or extract air handling units (AHU's) and individual fans

\[ SFP_E = \frac{P_{mains}}{q} \]

Where

- \( SFP_E \) = specific fan power of the AHU / fan in [W/m³/s]
- \( P_{mains} \) = the power supplied to the fans in the AHU in [W]
- \( q \) = the design airflow rate through the AHU / fan in [m³/s]

3.1.3 CEN/TR 14788 Design and dimensions residential ventilation


This Technical Report specifies recommendations for the performance and design of ventilation systems which serve singe family, multi family and apartment type dwellings, both during summer and winter. It is of particular interest to architects, designers, builders and those involved with implementing national, regional and local regulations and standards.

Four basic ventilation strategies are covered: natural ventilation, fan assisted supply air ventilation, fan assisted exhaust air ventilation and fan assisted balanced air ventilation, including combinations of these systems.

The Technical Report describes in detail the need for ventilation in dwellings (Chapter 5) and the design assumptions that need to be specified in order to be able to design a proper working ventilation system (Chapter 6), such as air-tightness of the building, outdoor meteorological conditions, pollutant level outdoors, outdoor noise levels, noise characteristics of the building, etc.

Chapter 7 deals with the performance requirements for ventilation systems and represents - together with Chapter 8 that covers the design rules for ventilation systems - the core of this Technical Report on residential systems. The key elements of these two chapters will be summarized here.

§ 7.1 Ventilation air volume rate

General
For all residential ventilation systems it is necessary to specify ventilation air volume flow rates such that assumed or predicted concentrations of certain known indoor pollutants are not exceeded. The ventilation air volume flow rate is specified in many different ways in the regulations and standards of different countries and unfortunately this TR does not give an overview of the different national regulations, nor does it give the common denominator of these national regulations. However, this Technical Report (TR) does describe a method of establishing the required ventilation air volume flow rate by calculation, using pollutant production rates and defined indoor and outdoor air conditions. Examples of the ventilation air flow rates resulting from such calculations are given in Annex F of this TR.

Pollutant groups

The most common pollutants occurring in dwellings may be grouped into three different groups which can lead to different but complementary ventilations strategies:

Group of background pollutants

The first type includes a large number of pollutants emitted by materials, furnishings and products used in the dwelling. They are generally not perceivable by the occupants and their sources are at a relatively low but continuous rate.

The second type includes metabolic products from occupants mainly represented by water vapor and carbon dioxide from respiration, and odours.

Group of specific pollutants

This group is mainly represented by water vapor, carbon dioxide and odours. Their production is related to specific human activities in the dwelling such as cooking, washing, bathing etc. whose duration is relatively short, resulting in high pollutant production in a specific location of the dwelling.

Group of combustions products

Combustion products from fuel burning appliances for space and water heating, the most dangerous of which is carbon monoxide. These should be dealt with by a chimney or flue system which carries the pollutant directly to the outside.

Ventilation strategies

One of the following two ventilation strategies is normally used:

Either a continuous and normally constant ventilation air flow rate is provided and deals with both the specific and the background pollutants together. Or a continuous (relatively low) background ventilation air flow rate is provided to deal with the background pollutants, together with a higher intermittently operated ventilation air flow rate in the rooms with the high specific pollutant production. This intermittent operation may be controlled manually (by the occupant), or automatically by suitable sensors.

Direction of the airflow

If the ventilation system allows for air transfer between rooms, the direction of this air flow between rooms should be from low polluting rooms to activity rooms. Air should be supplied and extracted in such a way as to restrict the movement of air from activity rooms to low pollution rooms. Low pollution rooms therefore usually have an outside air supply, whilst activity rooms have an air extract device. This intended air flow direction between rooms must be achieved with windows and all doors closed, meaning that air transfer openings between rooms are necessary to achieve the design air flow rates.

Energy

The main purpose of a residential ventilation system is to provide adequate indoor air quality for the occupants and to protect the dwelling fabric from damage due to high indoor humidity. It is
desirable to minimize the effect on energy consumption by a ventilation system (heat load, cool load, electrical consumption) but it is important that this strive for energy savings does not adversely affect the IAQ. Ventilation systems may be controllable (e.g. running time and/or flow rate) to eliminate or reduce the occurrence of high ventilation air flow rates when they are not needed. The control can be automatic (DCV) or manual. It is possible to use automatic controls which ensure ventilation is provided where and when occupants actually need it. For activity rooms (e.g. bathrooms, kitchens) the ventilation demand is best evaluated on bases of the relative humidity instead of presence or occupancy.

§ 8. Design rules for residential ventilation systems

General

The design process of residential ventilation systems consists of the five following basic steps:

i) specify the required design assumptions according to chapter 6

ii) determine the design performance requirements in accordance with chapter 7

iii) select the ventilation strategy (natural, mechanical) and control strategy (automatic, manual, continuous, intermittent)

iv) plan the layout of the system (locations air supply, transfer and extract devices

v) determine size and performance specifications of all components involved

System layout

Each low pollution (habitable) room should be equipped with at least one fresh air supply device. Precautions should be taken to ensure that the source of the outside air is not contaminated due to the proximity of an exhaust air outlet, flue terminal, or other avoidable sources of polluted air. The location of air inlets in rooms should be chosen or designed to minimize the risk of draughts (location on top level of occupied zone or following calculations based thermal comfort criteria in national regulations)

Air supply devices may also be fitted in activity rooms to provide adequate air supply when the extract system is running on boost setting, but these supply devices should not adversely affect pattern of air flows in the other rooms when running on a normal setting.

Each activity room should be outfitted with at least one extract device. Extract devices are usually placed at high level and as close to the pollutant source as possible.

Internal air transfer devices are used to allow air to move between rooms in a dwelling. They are best located near the floor to avoid transfer of smoke.

Ventilation systems should not allow significant re-entry of exhaust air into the dwelling or adjacent building. Arrangements should be made to avoid re-entry through outdoor air intakes and windows. This may be achieved by a careful design of terminals or by adequate special separation.

Where the systems uses ducts, the duct runs should be kept as short as possible to reduce heat losses, leakage and flow resistance.

System design

The ventilation system should be subjected to a schedule of periodic cleaning and maintenance to ensure it continues to meet the required performance. Therefore it should be possible to gain access to clean and maintain any parts of the ventilation system which could adversely effect the performance, the IAQ, or safety of the system if they were not cleaned or maintained. This includes air terminal devices, air transfer devices, ductwork, heat exchangers, fans and filters.

The thermal energy involved in establishing the requested IAQ with the requested air volume flow rates can be calculated with the following formula:
\[ P = c_{\text{air}} \times Q \times \Delta t \text{ in [W]} \]

*where*

\[ c_{\text{air}} = \text{specific heat of air : 1.224 [J/dm}^3\cdot\text{K]} \]
\[ Q = \text{the air flow rate in [dm}^3\text{/s]} \]
\[ \Delta t = \text{the indoor/outdoor air temperature difference in [K]} \]

**Informative Annex F**

Examples of calculated values for ventilation air flow rates

**F.3 Bedroom**

Assumptions for calculation:
- CO2 production per human adult while sleeping : 12 l/h
- Water vapor production per human adult while sleeping : 40 g/h
- Room temperatures : 16 °C
- Rooms size: floor area 9 m², ceiling height 2.5 m.
- Occupancy : 2 adults
- Ventilation air enters the room from outside

**Table 1-37 Calculated ventilation air flow rates for CO2 removal from a bedroom and related humidity /condensation risk at bedroom air temperature of 16 °C**

<table>
<thead>
<tr>
<th>Max CO2 level at equilibrium</th>
<th>Recom. vent. air flow rate</th>
<th>Outdoor temperature -5 °C</th>
<th>Outdoor temperature 0 °C</th>
<th>Outdoor temperature +10 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[m³/h]</td>
<td>[l/s]</td>
<td>[g/kg]</td>
<td>%RH</td>
</tr>
<tr>
<td>1000</td>
<td>36.4</td>
<td>10.1</td>
<td>3.8</td>
<td>34</td>
</tr>
<tr>
<td>1500</td>
<td>20.7</td>
<td>5.8</td>
<td>4.5</td>
<td>40</td>
</tr>
<tr>
<td>2000</td>
<td>14.4</td>
<td>4.0</td>
<td>5.0</td>
<td>45</td>
</tr>
<tr>
<td>2500</td>
<td>10.8</td>
<td>3.0</td>
<td>5.6</td>
<td>50</td>
</tr>
<tr>
<td>3500</td>
<td>6.9</td>
<td>1.9</td>
<td>6.8</td>
<td>60</td>
</tr>
<tr>
<td>5000</td>
<td>3.8</td>
<td>1.1</td>
<td>8.7</td>
<td>77</td>
</tr>
</tbody>
</table>

**F.4 Living room**

Assumptions for calculation:
- CO2 production per human adult while active : 18 l/h
- Water vapor production per human adult while active : 45 g/h
- Water vapor production from plants : 30 g/h
- Room temperatures : 20 °C
- Rooms size: floor area 20 m², ceiling height 2.5 m.
- Occupancy: room occupied by all persons living in dwelling for 6 h.
- Number of occupants 2, 4 and 6 persons
- Ventilation air enters the room from outside
### Table 1-38: Calculated ventilation air flow rates for CO₂ removal from a living room and related humidity/condensation risk at bedroom air temperature of 16 °C

<table>
<thead>
<tr>
<th>Max CO₂ level after 6 hours</th>
<th>Recom. vent. air flow rate</th>
<th>Outdoor temperature -5 °C</th>
<th>Outdoor temperature 0 °C</th>
<th>Outdoor temperature +10 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humidity</td>
<td>Risk?</td>
<td>g/kg</td>
<td>%RH</td>
</tr>
<tr>
<td>2 person occupancy</td>
<td></td>
<td></td>
<td>[ppm]</td>
<td>[m³/h]</td>
</tr>
<tr>
<td>1000</td>
<td>54.5</td>
<td>15.1</td>
<td>4.0</td>
<td>28</td>
</tr>
<tr>
<td>1500</td>
<td>30.2</td>
<td>8.4</td>
<td>4.8</td>
<td>33</td>
</tr>
<tr>
<td>2000</td>
<td>19.6</td>
<td>5.4</td>
<td>5.8</td>
<td>40</td>
</tr>
<tr>
<td>2500</td>
<td>13.3</td>
<td>3.7</td>
<td>6.9</td>
<td>48</td>
</tr>
<tr>
<td>3500</td>
<td>5.5</td>
<td>1.5</td>
<td>11.2</td>
<td>76</td>
</tr>
<tr>
<td>5000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 person occupancy</td>
<td></td>
<td></td>
<td>[ppm]</td>
<td>[m³/h]</td>
</tr>
<tr>
<td>1000</td>
<td>109</td>
<td>30.3</td>
<td>3.9</td>
<td>28</td>
</tr>
<tr>
<td>1500</td>
<td>62</td>
<td>17.2</td>
<td>4.7</td>
<td>33</td>
</tr>
<tr>
<td>2000</td>
<td>43.1</td>
<td>12.0</td>
<td>5.4</td>
<td>37</td>
</tr>
<tr>
<td>2500</td>
<td>32.6</td>
<td>9.1</td>
<td>6.1</td>
<td>43</td>
</tr>
<tr>
<td>3500</td>
<td>20.9</td>
<td>5.8</td>
<td>7.5</td>
<td>52</td>
</tr>
<tr>
<td>5000</td>
<td>11.5</td>
<td>3.2</td>
<td>10.3</td>
<td>71</td>
</tr>
<tr>
<td>6 person occupancy</td>
<td></td>
<td></td>
<td>[ppm]</td>
<td>[m³/h]</td>
</tr>
<tr>
<td>1000</td>
<td>163.5</td>
<td>45.4</td>
<td>3.9</td>
<td>27</td>
</tr>
<tr>
<td>1500</td>
<td>93.0</td>
<td>25.8</td>
<td>4.7</td>
<td>33</td>
</tr>
<tr>
<td>2000</td>
<td>65.0</td>
<td>18.1</td>
<td>5.5</td>
<td>38</td>
</tr>
<tr>
<td>2500</td>
<td>49.8</td>
<td>13.8</td>
<td>6.1</td>
<td>42</td>
</tr>
<tr>
<td>3500</td>
<td>33.5</td>
<td>9.3</td>
<td>7.4</td>
<td>51</td>
</tr>
<tr>
<td>5000</td>
<td>21.3</td>
<td>5.9</td>
<td>9.2</td>
<td>63</td>
</tr>
</tbody>
</table>

### F.5 Bathroom

Assumptions for calculation:

- CO₂ production not relevant
- Water vapor production from shower: 10 minutes at 3000 g/h = 500 g/shower
- Water vapor production from clothes drying: 15 h at 100 g/h per person in dwelling
- Room temperature: 22 °C
- Rooms size: floor area 6 m², ceiling height 2.5 m.
- Occupancy: All occupants take a shower every day. Number of occupants: 2, 4 or 6
- Extracted air is at 22°C and either 70% RH or 100% RH
- Ventilation air enters the room from outside, or from other rooms (at 19 °C and 50% RH)
- Assume that condensation is unavoidable but that it all evaporates and is totally removed by ventilation each day over a period of 14 h.
### Table 1-39. Calculated ventilation air flow rates for a bathroom; Extracted air at 100% RH and 22 °C

<table>
<thead>
<tr>
<th>Time for removal of water vapor</th>
<th>Required ventilation air volume flow rate</th>
<th>Outdoor temp. -5 °C</th>
<th>Outdoor temp. 0 °C</th>
<th>Outdoor temp. +10 °C</th>
<th>Air from dwelling at 19°C and 50% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
</tr>
<tr>
<td>2 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>16.8</td>
<td>4.7</td>
<td>18.3</td>
<td>5.1</td>
<td>26.1</td>
</tr>
<tr>
<td>20 h</td>
<td>11.8</td>
<td>3.3</td>
<td>12.8</td>
<td>3.6</td>
<td>18.2</td>
</tr>
<tr>
<td>24 h</td>
<td>9.8</td>
<td>2.7</td>
<td>10.7</td>
<td>3.0</td>
<td>15.2</td>
</tr>
<tr>
<td>4 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>33.7</td>
<td>9.4</td>
<td>36.5</td>
<td>10.1</td>
<td>52.1</td>
</tr>
<tr>
<td>20 h</td>
<td>23.6</td>
<td>6.6</td>
<td>25.6</td>
<td>7.1</td>
<td>36.5</td>
</tr>
<tr>
<td>24 h</td>
<td>19.7</td>
<td>5.5</td>
<td>21.3</td>
<td>5.9</td>
<td>30.4</td>
</tr>
<tr>
<td>6 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>50.5</td>
<td>14.0</td>
<td>54.8</td>
<td>15.2</td>
<td>78.2</td>
</tr>
<tr>
<td>20 h</td>
<td>35.4</td>
<td>9.8</td>
<td>38.3</td>
<td>10.7</td>
<td>54.7</td>
</tr>
<tr>
<td>24 h</td>
<td>29.5</td>
<td>8.2</td>
<td>32.0</td>
<td>8.9</td>
<td>45.6</td>
</tr>
</tbody>
</table>

### Table 1-40. Calculated ventilation air flow rates for a bathroom; Extracted air at 70% RH and 22 °C

<table>
<thead>
<tr>
<th>Time for removal of water vapor</th>
<th>Required ventilation air volume flow rate</th>
<th>Outdoor temp. -5 °C</th>
<th>Outdoor temp. 0 °C</th>
<th>Outdoor temp. +10 °C</th>
<th>Air from dwelling at 19°C and 50% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
<td>m³/h l/s</td>
</tr>
<tr>
<td>2 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>26.5</td>
<td>7.3</td>
<td>30.1</td>
<td>8.4</td>
<td>59.5</td>
</tr>
<tr>
<td>20 h</td>
<td>18.5</td>
<td>5.1</td>
<td>21.1</td>
<td>5.9</td>
<td>41.7</td>
</tr>
<tr>
<td>24 h</td>
<td>15.4</td>
<td>4.3</td>
<td>17.6</td>
<td>4.9</td>
<td>34.7</td>
</tr>
<tr>
<td>4 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>52.9</td>
<td>15.0</td>
<td>60.3</td>
<td>16.8</td>
<td>119.0</td>
</tr>
<tr>
<td>20 h</td>
<td>37.0</td>
<td>10.3</td>
<td>42.2</td>
<td>11.7</td>
<td>83.3</td>
</tr>
<tr>
<td>24 h</td>
<td>30.9</td>
<td>8.6</td>
<td>35.2</td>
<td>9.8</td>
<td>69.4</td>
</tr>
<tr>
<td>6 person occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 h</td>
<td>79.4</td>
<td>22.0</td>
<td>90.4</td>
<td>25.1</td>
<td>178.6</td>
</tr>
<tr>
<td>20 h</td>
<td>55.6</td>
<td>15.4</td>
<td>63.3</td>
<td>17.6</td>
<td>125.0</td>
</tr>
<tr>
<td>24 h</td>
<td>46.3</td>
<td>12.9</td>
<td>52.7</td>
<td>14.6</td>
<td>104.2</td>
</tr>
</tbody>
</table>

**F.6 WC**

Assumptions for calculation:
- odor produced at pollutant at a rate of 2 l/s for 1 min.
- odor to be reduced to 10, 20, 30, 40, 50, 60% of its initial concentration within 15 min. for each use
- Rooms size: floor area 3 m²; ceiling height 2.5 m.
- Zero odor in air entering the room
Table 1-41. Calculated ventilation air flow rates for a WC

<table>
<thead>
<tr>
<th>% of initial concentration after 15 min.</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air flow rate [m³/h]</td>
<td>69.5</td>
<td>48.6</td>
<td>36.4</td>
<td>27.4</td>
<td>20.9</td>
<td>15.5</td>
</tr>
</tbody>
</table>

3.1.4 EN 15665 Performance criteria residential ventilation


Scope:

This European Standard sets out criteria to assess the performance of residential ventilation systems (for new, existing and refurbished buildings) which serve single family and apartment type dwellings throughout the year. This standard specifies ways to determine performance criteria to be used for design levels in regulations and/or other standards. It is meant to give guidance and support to those who develop new regulations or standards for residential ventilation.

Interesting in the introduction is the acknowledgement that, although all ventilation requirement nowadays are based on airflow rates, there is limited knowledge about the basis for these airflow rates. This standard therefore proposes a more detailed approach to assess the way air exchange and dilution change human exposure to pollutants.

The standard is meant to be applied to, in particular:
- mechanically ventilated buildings (mechanical exhaust, supply or both)
- natural ventilation with stack effect or passive ducts
- hybrid systems, switching between mechanical and natural modes
- windows opening by manual operation for airing or summer comfort issues

The parts that are considered relevant for this Preparatory Study are summarized in this paragraph 1.2.5

Chapter 5. Needs for residential ventilation

This chapter explains the need for residential ventilation systems. It summarizes the sources of pollutants, acknowledges that these source related pollutants represent a risk for both human health & comfort and the building and finally describes the purpose of residential ventilation systems; so far no new elements.

Chapter 6. General approach

§ 6.1 Way of proceeding

This paragraph describes the following six steps that in general need to be used to determine the requested airflow rates:

Step 1: verify what national regulations/standards are applicable that lead to certain limits in airflows

Step 2: identify the pollutants that are considered relevant
Step 3: for each pollutant, make a detailed description of the nature, sources and distribution (in dependency of time); choose the appropriate criteria for each pollutant (according to chapter 7 of the standard). And finally describe the ventilation system, the occupancy patterns, the outdoor conditions and the relevant building parameters that are applicable.

Step 4: select and use the appropriate calculation method able to handle the chosen criteria and assumptions

Step 5: formulate requirements on the selected criteria and verify the performance of the calculation results with other applicable requirements (health, fire protection, noise, gas, etc.)

Step 6: present the results which can be expressed as an equivalent airflow

§ 6.2 Requirements for designing ventilation systems

The paragraph describes what the requirements are to design a ventilation systems and discriminates three different levels for calculation:

Level 1: Assumptions and criteria chosen for ventilation airflow rates

The design specification shall describe the following items:

a) Type of room, natural or mechanical supply or extract, floor level or the room
b) Ventilation regime: continuous (min, max), intermittent (min, max, time schedule), air inlets closable or not.

c) Air flow rates, expressed either in l/s per m², l/s per person, l/s per room
d) Global airflow rates
e) Global air infiltration

At the level of components (exhaust and supply air terminal devices, air transfer devices) requirements can be expressed in equivalent area mm², in airflow at a certain ΔP, etc. Pressure loss due to closed inside doors between air inlets and air exhaust shall be taken into account.

All in all resulting in a table giving the design airflow rates per individual room of the dwelling.

Level 2: Assumptions and criteria chosen for “a single calculation representing point”

This single calculation representing point can e.g. be used for designing or specifying a specific component in a certain (critical) point; for example an average point in winter time to roughly design a natural shaft (passive stack). The table containing the necessary assumptions could then look like the table below.

Table 1-42. Assumptions for level 2 (Table 2, page 10 of EN 15665)

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Case under consideration</th>
<th>Default value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor temperature</td>
<td>19</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Outdoor temperature</td>
<td>8</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td>1</td>
<td>m/s</td>
<td></td>
</tr>
<tr>
<td>Wind direction*</td>
<td>60° windward</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Shielding*</td>
<td>Shielded</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Air leakage class</td>
<td>N_{50} = 1</td>
<td>1/h</td>
<td></td>
</tr>
<tr>
<td>Air leakage splitting</td>
<td>See table 4 of EN 15665</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Outdoor humidity</td>
<td>optional</td>
<td>% RH</td>
<td></td>
</tr>
</tbody>
</table>

* According to EN 15242
Level 3: Assumptions and criteria chosen for a yearly calculation done for design days

For this level of calculation, assumptions shall be made for one day, at a suitable frequency for all patterns concerning occupancy, outside conditions, ventilation system use and pollutant sources (see table below). This level shall be used for daily or yearly calculations. Each day can have the same or different patterns if needed, e.g. week-end patterns are often used and are different from week patterns.

Airflow rates shall be calculated according to chapter 6 of EN 15242:2007

Table 1-43 . Assumptions for level 3 (Table 3, page 14 of EN 15665)

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Case under consideration</th>
<th>Default value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal and meteorological assumptions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor temperature</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Outdoor temperature</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td>1</td>
<td>m/s</td>
</tr>
<tr>
<td>Wind direction</td>
<td></td>
<td>60° windward</td>
<td></td>
</tr>
<tr>
<td>Shielding</td>
<td></td>
<td>Shielded</td>
<td></td>
</tr>
<tr>
<td>Outdoor humidity</td>
<td></td>
<td></td>
<td>% RH</td>
</tr>
<tr>
<td><strong>Building assumptions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air leakage classes</td>
<td></td>
<td>N₅₀ = 1</td>
<td></td>
</tr>
<tr>
<td>Air leakage splitting</td>
<td></td>
<td>See table 4 of EN 15665</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Occupancy pattern</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ventilation assumptions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pollutant emission (water)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water vapour awake</td>
<td></td>
<td>55</td>
<td>g/h/pp</td>
</tr>
<tr>
<td>Water vapour sleeping</td>
<td></td>
<td>40</td>
<td>g/h/pp</td>
</tr>
<tr>
<td>Breakfast</td>
<td></td>
<td>50</td>
<td>g/pp</td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
<td>75</td>
<td>g/pp</td>
</tr>
<tr>
<td>Dinner</td>
<td></td>
<td>300</td>
<td>g/pp</td>
</tr>
<tr>
<td>Natural gas cooking</td>
<td></td>
<td>350</td>
<td>g/day</td>
</tr>
<tr>
<td>Shower³</td>
<td></td>
<td>300</td>
<td>g/shower</td>
</tr>
<tr>
<td>Washing drying inside</td>
<td></td>
<td>1200</td>
<td>g/washing</td>
</tr>
<tr>
<td>Frequency of showers/person</td>
<td></td>
<td>1</td>
<td>shower/pp/day</td>
</tr>
<tr>
<td>Frequency of washing/person</td>
<td></td>
<td>1</td>
<td>washing/pp/day</td>
</tr>
<tr>
<td><strong>Pollutant emission (metabolic CO₂)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ awake</td>
<td></td>
<td>16</td>
<td>l/h/pp</td>
</tr>
<tr>
<td>CO₂ sleeping</td>
<td></td>
<td>10</td>
<td>l/h/pp</td>
</tr>
</tbody>
</table>

According to EN 15242
In case of calculations, assumptions of one or more pollutants is needed, in relation with the criteria chosen for the requirements
If the parameter is used
Drying towels is included in the shower (default value): it is a 6 minutes shower
Chapter 7. Criteria

§ 7.1 General

The starting point for the calculation method is to define the most important or key pollutant in each type of room in the dwelling. It is assumed that if the key pollutant is adequately controlled, then other pollutants in that room are also adequately controlled. For some rooms calculations might be necessary to determine what the key pollutant is. The following key pollutants shall be taken into account:

- metabolic CO\textsubscript{2} emissions and water vapour for low polluting rooms
- water vapour, odours and CO\textsubscript{2} from combustion of fuels in kitchens
- water vapour in bathrooms and laundry/utility room
- odours in WC

Pollutant emission rates shall be calculated for each room separately based on either known emission rates or data given as assumptions in the standard frame defined in chapter 6. This may require assumptions about the number of occupants and their presence in the various room of the dwelling, the type and rating of combustions appliances, and occupant habits (clothes washing, cooking, bathing, etc.)

Humidity is taken into account in a separate way due to the fact that it impacts on building independent of occupancy and external value is varying in large proportion. Another particularity of humidity is that both too high levels and too low levels can induce discomfort or impact the building.

The actual criteria used to value pollutant levels can be one of the following (§ 7.2 - § 7.7):

§ 7.2 Threshold or limit of the level

The criteria is the threshold of the pollutants concentration. It shall be associated with one or more of the following:

- time above threshold during a reference period
- maximum continuous duration above this threshold during the reference period

The reference period can be for example the occupied period (e.g. for CO\textsubscript{2}) or the whole year (for humidity).

Criteria can e.g. be the average concentration during a reference period.

§ 7.3 Weighted average concentration

Here different concentration classes are weighted (continuous function or discrete classes). In the following example C is the original concentration, C' = value after discrete weighting, C'' = value after continuous weighting. Example discrete weighting:

\[
\begin{align*}
C < 1000 & \quad C' = C \\
1000 < C < 1500 & \quad C' = 2 \times C \\
1500 < C < 2000 & \quad C' = 3 \times C \\
2000 < C & \quad C' = 4 \times C \\
\end{align*}
\]

Example continuous weighting:

\[C'' = C \times (C/500)\]
§ 7.4 Average concentration above a threshold with limited compensation

This method does not compensate values that are higher than the limit with values that are lower than the limit values. All values that are lower than the limit are considered equal to the limit. On this basis, the average concentration is calculated.

§ 7.5 Average concentration above a limit

This method sets criteria for the average value above a limit value, calculated with the time during which this value is exceeded.

§ 7.6 Dose above a given value

This method sets criteria on the basis of the time integral of the concentration above a certain limit value

§ 7.7 Decay criteria

The decay method is based on defining a time limit that is necessary for the ventilation system to achieve a given reduction in concentration levels

Which of these methods should be used depends on the type of pollutant.

§ 7.8 Use of criteria depending on pollutant

Three families of criteria are considered:

1. criteria for humidity
   - number of hours under a certain limit
   - max. duration under a certain limit
   - number of times the level is under the limit for more than a certain duration
   - number of hours above a certain limit
   - max. duration above a certain limit
   - number of times the level has exceeded the limit for more than a certain duration

2. criteria for specific activities such as cooking, showers/bathing, odours in toilets, hobbies
   - time to obtain a given percentage of the max. value
   - value after a certain time
   - dose above a certain value
   - average
   - average above a threshold

3. criteria for background pollutants (CO2, VOC from furniture and building materials)
   - maximum limit
   - average
   - weighted average
   - average above a certain limit
   - dose above a certain limit
3.1.5 **EN 15242 Calculation ventilation rates**

**Full title:** EN 15242: 2007, *Ventilation for buildings – Calculation methods for the determination of air flow rates in buildings including infiltration. June 2007*

This standard defines the way to calculate the airflows due to the ventilation system and due to the infiltration. The calculation of the airflows through the building envelope and the ventilation system for a given situation is described in chapter 6. Applications depending on the intended use are described in chapter 7.

These calculated airflow rates can be used for applications such as energy calculations, heat and cooling load calculations, summer comfort and indoor air quality evaluation.

The results provided by this standard are ‘the building envelope flow either through leakages or purpose provided openings and the air flows due to the ventilation system, taking into account the product and system characteristics’.

---

**Note:**

In the context of this Preparatory Study the study team will only look at the airflow rates that are induced by the dedicated ventilation system. Airflow rates caused by infiltration and airing are the domain of the EPBD (see also § 1.1.3 Scope).

---

**Chapter 5. General approach**

The airflows are calculated for a building or a zone in a building. A building can be separated in zones if:

- the different zones are related to different ventilation systems
- the zones can be considered as more or less airflow independent (e.g. air leakage between two adjacent zones are negligible and there is no air transfer between the zones)

The best way to do the calculation is to consider the air mass (dry air) flow rate balance, but it is also allowed to consider the volume flow rate when evident. For air heating and air-conditioning systems however the use of mass flow rate is mandatory.

The INPUT data are the ventilation system airflows and the airflows vs pressure characteristics of openings (vents) and leakages. The OUTPUT data are airflows entering and leaving the building through:

- leakages
- openings (vents)
- airing (windows opening)
- ventilation systems, including duct leakages

Air entering the building/zone is counted positive; air leaving is counted negative.

**Chapter 6. Instantaneous calculation (iterative method)**

§ 6.1 **Basis of the calculation method**

An iterative method is used to calculated the air handling unit air flow, and the air flow through envelope leakages and openings for a given situation of:

- outdoor climate (wind and temperature)
- indoor climate (temperature)
- system running
This chapter explains the different steps of calculation:

1. Calculation airflow rate of mechanical ventilation
2. Passive duct for residential and low rise non-residential buildings
3. Calculation of infiltration and exfiltration
4. Combustion air flow
5. Calculation of additional airflow through windows (airing)
6. Overall airflow

§ 6.2 Mechanical airflow calculation

The ventilation is based on required airflow (either supplied or extracted in each room) which is defined at national level, assuming in general perfect missing of the air. To pass from these room-based values to an overall figure for the mechanically induced airflow, the following coefficients (and impacts) shall be taken into account:

1. $C_\text{use}$: coefficient corresponding to switching on ($C_\text{use} = 1$) or off ($C_\text{use} = 0$) the fan
2. $\varepsilon_v$: local ventilation efficiency
3. $C_\text{cont}$: coefficient depending on local air flow control
4. $C_\text{syst}$: coefficient depending on inaccuracies of the components and system (adjustment...etc)
5. $C_\text{leak}$: due to duct and AHU leakages
6. $C_\text{rec}$: recirculation coefficient, mainly for VAV system

The mechanical airflows supplied to or extracted from the zone are calculated by:

\[
q_{v;\text{sup}} = \frac{q_{v;\text{sup};\text{req}} \cdot C_\text{cont} \cdot C_\text{indooleak} \cdot C_\text{rec}}{\varepsilon_v}
\]

\[
q_{v;\text{exh}} = \frac{q_{v;\text{exh};\text{req}} \cdot C_\text{cont} \cdot C_\text{indooleak} \cdot C_\text{rec}}{\varepsilon_v}
\]

With:

- $q_{v;\text{sup};\text{req}}$: supply airflow according to building design and national regulations
- $q_{v;\text{sup};\text{req}}$: exhaust airflow according to building design and national regulations
- $C_\text{indooleak} = C_\text{ductleak} + C_\text{AHUleak}$

Where

\[
C_\text{ductleak} = 1 + \frac{q_{v;\text{req}} \cdot C_\text{cont} \cdot C_\text{syst}}{\varepsilon_v}
\]
where

\[ q_{\text{v;duct leak}} = \frac{A_{\text{duct}} \times K \times dP_{\text{duct}}^{0.65}}{3600} \]  
\[ = \text{air through the duct leakages in m}^3/\text{h} \]

\[ A_{\text{duct}} = \text{duct area in m}^2 \]  
\[ \text{(to be calculated according to EN 14239)} \]

\[ K = \text{air tightness of duct in m}^3/\text{s/m}^2 \text{ at 1 Pa; the duct leakage shall be determined} \]
\[ \text{according to EN 12237 (for circular ducts); EN1507 (rectangular ducts)} \]

\[ dP_{\text{duct}} = \text{pressure difference between duct and ambient air in Pa} \]

\[
\frac{q_{\text{v;AHU leak}}}{CAHULeak} = 1 + \frac{q_{\text{v;req}} \times C_{\text{cont}} \times C_{\text{syst}}}{\epsilon_v}
\]

where

\[ q_{\text{v;AHU leak}} = \text{airflow lost by the AHU determined according to EN 1886} \]

The mechanical airflows supplied to or exhausted from the AHU are calculated by:

\[
q_{\text{v;sup;AHU}} = \frac{q_{\text{v;sup;req}} \times C_{\text{cont}} \times C_{\text{leak}} \times C_{\text{rec}}}{\epsilon_v}
\]

\[
q_{\text{v;exh;AHU}} = \frac{q_{\text{v;exh;req}} \times C_{\text{cont}} \times C_{\text{leak}} \times C_{\text{rec}}}{\epsilon_v}
\]

with

\[ C_{\text{leak}} = C_{\text{indoor leak}} + C_{\text{outdoor leak}} \]

If the AHU is situated indoor:

\[ C_{\text{indoor leak}} = C_{\text{duct leak}} + CAHULeak \]
\[ C_{\text{outdoor leak}} = 1 \]

If the AHU is situated outdoor:

\[ C_{\text{indoor leak}} = 1 + R_{\text{indoorduct}} \times (1 - C_{\text{duct leak}}) \]
\[ C_{\text{outdoor leak}} = 1 + (1 - C_{\text{duct leak}}) \times (1 - R_{\text{indoorduct}}) \times CAHULeak \]
with
\[ R_\text{indoorduct} = A_\text{indoorduct} / A_\text{duct} \]
\[ A_\text{duct} = \text{area of duct situated indoors} \]

\section*{§ 6.3 Passive and hybrid duct ventilation}
This paragraph presents formulas for calculating the cowl airflow in a natural ventilation system with a ducted natural exhaust, depending on:
- wind velocity
- pressure loss coefficient
- roof angle and position and height of cowl
- duct pressure drop

The other airflows that are calculated in this chapter relate to airflows that are not within the scope of this preparatory study (domain of EPBD); these are the following:

§ 6.4 Combustions air flows
§ 6.5 Air flow due to window openings
§ 6.6 Exfiltration and infiltration using iterative method
§ 6.7 Exfiltration and infiltration using direct method

\section*{Chapter 7. Applications}
\section*{§7.1 General}
The airflows that are calculated according to this standards can be applied for:
- energy calculation
- determining heating load
- determining cooling load
- determining summer comfort
- determining IAQ

\textbf{Note:}
An assessment that does not look into the airflows per individual room, is not sufficient for assessing the energy rating of the ventilation function on the basis of the IAQ-performance. To compare energy performance of the ventilation function in a correct manner, it is also necessary to look at the airflows (IAQ) per individual room.

For this Preparatory Study we will have to try to link the IAQ and the related airflows in separate rooms with the energy use. § 7.6 of this standard give some leads for such an assessment, since it states that for IAQ-purposes, not only the overall air exchange needs to be looked at, but also the fresh supply air for all habitable rooms, and the exhaust air for all service/utility/wet rooms.

\section*{§7.2 Energy calculation}
For energy calculations it is allowed to neglect the internal partition in each zone.
**Default values for $C_{use}$, $\varepsilon_v$, $C_{cont}$, $C_{syst}$, $C_{airing}$**

The following default values are proposed for calculating airflow rates (can be modified in national annexes)

- $C_{use} = 1$ for occupied hours, 0 for unoccupied hours
- $\varepsilon_v = 1$
- $C_{cont} = 1$
- $C_{syst} = 1.2$
- $C_{airing} = 1.8$

In other words, it is assumed here that:
- ventilation airflows are only applied when rooms are occupied (fans are switched on during occupancy and switched off when no one is present);
- the ventilation effectiveness of the applied ventilation system is always 1 (the extracted air has the same pollutant concentration as the indoor air);
- the coefficient for local airflow control is 1, which implies that the airflow per room is exactly tailored to the actual need;
- the inaccuracies of the ventilation system and its components are within the 20% range.

**Note:**

In order to be able to differentiate between the ventilation performance and related energy use of different ventilation systems, the technical analysis of this Preparatory Study will assess the differences in $C_{use}$, $\varepsilon_v$, $C_{cont}$, $C_{syst}$ for the various ventilation systems and their components.

The default values that are assumed here, highly overestimate the performance of ventilation systems and their components. Accepting these default values implies that further differentiation between ventilation systems is no longer possible. The energy saving potential related to ventilation systems that have better ventilation effectiveness, better controls, less system inaccuracies etc. cannot be assessed when these default values would be accepted for this Preparatory Study.

**Duct system air leakages**

For energy calculation purposes, the AHU leakages may be neglected if the AHU has been tested according to EN 1886 and the class obtained is at minimum L3.

If the values of $A_{duct}$ and $dp_{duct}$ are not known, it is allowed to apply default a value of $C_{leak}$ according to the following tables:

**Table 1-44. Typical values for indoor duct leakages**

<table>
<thead>
<tr>
<th></th>
<th>$K$</th>
<th>% airflow lost</th>
<th>$C_{indoor\text{leak}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default = 2.5 ; class A</td>
<td>0.0000675</td>
<td>15</td>
<td>1.15</td>
</tr>
<tr>
<td>Class A</td>
<td>0.000027</td>
<td>6</td>
<td>1.06</td>
</tr>
<tr>
<td>Class B</td>
<td>0.000009</td>
<td>2</td>
<td>1.02</td>
</tr>
</tbody>
</table>
### 3.1.6 EN 15241 Calculation ventilation energy loss, commercial buildings


This standard defines the way to calculate the energy impact of airflows due to the ventilation system, including airing. Its purpose is to define how to calculate the characteristics (temperature, humidity) of the air entering the building, and the corresponding energies required for its treatment and the auxiliary electrical energy required.

The ventilation systems considered here, do not directly include the room controlled heating and cooling functions, but only preheating and precooling coils.

The aim of this standard therefore is to provide the following information:

- Air flows (from EN 15242), temperature and humidity, entering the heated/conditioned area both for ventilation and infiltration
- Electrical needs for fan and ventilation system auxiliaries
- Required energy for defrosting, preheating, precooling, humidifying, dehumidifying

The heating and cooling needs due to infiltration are not part of the standard.

The applicable calculation procedures are described in Chapter 6.

### Chapter 6: Steady state calculation

§ 6.1 General principle is to define the airflow rates, their temperatures and humidity, that are entering the heated or cooled areas and to assess the energy needed for the air treatment applied.

§ 6.2 For air that enters the building through infiltration, passive air inlets or windows, the air characteristics are similar to the outdoor ones. If the air is taken from an adjacent space, the air temperature in this space shall be calculated according to prEN ISO 13790.

§ 6.3 For air entering the building through balanced or supply only systems, the following clauses describe how to calculate the energy related parameters for each component:

**§ 6.3.2 Duct heat losses**

Heat transfer through the parts of ducts situated in the heated/conditioned area can be neglected for systems that do not provide heating or cooling. If the system provides heating/cooling and the

### Table 1-45 . Typical values for indoor AHU leakages

| Class C or better | 0.000003 | 0.00 | 0 |

### ENTR LOT 6, FINAL REPORT TASK 1 VENTILATION SYSTEMS, 14.06.2012
losses are considered significant, the equations are the same as for systems with ducts situated out of the heated/conditioned area, in which case the equations are:

\[ \begin{align*}
\vartheta_2 &= \vartheta_1 + \Delta T_{duct} \\
x_2 &= x_1
\end{align*} \]

where

- \( \Delta T_{duct} \) = the difference in air temperature between the inlet and the outlet of the duct, in [K]
- \( \vartheta_1, x_1 \) = air temperature and humidity at the inlet of the duct, in [°C] and [g/kg] of dry air
- \( \vartheta_2, x_2 \) = air temperature and humidity at the outlet of the duct, in [°C] and [g/kg] of dry air

\( \Delta T_{duct} \) is calculated by:

\[ \Delta T_{duct} = (\vartheta_1 + \vartheta_{surduct})(1 - e^{-\frac{H_{duct}}{0.34 q_{vduct}}}) \]

Where:

- \( \vartheta_{surduct} \) = the temperature of the air surrounding the duct (equal to the outdoor air) in [°C]
- \( H_{duct} \) = the heat loss from the duct to the surrounding, in [W/K]
- \( q_{vduct} \) = the air volume flow rate in the duct, in [m³/h]

§ 6.3.3 Duct flow losses

The infiltrated or exfiltrated flow into or from the duct is calculated according to EN15242. If the air is exfiltrated, there is no change in air characteristics in the duct (but only a difference in air flows). If the air is infiltrated, the outdoor air is mixed with the air entering the duct.

§ 6.3.4 Fan

The air temperature is increased by the fan with a \( \Delta T_{fan} \) value:

\[ \Delta T_{fan} = F_{fan} \cdot R_{fr} / \rho \cdot c \cdot q_{vfan} \]

Where:

- \( \Delta T_{fan} \) = the difference in air temperature between the inlet and the outlet of the duct, in [K]
- \( F_{fan} \) = the fan power, in [W]
- \( R_{fr} \) = the fan power recovered ratio
- \( \rho \cdot c \) = the product of the air density and the specific heat, in [Wh/m³/K]. A default value of 0.34 may be used (value at 20 °C)
- \( q_{vfan} \) = the airflow through the fan, in [m³/h]
The fan power recovered ratio is the ratio of the electrical energy to the fan transferred to the air. The table below gives default values. When the position is unknown, the worst value shall be used (motor in airflow for cooling, out of airflow for heating).

Table 1-46. Default values for \( R_{fr} \)

<table>
<thead>
<tr>
<th>Motor position</th>
<th>( R_{fr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>In airflow</td>
<td>0.9</td>
</tr>
<tr>
<td>Out of airflow</td>
<td>0.6</td>
</tr>
</tbody>
</table>

For demand controlled ventilation (DCV) or VAV systems without any recirculation air (100% outdoor air), it may be assumed that the fan power consumption in average is similar to the fan power level obtained at the average airflow of \( C_{cont} \times q_v \) in order to simplify the calculation.

For VAV systems with recirculation, \( C_{cont} \) depends on the action of the outdoor air damper while the fanned absorbed power depends on the average supply air ratio compared to the maximum.

If no information is available, the following curve gives some ideas of the fan absorbed power ratio versus the airflow ratio for different type of airflow control principles:

![Figure 1-6. Examples of fan absorbed power versus airflow](image)

If no design assumption is possible, the average airflow and a default value of 80% can be used.

Example:
If it has been determined that $C_{cont} = 0.5$ on a DCV system, it may be assumed that the fan power consumption is equivalent to the power at 50% ratio, i.e. in this case 30% of the maximum one with speed control.

The following table gives the ratio that may be applied to the fan power at max speed, depending on $C_{cont}$ and the airflow control principle.

**Table 1-47. Example of fan power ratio in relation to airflow ratio and airflow control principle**

<table>
<thead>
<tr>
<th>Airflow control principle</th>
<th>Airflow ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Damper control on forward blades centrifugal fan</td>
<td>55%</td>
</tr>
<tr>
<td>Damper control on backward blades centrifugal fan</td>
<td>50%</td>
</tr>
<tr>
<td>Speed control</td>
<td>10%</td>
</tr>
</tbody>
</table>

§ 6.3.5 *Heat exchanger*

*"Sensible heat only" heat exchangers*

For balanced supply and extract airflows, the temperature variations are calculated with:

\[
\theta_{S2} = \theta_{S1} + \Delta T_{HE_{sup}} \\
\theta_{E2} = \theta_{E1} + \Delta T_{HE_{extr}}
\]

Where:

\(\theta_{e1}\) = temperature of the extract air before the heat exchanger

\(\theta_{e2}\) = temperature of the extract air after the heat exchanger

\(\theta_{s1}\) = temperature of the supply air before the heat exchanger

\(\theta_{s2}\) = temperature of the supply air after the heat exchanger

\(\Delta T_{HE_{sup}} = Eff_{HE} \ (\theta_{e1} - \theta_{s1})\)

\(\Delta T_{HE_{extr}} = -\Delta T_{HE_{sup}}\)

\(Eff_{HE}\) = the heat exchanger efficiency for a given set of (almost) equal supply and extract airflows.

For single residential supply and exhaust units (tested according to EN13141-7) the overall efficiency includes fan temperature increase when the position of fan allows it to be recovered.

*"Sensible and latent" heat exchangers*

It is possible to write the equations separating temperatures and humidity impacts, but product standards have only one point of testing for hygroscopic units, which is not enough to characterize both impacts.

*Defrosting issues*

Testing for defrosting is dealt with in EN 13053, Annex A

Preventing frosting can be done in several ways, amongst which:

a. direct defrosting control by action on the heat exchanger

b. use a defrosting coil that preheats the outdoor air
In both cases $\theta_2$ is limited to a certain value $\theta_{2\text{min}}$. The following default values for $\theta_{2\text{min}}$ can be used if no national information is available:

- Residential applications : 5 °C
- Non residential plate exchanger : 0 °C
- Non residential rotary exchanger : -5 °C
- Default value : 5 °C

In case of a) direct defrosting control, a correction value shall be applied to $\theta_2$. If exhaust and supply flow are equal, the same correction has to be applied to $\theta_s$.

In case of b) the outdoor air is preheated to a $\theta_{\text{setdefrost}}$ value. The power needed to preheat the air, $P_{\text{defrost}}$ is calculated by:

$$P_{\text{defrost}} = \max(0; 0.34 \times q_v \times (\theta_{\text{setdefrost}} - \theta_{s1})$$

The $\theta_{\text{setdefrost}}$ value shall be calculated in such a way that the requested $\theta_{2\text{min}}$ can be achieved. For situations in which the supply and extract flow are equal this leads to the following formula:

$$\theta_{\text{setdefrost}} = \theta_{e1} + (\theta_{2\text{min}} - \theta_{e1}) / \text{EffHE}$$

The air characteristics to be used here are:

$$\theta_{s1} = \theta_{\text{ext}}$$

$$x_{s1} = x_{s2} = x_{\text{extr}}$$

**Free cooling / Limitation of supply temperature** (Only valid with by-pass provisions)

The $\theta_{s2}$ can be limited to a $\theta_{s2\text{max}}$ value in order to prevent air heating in a cooling period. The $\Delta T_{\text{HEsup}}$ must then be corrected with the related value.

§ 6.3.6 Mixing boxes

When mixing (or recirculation) boxes are used, the supply air is a mix of outdoor air and recirculated air. Mixing is established in the mixing box with dampers.

If the airflow to and from the building (supply and exhaust) are known, the recirculation factor $R_{\text{rec}}$ (= ratio of recirculation air in the supply air) can be used to determine the different flows and temperatures using the following formulas:

$$q_{vs1} = (1 - R_{\text{rec}}) \times q_{s2}$$

$$q_{ve2} = (1 - R_{\text{rec}}) \times q_{e1}$$

$$\theta_{s2} = R_{\text{rec}} \times \theta_{e1} + (1 - R_{\text{rec}}) \times \theta_{s1}$$

$$x_{s2} = R_{\text{rec}} \times x_{e1} + (1 - R_{\text{rec}}) \times x_{s1}$$
\[
\begin{align*}
\theta_{e2} &= \theta_{e1} \\
xe_2 &= xe_1
\end{align*}
\]

§ 6.3.7 Pre-heating

With pre-heating the supply air is warmed up to a \( \theta_{setPH} \) value for comfort reasons. The heating power \( P_{preheat} \) required, the temperature and the humidity can be calculated with the following formulas:

\[
P_{preheat} = \max (0; 0.34 * qv_{PH} * (\theta_{setPH} - \theta_{s1}))
\]

\[
\theta_{s2} = \max (\theta_{s2}, \theta_{setPH})
\]

\[
x_2 = x_1
\]

§ 6.3.8 Pre-cooling

With pre-cooling the supply air is cooled down to a \( \theta_{setPC} \) value for comfort reasons. The cooling power \( P_{precool} \) required, the temperature and the humidity can be calculated with the following formulas:

\[
P_{precool} = q_{pc} * (0.83 * (x_2 - x_1) + 0.34 * (\theta_{s2} - \theta_{s1}))
\]

\[
\theta_{s2} = \theta_{s1} + \Delta T_{pc}
\]

\[
x_{s2} = x_{s1} + \Delta x_{pc}
\]

with:

\[
\Delta T_{pc} = \max (0; \theta_{s1} - \theta_{setPC})
\]

\[
\Delta x_{pc} = \min (0; x_{coil} - x_1) * (1 - BP_{avfactor})
\]

\[
x_{coil} = EXP(18.8161 - 4110.34 / (\theta_{coil} + 235))
\]

\[
\theta_{coil} = \text{coil temperature with a default value of 8°C}
\]

\[
BP_{avfactor} = \min (1; (\theta_{s2} - \theta_{coil}) / (\theta_{s1} - \theta_{coil})
\]

The \( BP_{avfactor} \) is an averaged Bypass factor, taking into account the temperature control and can therefore be higher than the actual coil bypass factor.

3.1.7 EN 13465 Calculation air flow rates in dwellings.

This European Standard specifies methods to calculate basic whole house air flow rates for single family houses and individual apartments up to the size of approximately 1000 m³. This European standard may be used for applications such as energy loss calculations, heat load calculations and indoor air quality evaluations.

The Standard covers natural, mechanical extract and balanced ventilation systems. Flows due to window opening are also considered, but only as a single sided effect (i.e. no cross ventilation). Therefore, the application is limited mainly to the heating season.

The ventilation air flow rates in this supplementary Preparatory Study are discussed in paragraph 6.3.1 System flow (page 11 of the standard) and paragraph 7.5 to 7.7 (page 14 of the standard).

Informative Annex A gives a selection of input data values, amongst which leakages values for different buildings construction types and different age of dwellings are given (\(Q_{infiltration}\)).

### 3.1.8 prEN 13142 Performance components/products residential ventilation


This European Standard specifies and classifies the component/product performance characteristics which may be necessary for the design and dimensioning of residential ventilation systems to provide the pre-determined comfort conditions of temperature, air velocity, humidity, hygiene and sound in the occupied zone.

It defines those performance characteristics (mandatory or optional) which shall be determined and measured and presented according to relevant test methods. It will provide a classification scheme which lead to a full definition of product properties based on European test methods described in various EN standards and gives an overview of the Test Standards in various CEN TC’s. Distinction between mandatory and optional requirement is left to each national regulations. This standard gives an informative national annex in which the member states define the valid parameters.

The codification part in Clause 8 and the classification part in Clause 9 of this standard applies to the following products: “mechanical supply and exhaust unit according to EN 13141-7 and EN 13141-8”.

This standard does not apply to other products such as filters, fire dampers, ducts, control devices, sound attenuators, which may also be incorporated in residential ventilation.

All classifications that are considered relevant for this study are summarised in Chapter 1 of this report:

- Table 1-11. Specific Power Input
- Table 1-12. Temperature ratio
- Table 1-13. Humidity ratio
- Table 1-15. Standby power
- Table 1-16. Control types
- Table 1-17. Sound power classification (tests according to EN 13141-7/8)
- Table 1-18. Sound-damping performance (tests according to EN 20140-10)

Note that, apart from the above, the standard also defines a new parameter, i.e. Nominal Temperature Performance factor.
The Nominal Temperature Performance Factor (NTPF) is defined as:

\[
NTPF = \frac{\eta_{\theta, su} \rho \cdot \Delta t}{SPI} \quad [-]
\]

Where:
- \(\eta_{\theta, su}\) = Temperature ratio (EN 13141-7 / -8) at reference air volume flow
- \(\rho\) = Air density : 1.2 [kg/m³]
- \(C_p\) = Heat capacity air : 1007 [J/kg.K]
- \(\Delta t\) = Nominal temperature difference at 13 [K] (EN 13141-7 mandatory point 1 table 6)
- \(SPI\) = Specific Power Input [W/m³/s]

The classification, which was not included in Chapter 1 because it is not (yet) frequently used in practice, is given in the table below:

Classification of nominal temperature performance factor NTPF, determined according to EN 13142 (residential units).

<table>
<thead>
<tr>
<th>Class</th>
<th>Nominal Temperature Performance Factor NTPF (with (\eta) measured on supply side at reference air volume flow and nominal (\Delta T))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(\geq 15)</td>
</tr>
<tr>
<td>2</td>
<td>(\geq 12)</td>
</tr>
<tr>
<td>3</td>
<td>(\geq 10)</td>
</tr>
<tr>
<td>4</td>
<td>(\geq 8)</td>
</tr>
<tr>
<td>5</td>
<td>(\geq 5)</td>
</tr>
<tr>
<td>6</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>-</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

3.1.9 EN 13053 Air handling units, rating and performance


This standards specifies requirements and testing for ratings and performance of air handling units as a whole. It also specifies requirements, recommendations, classification, and testing of specific components and sections of air handling units. For many components and sections it refers to component standards, but it also specifies restrictions or applications of standards developed for stand alone components. This standard is applicable both to standardised designs, which may be in a range of sizes having common construction concepts, and also to custom-design units. It also applies both to air handling units, which are completely prefabricated, and to units which are built up on site. Generally the units within the scope of this standard include at least a fan, a heat exchanger and an air filter. This standard is not applicable to the following: a) air conditioning units serving a limited area in a building, such as fan coil units; b) units for residential buildings; c) units producing ventilation air mainly for a manufacturing process.
After the introductory chapters 1 to 4, chapter 5 deals with performance ratings for the entire air handling unit. Chapter 6 then discusses ratings per AHU-component: casing, fans, heat recovery, filters, coils, dampers & valves, mixing sections, attenuators and humidifiers. Annex A deals mainly with defrosting and Annex B expands on heat recovery.

From chapter 5 the Table 2 is given below, providing the tolerances for declaration of several parameters:

### Table 1-49. Tolerances AHU technical parameters

<table>
<thead>
<tr>
<th>Working values</th>
<th>Tolerance range</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air volume flow $q_v$ in m$^3$ × s$^{-1}$</td>
<td>± 5 %</td>
<td>$D_{qv} = (t_{qv}/100 %) \times q_v$</td>
</tr>
<tr>
<td>External total pressure difference $p_{tu}$ in Pa</td>
<td>± 5 %</td>
<td>$D_{ptu} = (t_{Dp}/100 %) \times p_{tu}$</td>
</tr>
<tr>
<td>Electrical motor input power $P_E$ in W *)</td>
<td>+ 8 %</td>
<td>$D_{PE} = (t_{P}/100 %) \times P_E$</td>
</tr>
<tr>
<td>Negative deviations are permissible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sound power level emitted to the ductwork and by the casing $L_{WA}$ in dB</td>
<td>+ 4 dB</td>
<td>$D_{LWA} = t_{LWA}$ The value $t_{LWA}$ in dB is identical to the numerical value for the deviation limit for sound power level of the sound power level stated in dB(A). Negative deviations are permissible.</td>
</tr>
</tbody>
</table>

In chapter 6 the sections on casing, fans, heat recovery and filters are the most relevant for the underlying report on ventilation systems.

**Casing (par. 6.2)**

As regards the casing, mainly the leakage is important, where the standard stipulates that the casing air tightness shall comply with the requirements specified in Table 2 of EN 1886:1998.

**Fans (par. 6.3)**

*The arrangement of the fan in the air handling unit casing shall ensure an even inflow and outflow of air.*

*Additional inflow and outflow devices should be fitted for this purpose if necessary.*

*The dynamic pressures on entry and exit should be low on economic aspects. The air velocity class in the unit shall be defined according to Table 4.(see below)*

*Fans with blades curved backward should be provided for energy reasons. To further reduce the consumption of electric power, energy-saving motors (e.g. class EFF1 CEMEP) with increased efficiency should preferably be fitted.*

*A classification of (face) air velocity levels inside the casing is given in Table 1-17 (pp. 18)*

*The power consumption of drives can be defined in classes. The maximum power consumption has to be calculated by the following formula:*

$$P_{m_{ref}} = (\frac{P_{stat}}{450})^{0.925} \cdot (q_v + 0.08)^{0.95}$$

*with*
P_m_{\text{ref}} = \text{reference power consumption [kW]}
_p_{\text{stat}} = \text{static pressure to be measured at the fan section [Pa]}
q_v = \text{air flow of the fan [m}^3\text{/h]}

The table below defines the power consumption (P_{\text{max}}) classes:

### Table 1-50 — Classes of power consumption of drives (fans)

<table>
<thead>
<tr>
<th>Class</th>
<th>P_{\text{ref}} \times \frac{0.85}{\varepsilon}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class P1</td>
<td>P_{\text{ref}} \times 0.85</td>
</tr>
<tr>
<td>Class P2</td>
<td>P_{\text{ref}} \times 0.90</td>
</tr>
<tr>
<td>Class P3</td>
<td>P_{\text{ref}} \times 0.95</td>
</tr>
<tr>
<td>Class P4</td>
<td>P_{\text{ref}} \times 1.00</td>
</tr>
<tr>
<td>Class P5</td>
<td>P_{\text{ref}} \times 1.06</td>
</tr>
<tr>
<td>Class P6</td>
<td>P_{\text{ref}} \times 1.12</td>
</tr>
<tr>
<td>Class P7</td>
<td>&gt; P_{\text{ref}} \times 1.12</td>
</tr>
</tbody>
</table>

NOTE: Each fan has to be specified in the power consumption classes. All values are based on nominal conditions with a density of 1.2 kg/m³

This classification was not incorporated in Chapter 1, because it is rather specific (450 Pa) and the classification seems not to be popular.

When selecting a fan for an air-handling unit, the pressure loss allowed for filters shall be in accordance with par. 6.9.2 and for the cooling coil pressure loss, the dry coil value shall be used unless otherwise stated.

### Heat Recovery section (par. 6.5)

Applicable standard for performance classification of heat recovery in complete ventilation units for the non-residential sector is EN 13503:2006, where a draft is now under review (prEN 13503; Jan. 2010). The energy efficiency η_e is calculated from EN 308 data at reference conditions of +5 °C outside and +25 °C inside. For other-than-reference conditions the values are to be recalculated using thermal efficiency η_t and the coefficient of performance ε. The equations are

\[
\eta_e = \eta_t \cdot (1 - \frac{1}{\varepsilon})
\]

where the thermal efficiency (η_t) under dry conditions is

\[
\eta_t = \frac{(t_2'' - t_2''')}{(t_1' - t_2'}
\]

with:

- \( t_2'' \) = temperature of the supply air [°C]
- \( t_2''' \) = temperature of the outside air [°C]
- \( t_1' \) = temperature of the exhaust air [°C]

and the coefficient of performance (ε) is

\[
\varepsilon = \frac{Q_{\text{HRS}}}{P_{\text{el}}}
\]

with maximum heat exchanger capacity \( Q_{\text{HRS}} \) [in kW]:

---

23 At dry conditions. Annex B of EN 13053 also gives a method to include humidity and latent heat.
\[ Q_{\text{HRS}} = q_{m2} \cdot c_{pa} \cdot (t_2 - t_1) \]

where

\[ q_{m2} = \text{smallest of exhaust or supply air mass flow (in kg/s)} \]
\[ c_{pa} = \text{specific thermal capacity [kJ / kg K]} \]

with electric power consumption \( P_{el} \) [in kW] is

\[ P_{el} = q_v \cdot \Delta p_{\text{HRS}} \cdot 1 / \eta_0 + P_{el \text{ aux.}} \]

with:

\[ q_v = \text{air flow [m}^3/\text{s]} \text{ (standard density of 1.2 kg/m}^3\text{)} \]
\[ \eta_0 = 0.6 \text{ average overall static efficiency of power consumption [. / .]}^{24} \]
\[ P_{el \text{ aux.}} = \text{auxiliary electric power consumption (e. g. pumps, etc.) in [kW]} \]
\[ \Delta p_{\text{HRS}} \text{ is the sum of the pressure loss on the supply side and the pressure loss of the exhaust side of the heat recovery system} \]

The Table 1-13 (pp. 17) gives the efficiencies at balance mass flow (1:1)

Note that the efficiencies mentioned above apply to thermal efficiency under ‘dry conditions’.

EN 13053 further stipulates “requirements for heat exchangers” as follows:

a) all heat recovery sections should have 4 pressure tapping points, one on each air flow side of the exchanger;

b) all heat exchangers shall be fitted with seals to minimise air leakage;

c) within heat recovery sections fitted with category I and II heat exchangers there shall be a drain pan for condensate;

d) category III heat exchangers shall include a purge sector, except when recirculation air is used.

Filter section (par. 6.9)

The new prEN 13053 (Jan. 2010) stipulates the following requirements regarding filters:

“The task of air filters in HVAC systems is not only to protect the ventilated rooms from too severe a level of contamination but also the HVAC system itself. This is guaranteed by the use of fine filters of filter class F5 to F9 according to EN 779. When manufacturing air filters, no components or materials may be used which can serve microbes as nutrients.

The requirements for air tightness, strength, and bypass leakage are specified in EN 1886.

The side wall on the service side of the filter section shall be equipped with an inspection door. The width and height of the door shall be greater than the external dimensions of the replaceable filter elements. There shall be a free space to the side of the access door and immediately upstream of front access filters sufficient to allow unrestricted access for filter removal and replacement.

The filter section shall be equipped with tapings for a pressure loss gauge/ manometer.

Additional requirements can be specified which take into account the climatic conditions (e.g. low temperatures, moisture, sand, and salt mist).^{25}


^{24} \text{Note that in EU-27 an average efficiency of 0.4 is used for power generation and –distribution.}

^{25} \text{In cold climates the possible accumulation of rime may require the slight preheating of supply air and}
Filters installed in air handling units:

The first filter stage is to be fitted on the intake side, as close as possible to the outer air intake aperture to keep the air treatment elements as clean as possible. Additional coarse filters G1 to G4 are permissible. The second filter stage is arranged on the output side at the beginning of the supply duct in order to keep the ductwork clean.

If a single stage filter system is used for supply air system, a minimum of filter class F7 shall be fitted. If two-stage filtering is used, the supply air fan shall be arranged between the first and second filter stage. To avoid microbial growth on air filters of the second or higher filter stage, the relative humidity in the area of the filter is to be limited to 90%; dropping below the dew point in the area of the air filter shall always be avoided. Air filters shall not be arranged immediately after coolers with dehumidification or after humidifiers (exception – steam humidifiers).

If bag filters are used, the filter area should be at least 10 m² per 1 m² equipment cross-section. The seals used shall be of a closed cell type, shall not absorb any moisture and shall not form a nutrient substrate for micro-organisms. A permanent tight fit shall be guaranteed for the seal (e.g. operation from the dusty air side). Starting from a interior height of 1.6 m, the filter chamber should be fitted with an inspection window (sight glass, inside diameter minimum 150 mm) and with light.

For fan selection purposes the filter pressure loss value at design volume flow shall be the average of the initial and final pressure losses for clean and dust loaded filters. The filter section shall be equipped with measuring devices for pressure drop.26

EN 13053 stipulates that the pressure loss of a filter section loaded with dust shall not exceed the values given in Table 9. (see Table below). Lower final pressure drops can be also specified where appropriate.

Table 1-51. EN 13053. Table 9. Maximum final pressure drop for filters27

<table>
<thead>
<tr>
<th>Filter class</th>
<th>Final pressure drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1-G4</td>
<td>150 Pa</td>
</tr>
<tr>
<td>F5-F7</td>
<td>200 Pa</td>
</tr>
<tr>
<td>F8-F9</td>
<td>300 Pa</td>
</tr>
</tbody>
</table>

Filters installed in air handling units used for human occupancy shall be tested and classified according to EN 779”

The following data shall be displayed in a clear, visible form (e.g. label) on the filter section: filter class, type of filter medium, final pressure drop. On changing the filter, the user shall check and update this information.”

26 Variation in volume flow caused by the accumulation of dust should be given in technical specifications. If specific tolerances for an application are not specified, ± 10 % based on the average pressure drop is acceptable.

27 The final pressure drops tabulated in Table 9 are the typical maximum values for air-handling units in operation and lower than those used in EN 779 for classification purposes, for reasons of energy saving, and the performance obtained from tests according to EN 779 are not necessarily met at these lower pressure drops. (note from the standard)
Defrosting (Annex A)

Annex A gives a test procedure for defrosting energy, related to the heat recovery heat exchanger, determining the defrost heat factor $\varepsilon_D$. With cross-flow heat exchangers the phenomenon occurs typically at supply air of -5 °C when moisture is added to the air, not only by the emission from human beings but also due to activities and processes such as, cooking, washing and drying. In other words, it is not relevant for average and warm climates, but mostly for cold climates.

The annex covers the laboratory testing of the correct functioning and energy recovery of air-handling units with air-to-air heat exchangers of category I or II according to EN 308 under conditions where frosting can occur. The tests are performed at specified duty points (-7 °C and -15 °C supply air) and the result can be used for comparisons and calculations of recovered heat during a longer period (normally one year).

Humidity Recovery (Annex B)

In the case of a possible humidity transmission the efficiency of humidity ($\Psi$) results from

$$\eta_x = \frac{(x_2' - x_1)}{(x_1 - x_2')}$$

where

$x = \text{absolute humidity of the air [g / kg]}

Here it is to be noted that the efficiency of the humidity transmission is not constant contrary to the ratio of temperature transmission and strongly depends on the humidity difference between the two air flows. This potential $\kappa$ is calculated by:

$$\kappa = x_1' - x_{25}$$

where:

$x_{25} = \text{saturation humidity of the cold air flow x}_1'$

With sorptive heat exchangers the potential depends additionally on the temperature difference of the two air flows.

In summary, the enthalpy efficiency can be calculated with:

$$\eta_h = \frac{(h_2' - h_1)}{(h_1' - h_2')}$$

where:

Compare (other standards):

For residential products, EN 13141-8 gives a classification of filter bypass leakage. Also here EN 1886 is the basis (at 200 Pa). Due to the fact that filter bypass leakage measurements can be difficult to perform, it is also possible to give a classification on the basis of a visual inspection of the design details. The classification is given in Table 1-8 (page 15).
\[ h = c_{pa} \cdot t + x \cdot (c_{ps} \cdot t + r_0) \]

with:

- \( c_{pa} \) = specific thermal capacity of air \([kJ / (kg \cdot K)]\)
- \( t \) = temperature \([\degree C]\)
- \( c_{ps} \) = specific thermal capacity of water vapor \([kJ / (kg \cdot K)]\)
- \( r_0 \) = Heat for vaporization of water \([kJ / kg]\)

Under dry conditions with \( \Delta x = 0 \) the enthalpy is calculated with:

\[ h = c_{pa} \cdot \vartheta \]

### 3.1.10 EN 308 Performance testing air-to-air heat recovery devices


This European Standard specifies methods to be used for laboratory testing of air-to-air heat recovery devices or those recovering heat from flue gases of heating appliances in buildings (except process-process applications) to obtain rating data. It gives test requirements and procedures for performing such tests and specifies input criteria required for tests to verify performance data given by the manufacturer.

For the purposes of this standard, the term exhaust air may also be taken to mean the products of combustion.

This European Standard is intended to be used as a basis for testing heat recovery devices for HVAC-systems, which as specified in prEN 247 consist of the heat exchanger itself installed in a casing having the necessary air duct connecting elements and in some cases the fans and pumps, but without any additional components of the HVAC-system.

This European Standard is applicable to the following categories of heat exchangers:

**EN 308 distinguishes:**

- **Category I** Recuperators
- **Category II** With intermediary heat transfer medium
  - * Category IIa - without phase-change
  - * Category IIb - with phase-change (heat-pipe...)
- **Category III** Regenerators (containing accumulating mass)
  - * Category IIIa - non-hygroscopic
  - * Category IIIb - hygroscopic

Heat recovery devices with exchangers and intermediary heat transfer medium without phase change
(category IIa) are to be tested as one unit including pump and pipe system between the coils.

This European Standard prescribes test methods for determining:

a) the external leakage;

b) the internal leakage of exhaust air to the supply-air within the device at a given pressure difference between air ducts, for recovery devices of categories I and II;

c) the carry-over of exhaust air to the supply air in recovery devices of category III;

d) the temperature and humidity ratios;

e) the pressure drop of exhaust-air and supply-air sides.

The standard describes the test procedures, the results of which are then used in EN 13053 (see there).

Some selected details:

• Reference conditions for heat recovery testing are at 25 °C db (wb 18 °C) exhaust and 5 °C supply air.

• The pressure drop on the supply-air side and exhaust-air side shall be determined for at least five different air flow rates on both sides of the recovery device in the range of 50 % to 150 % of the nominal air flow rate with the test points well spaced over the whole flow range.

• Uncertainties of measurements are prescribed for all tested parameters.

3.1.11 EN ISO 13348 Industrial fans, tolerances


Specifies performance tolerances and the technical data presentation of industrial fans of all types. It does not apply for fans designed solely for low-volume air circulation, such as those used for household or similar purposes (ceiling and table fans, extractor fans, etc.). For jet fans refer to ISO 13350. The upper limit of fan work per unit mass is normally 25 kJ kg⁻¹, corresponding to an increase of fan pressure of approximately 30 kPa for a mean density in the fan of 1.2 kg m⁻³. For higher values, agreement is to be reached between the supplier and the user. This International Standard embraces the four installation categories defined in ISO 5801: A) free inlet, free outlet; B) free inlet, ducted outlet; C) ducted inlet, free outlet; D) ducted inlet, ducted outlet. The performance of a fan can vary considerably with the installation category it is operating within. Therefore, these categories form an important part of the definition of the fan's technical data presentation.

The standard is relevant especially for the Ecodesign Fan Regulation, but also on the fan section of ventilation units.

3.1.12 ISO 12759 Fan efficiency

Full title: ISO 12759:2010, Fans -- Efficiency classification for fans

ISO 12759:2010 (under development) specifies requirements for classification of fan efficiency for all fan types driven by motors with an electrical input power range from 0.125 kW to 500 kW. It is applicable to (bare shaft and driven) fans, as well as fans integrated into products. Fans integrated into products can be measured as stand-alone fans.
This ISO standard is related to the AMCA 205 standard\textsuperscript{28} and has been established to define an classification system for fan systems called ‘Fan-&-Motor Efficiency Grade’ (FMEG) for fans larger than 125 mm diameter. The curves account for the physical laws governing efficiency of scale, which makes small fans less efficient than large fans of the same design. Well designed large fan systems can achieve at least FMEG60 (i.e. 60% efficiency for a 10 kW system). FMEG limits can be set in building regulations as minimum energy-performance requirements.

The FMEG curves are defined by the following equation:

$$\eta_{\text{tot,peak}} = a \cdot \ln(P) + b + \text{FMEG}$$

where

$\eta_{\text{tot,peak}} = $ fan system efficiency (total pressure) at the operating point giving peak efficiency [%]
$a,b =$ coefficients, see Table below
$P =$ fan system input electric power [kW]
$\text{FMEG} =$ efficiency grade [0-100] in steps of 5 %

<table>
<thead>
<tr>
<th>Table 1-52 Coefficients $a$ &amp; $b$ depend on fan type &amp; size</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-wheel</td>
</tr>
<tr>
<td>$0.125 \leq P \leq 10$</td>
</tr>
<tr>
<td>$a$</td>
</tr>
<tr>
<td>4.56</td>
</tr>
<tr>
<td>$10 \leq P \leq 500$</td>
</tr>
<tr>
<td>$a$</td>
</tr>
<tr>
<td>1.10</td>
</tr>
<tr>
<td>other fans</td>
</tr>
<tr>
<td>$0.125 \leq P \leq 10$</td>
</tr>
<tr>
<td>$a$</td>
</tr>
<tr>
<td>2.74</td>
</tr>
<tr>
<td>$10 \leq P \leq 500$</td>
</tr>
<tr>
<td>$a$</td>
</tr>
<tr>
<td>0.78</td>
</tr>
</tbody>
</table>

\textsuperscript{28} AMCA 205. Energy efficiency classification for fans
**3.1.13 EN 13141-4  Performance testing residential fans**


This European Standard specifies aerodynamic, acoustic and electrical power performance test methods for fans used in residential ventilation. These methods primarily concern:

- ventilation fans installed on a wall or in a window without any duct;

---

29 With the exception of cross-flow (tangential) fans, which have their own FMEG curve system.
- ventilation fans installed in the downstream of a duct;
- ventilation fans installed in the upstream of a duct;
- ventilation fans installed in a duct;
- encased ventilation fans having several inlets.

For acoustic performance testing one of the following methods is be used:
- in duct method;
- reverberant field method;
- free field or semi-reverberant method.

3.1.14 EN 13141-6 Performance exhaust ventilation system packages in single dwellings


This European standard provides test methods for a system package to help the designer, and avoid the necessity of testing each component separately.

If however a component of the package is not physically linked to the others (e.g. externally/internally mounted air transfer devices), then it is assumed to have been tested according to the test method related to this component.

The European standard specifies laboratory methods for measuring the aerodynamic and acoustic performance characteristics and energy consumption of assembled exhaust ventilation system packages for a single dwelling. The object of this standard is to provide tested characteristics for a system package in worst case conditions so that the user be confident that better values will be achieved on site when the system package is installed in accordance with the manufacturer’s instruction and within these limits of the test conditions.

3.1.15 prEN 13141-7 Performance mechanical supply & exhaust units (incl. HR) for dwellings


This European Standard specifies methods for the performance testing of components used in residential ventilation systems to establish the performance characteristics as identified in EN 13142.

The standard does not contain any information regarding ductwork and fittings, which are covered by other EU standards.

This particular part of the EN 14141 specifies the laboratory test methods and test requirements for the testing of aerodynamic, thermal and acoustic performance characteristics of a mechanical supply and exhaust ventilation unit used in a single dwelling.

It covers units that contain at least, within one or more casings:
- supply and exhaust air fans;
- air filters;
- air-to-air heat exchangers and/or extract-air to outdoor-air heat pump for extract air heat recovery;
- control system.

Such unit can be provided in more than one assembly, the separate assemblies of which are designed to be used together.

The standard supplied test methods for:
- Performance testing of aerodynamic characteristics (chapter 6.2):
  i.e. leakages / airflow/pressure curves and filter bypass;
- Performance testing of thermal characteristics (chapter 6.3):
  i.e. Temperature & humidity ratio's and heat pump performance;
- Performance testing of acoustic characteristics (chapter 6.4)
  i.e. noise radiated through the casing; sound power levels in duct connections of the unit;
- Electric power input (chapter 6.5).

Leakage rate classification according to this standard for the pressurisation test is given in Table 1-5 (pp. 14).

Leakage rate classification according to this standard for the tracer gas method is given in Table 1-6 (pp. 14).

3.1.16 EN 13141-8 Performance mechanical supply & exhaust units (incl. HR) for rooms

Full title: EN 13141-8:2006, Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of unducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room. March 2006 (currently being revised, Nov. 2010)

This European Standard specifies methods for the performance testing of components used in residential ventilation systems to establish the performance characteristics as identified in EN 13142.

This particular part of the EN 14141 specifies the laboratory test methods and test requirements for the testing of aerodynamic, thermal and acoustic performance characteristics of a mechanical supply and exhaust ventilation unit used in a single room.

It covers units that contain at least, within one or more casings:

- supply and exhaust air fans;
- air filters;
- air-to-air heat exchangers and/or extract-air to outdoor-air heat pump for extract air heat recovery;
- control system;

Such unit can be provided in more than one assembly, the separate assemblies of which are designed to be used together.

The standard supplied test methods for:
- Performance testing of aerodynamic characteristics (chapter 6.2):
  i.e. leakages and mixing; airflow/pressure curves and filter bypass;
- Performance testing of thermal characteristics (chapter 6.3):
i.e. Temperature & humidity ratio’s; operation at low outdoor temperatures;
- Performance testing of acoustic characteristics (chapter 6.4)
  i.e. radiative sound power in the indoor or outdoor space;
- Electric power input (chapter 6.5).

Internal and external unit leakage rate classifications according to this standard are given in Table 1-7 (pp. 14).
Filter bypass leakage rate classifications according to this standard are given in Table 1-8 (pp. 15).

3.1.17 EN 1886 Mechanical performance air handling units

**Full title:** EN 1886:2007, *Ventilation for buildings - Air handling units - Mechanical performance. 2007*

This standard specifies test methods, test requirements and classifications for air handling units, which are supplying and/or extracting air via a ductwork ventilating/conditioning a part or the whole of the building. This standard is not applicable to the following: a) air conditioning units serving a limited area in a building, such as fan coil units; b) units for residential buildings; c) units producing ventilation air mainly for a manufacturing process. Except for the thermal and acoustic performance of the casing, the test methods and requirements are applicable to both complete units and any separate sections. The filter bypass test is not applicable to the testing of high efficiency particulate air filters (HEPA).

3.1.18 EN ISO 5801 Industrial fans, performance testing

**Full title:** EN ISO 5801:2008, *Industrial fans - Performance testing using standardized airways. 2008*

This 249-page International Standard is the result of almost 30 years of discussion, comparative testing and detailed analyses by leading specialists from the fan industry and research organizations throughout the world. It is applicable to fans and the basis for the Ecodesign Fan Regulation. For more details see Chapter 4.

3.1.19 EN ISO 3741, 3744, 3746, 5136 Acoustics

The following standards, especially ISO 3746 and ISO 5136, are relevant for noise power testing of ventilation units

EN ISO 3741:1999, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms*

EN ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

EN ISO 3746:1995, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

EN ISO 5136:2003, *Acoustics — Determination of sound power radiated into a duct by fans and other air moving devices — In-duct method*

3.1.20 EN 779, EN 1822 Air filters performance

**Full titles:**
EN 779:2003, Particulate air filters for general ventilation - Determination of the filtration performance. (currently under review; latest publication prEN 779:2009)

EN 1822:2009, High efficiency air filters (EPA, HEPA and ULPA) – Parts 1 to 5 (Part 1: Determination of the filtration performance)


European standards EN-779:2003 and EN-1822 define filter efficiency classes EU1 to EU18 for mechanical filters. ISO 10121 deal with gas adsorption filters.

Class EU1 to EU4 defines coarse filter classes, better known as G1 to G4. The G classification is determined by the overall gravimetric efficiency (mass retained) which is mainly determined by particles of 1 micron (μm) upwards. The efficiency is measured at several intervals until the pressure drop reaches a level of 250 Pa (Pascal). Filters of type G2 or G3 are mostly used in residential ventilation systems. Table 1-9 (pp. 15) gives examples of particles that are retained. Lower limits of G-classes are 50/65/80/90%.

Fine filters EU5 to EU9 (F5 to F9) relate to the efficiency in capturing particles of 0.4 micron (μm) and the efficiency is measured with an optical particle counter (OPC) up to a pressure drop of 450 Pa. Lower limits of F-classes are 40/60/80/90/95%.

Filters class EU10 to EU14 describe the so-called HEPA (High Efficiency Particulate Air) filters which are used in the pharmaceutical and food industry, hospitals, etc. The test is described in EN 1822-1 and the classification is based on the efficiency in capturing particles of 0.3 μm. Lower limits of the H10 to H14 classes are 85/95/99.9/99.95/99.995%.

ULPA (Ultra Low Penetration Air) filters are used almost exclusively in clean rooms of the electronics industry and are tested on their efficiency in capturing 0.12 μm particles. Efficiency limits are from 99.995% upwards.

Table 1-10 (pp. 16) gives an overview of EN 1822-1 classifications.

Although it is not mentioned explicitly, the EN 779 and EN 1822-1 apply only to mechanical filters, typically in larges air conditioning and air treatment installations that can be found e.g. on the rooftops of large buildings. The test rig is set up for an air duct of 61 x 61 cm section and the default air flow is 3400 m³/h (face velocity 2.5 m/s). Coarse filters G-class should be tested up to a pressure drop of 250 Pa and Fine filters (F-Class) up to 450 Pa. Both values are relatively high compared to real-life. EN 13799 mentions typical pressure drop values for filters (see table).

---

30 EN 779:2002 test procedure is: firstly test pressure drop with ambient atmospheric dust under 4 different air flow rate (50%, 75%, 100% and 120% of rated air flow), secondly use the optical particle counter to sample sequentially between upstream and downstream to determine the 0.4μm particle size efficiency, thirdly liquid DEHS (Sebacic acid-bis ester) is fed to the filter gradually, and the feeding is interrupted periodically to test the arrestance or counting efficiency, pressure drop and weight of dust fed. Then the type of air filter is determined upon its average performance.
Table 1-53. Examples for pressure drops for specific components in air handling systems (acc. table A.8 of EN13779). EXTRACT from table 1-33.

<table>
<thead>
<tr>
<th>Component</th>
<th>Pressure losses in [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Air filter F5 – F7 per section</td>
<td>100</td>
</tr>
<tr>
<td>Air filter F8 – F9 per section</td>
<td>150</td>
</tr>
<tr>
<td>HEPA filter</td>
<td>400</td>
</tr>
<tr>
<td>Gas filter</td>
<td>100</td>
</tr>
</tbody>
</table>

### 3.1.21 EN 14134 Installation checks residential ventilation

EN 14134:2004, *Ventilation for buildings - Performance testing and installation checks of residential ventilation systems.* 2004

Specifies checks and test methods in order to verify the fitness for purpose of installed ventilation systems in dwellings. It can be applied to commissioning of new systems and performance testing of existing systems. The standard enables the choice between simple test methods, when sufficient, and extensive measurements, when necessary. The standard applies to mechanical and non-mechanical (natural) ventilation systems comprising any of the following: - passive stack ventilation ducts; - air terminal devices (supply, exhaust); - air transfer devices (externally mounted, internally mounted); - controls; - ducts; - fans; - filters; - heat recovery; - heating/cooling of supply air; - recirculation air; - cooker hood; - cowl; - dampers; - sound reduction devices. The standard is intended to define the procedure by which the system is checked and assessed before handing over.

### 3.1.22 EN 12599 : 2000 (AC : 2002) Installation checks ventilation and air conditioning

EN 12599 : 2000, *Ventilation for buildings - Test procedures and measuring methods for handing over installed ventilation and air conditioning systems (standard under revision, Nov. 2010)*

Specifies checks, test methods and measuring instruments in order to verify the fitness for purpose of the installed systems at the stage of handing over. The standard enables the choice between simple test methods, when sufficient, and extensive measurements, when necessary. The standard applies to mechanically operated ventilation and air conditioning systems comprising any of the following: - Air terminal devices and units - Air handling units - Air distribution systems (supply, extract, exhaust) - Fire protection devices - Automatic control devices.

### 3.1.23 EN 1507, EN 12237 Ductwork (not in scope)

Ductwork is out of the scope of the study, but the following standards are mentioned regarding the tightness of ductwork for possible future action:

EN 1507: 2006, *Ventilation for buildings - Sheet metal air ducts with rectangular section - Requirements for strength and leakage*

EN 12237: 2003, *Ventilation for buildings - Ductwork - Strength and leakage of circular sheet metal ducts*

---

31 Pers. Com. Lindab GmbH
3.2 Subtask 1.2.2 - Standards at Member State level

Most countries adopt the European standards. Some of the standards may have national appendices to explicit default values required in the standards but when this is the case, this has been developed when describing the European standards.

No national Member State standard has been indicated as useful for this study by stakeholders except for standards relating to national building codes. In that case, these standards are addressed in the subtask 1.3 of this report.

3.3 Subtask 1.2.3 – Third country standards

No Third Country standard has been indicated as useful for this study by stakeholders except ISO standard which are compatible with or referred to by EN standards as fundamental standards.

3.4 Discussion and guidance

As mentioned in par. 1.1, the scope of the study relates to mechanical ventilation systems with individual fan power of more than 125 W, used predominantly in non-domestic or collective domestic applications. Hence, both the sets of standards for non-residential and residential applications shown in par. 3.1 are relevant. Having said that, a proportionate analysis in terms of environmental and resources impact of measures—as will be shown in the following task reports—would focus more on the non-residential standards in the right-hand side of Table 1-21 in par. 3.1.

The function of products in the scope is to provide ventilation of buildings, as defined in par. 2.2. As such, mechanical ventilation systems compete amongst each other and with natural ventilation solutions (infiltration, opening windows, etc.). Hence all standards in Chapter 3 that relate to ventilation requirements of buildings are relevant. As mentioned above, a proportionate analysis would focus on the ventilation requirements of non-residential buildings, e.g. EN 13779 and EN 15251.

Ultimately, the analysis of test standards should help in constructing robust measures for the products in the scope. Hence, it would be more proportionate to spend more effort in the analysis of the products, i.e. EN 13053, than of the ventilation requirements of buildings.

A significant part of the products in the scope are modular products, i.e. built from components (fans, heat exchangers, filters, etc.) which may or may not be supplied by outside sources and which may or may not answer to their own set of test standards. In order to avoid inconsistencies and loopholes between product test requirements and test requirements for modules, it is relevant that the underlying study covers the test standards for the most important components, at least in as much as they are referenced in the product standards, e.g. EN 308 (heat recovery devices), EN 1886 (mechanical performance), EN 779 (filter performance), etc.. Having said that, a proportionate analysis would spent more effort in analysing strict product standards, i.e. EN 13053.

The following summarizes the most important contradictions between standards:
Heat recovery efficiency tests incompatible:
EN 13142 (residential) prescribes tests at temperature difference $\Delta T = 13$ K and allows the inclusion of motor waste heat. EN 13053 with reference to EN 308 (non-residential) prescribes tests at temperature difference $\Delta T = 20$ K and does not allow the inclusion of motor waste heat. EN 13142 values are thus higher.

Heat recovery efficiency definitions incompatible:
EN 1342 always defines heat recovery efficiency as thermal efficiency (based on in- and output air flows and temperatures or enthalpies). EN 13053 (also) defines energy efficiency, taking into account some subtraction from thermal efficiency for the extra (fan) electricity consumption arising from the pressure drop over the heat exchanger. EN 13142 values are thus higher.

Electrical efficiency definitions and tests incompatible:
EN 13142 (residential) defines Specific Power Input (SPI) for the unit in W/(m$^3$/h) for the unit at nominally (max.) 100 Pa and a reference air volume flow that is 70% of the maximum air volume flow at standard air conditions (20°C and 101 325 Pa). The measurement includes the (internal pressure drop of the) complete unit, including fans, heat recovery unit and filter.

EN 13799 (non-residential) defines Specific Fan Power (SFP) at a reference point for a ventilation system also in W/(m$^3$/h) or W/(m$^3$/s) but does not specify external pressure difference, i.e. the external pressure is implicitly assumed for the specific application. The reference point is at the nominal power input (for fixed speed fans), at a defined partial airflow and related pressure (for variable air flow systems) or if data on partial airflow rate and related external pressure is not specified, at 65% of the maximum design airflow rate and external pressure. The measurement includes the (internal pressure drop of the) complete unit, including fans, heat recovery unit and filter.

EN 13053 (non-residential) defines electric power classes P1..9, following a linear multipliers for an empirical reference curve that includes flow rate $q_v$ and external static pressure $p_{stat}$ at a reference point (formula $P_{ref} = (p_{stat} / 450)^{0.925} \times (q_v + 0.08)^{0.95}$ see par. 3.1.9). The reference point is not defined in the standard, but it is assumed to be the best efficiency point at nominal fan speed (typically also at 65-70% of nominal flow rate). The measurement is done for fan and casing, i.e. it excludes the (internal pressure drop of the) heat recovery unit and filter. The electricity consumption caused by the internal pressure drop of heat recovery and filter module is taken into account elsewhere in EN 13053 through the energy efficiency definition of the heat recovery unit and maximum pressure drop requirements for filters.

EN ISO 5801, which is the basis the Fan Regulation 327/2011 (see Chapter 4), defines a calculated efficiency $\eta_e$ composed from nominal measured motor efficiency $\eta_m$, transmission efficiency (following defaults) $\eta_T$, fan impeller efficiency $\eta_r$, a compensation factor for matching of components $C_m$ and a part load compensation factor $C_c$. In formula: $\eta_e = \eta_r \times \eta_m \times \eta_T \times C_m \times C_c$. The reference for the fan impeller efficiency is the best efficiency point vis-à-vis the ductwork configuration defined in the standard (and indirectly indicated by the fan manufacturer). Fan efficiencies according to ISO 5801, or rather the Fan Regulation 327/2011, will be slightly higher than those according to EN 13053, because the Fan Regulation measurement does not incorporate casing losses (ca. 10-20 Pa) and compensates for variable speed drive losses (e.g. factor $C_c$, see par. 4.1.2 and task 4 report).

Leakage test differences:
Leakage tests for residential units are defined in EN 13141-7 and -8 (residential) as well as EN 308 (non-residential, heat exchangers). The methods (tracer gas and overpressure) are different and for overpressure measurements the test pressures are different.
Ventilation requirements differences:

The recommended minimum ventilation rates for non-residential buildings for EN 15251 at times of non-occupancy seem significantly higher than those used for residential buildings (see Chapter 4, also see CEN/TR 14788). This subject will be discussed in Task 7 (remarks REHVA) and it may be just a matter of clarification. If not, there is a case for substantial energy saving. Note that this issue is important also for the study of mechanical ventilation units, because it can have a considerable influence on the merits of variable speed control and other control-related issues for these products.
4 Subtask 1.3 - Existing legislation

4.1 Subtask 1.3.1 - Legislation and Agreements at European Community level

4.1.1 Ecodesign Directive for Energy-related Products 2009/125/EC (recast)

The recast Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products was adopted by the European Parliament and the Council the 21 October 2009. This Directive shall not apply to means of transport for persons or goods.

The Ecodesign Directive was introduced in 2005 for energy-using products (Directive 2005/32/EC) and extended in 2009 to energy-related products. It is a new approach Directive, which means that the so-called blue guide is applicable\(^{32}\) and the Directive should make use of harmonised EN standards. The directive is a so-called Article 95 Directive, i.e. set up with the aims of promoting the EU single market, free movements of goods and harmonisation of national legislation within the EU. The Directive offers to set generic or specific requirements and it offers the possibility to employ voluntary agreements as an equivalent to legislation.

4.1.2 Ecodesign Fan Regulation

The Ecodesign Commission Regulation 327/2011 on Fans >125 W (hereafter ‘Fan Regulation’), covers fans with rated electric motor power of 125 W or higher.

It uses the fan system efficiency as a parameter for Minimum Efficiency Performance Standards (MEPS).

It is based on the ISO 5801 standard for the performance assessment.

The Fan Regulation uses 4 different measurement categories, depending on whether the fan inlet and outlet are both free (category A), ducted on the outlet side (B), on the inlet side (C) or ducted on both sides. ISO 5801 defines the standard airways (ducts) that allows fans to be tested with harmonized test set-ups. A fan adaptable to more than one measurement category will have more than one performance characteristic.

The Fan Regulation then distinguishes, depending on measurement category, an efficiency category which may be based on either static pressure\(^{33}\) or total pressure\(^{34}\), resulting in either static efficiency or total efficiency. The Fan Regulation proposes an assessment at the Best Efficiency Point (BEP).


\(^{33}\) ‘Fan static pressure’ \(p_{sf}\) means the fan total pressure \(p_{f}\) minus the fan dynamic pressure corrected by the Mach factor; ‘Mach factor’ means a correction factor applied to dynamic pressure at a point, defined as the stagnation pressure minus the pressure with respect to absolute zero pressure which is exerted at a point at rest relative to the gas around it and divided by the dynamic pressure; ‘Stagnation pressure’ means the pressure measured at a point in a flowing gas if it were brought to rest via an isentropic process;
The nominal rated motor efficiency $\eta_m$ should be determined in accordance with Regulation 640/2009 whenever applicable. If the motor is not covered by Regulation 640/2009 or in case no motor is supplied a default $\eta_m$ is calculated for the motor using empirical equations given in the regulation.

As regards the use of Variable Speed Drives, the Fan Regulation recognizes that —although in a standard test it may cost some energy— in practice this is an efficient feature and it has introduced a part load compensation factor $C_c$ in the equation for the fan system efficiency. The drive efficiency $\eta_T$ is 100% for a direct-drive, 89% for a ‘low-efficiency drive’ and 94% for a ‘high efficiency drive’.

In case the fan is not placed on the market as a ‘final assembly’ —not relevant for products in the scope of ENTR Lot 6 but mentioned to complete the picture—there is a compensation factor $C_m$ in the equation (default 0.9) that accounts for matching of components.

All in all, the generic equation for fan system efficiency in the Fan Regulation, using the notation from the Fan Regulation is

$$\eta_e = \eta_r \cdot \eta_m \cdot \eta_T \cdot C_m \cdot C_c,$$

where:

- $\eta_e$ is the overall efficiency;
- $\eta_r$ is the fan impeller efficiency according to $P_{u(s)}/P_a$, where:
  - $P_{u(s)}$ is fan gas power determined at the point of optimal energy efficiency for the impeller;
  - $P_a$ is the fan shaft power at the point of optimal energy efficiency of the impeller;
- $\eta_m$ is the nominal rated motor efficiency in accordance with Regulation 640/2009 whenever applicable. If the motor is not covered by Regulation 640/2009 or in case no motor is supplied a default $\eta_m$ is calculated for the motor using the following values:
  - if the recommended electric input power $P_e$ is $\geq 0.75$ kW,
    $$\eta_m = 0.000278*(x^3) - 0.019247*(x^2) + 0.104395*x + 0.809761$$
    where $x = \log(P_e)$
  - and $P_e$ is as defined in 3.1.(a);
  - if the recommended motor input power $P_e$ is $< 0.75$ kW,
    $$\eta_m = 0.1462\ln(P_e) + 0.8381$$
  - and $P_e$ is as defined in 3.1.(a), where the electric input power $P_e$ recommended by the manufacturer of the fan should be enough for the fan to reach its optimum energy efficiency point, taking into account losses from transmission systems if applicable;
- $\eta_T$ is the efficiency of the driving arrangement for which the following default values must be used:
  - for direct drive $\eta_T = 1.0$;
  - if the transmission is a low-efficiency drive then
    - $P_a \geq 5$ kW, $\eta_T = 0.96$ or $1$ kW $< P_a < 5$ kW, $\eta_T = 0.0175 \times P_a + 0.8725$ or
    - $P_a \leq 1$ kW, $\eta_T = 0.89$
  - if the transmission is a high-efficiency drive then

34 ‘Fan total pressure’ ($p_f$) means the difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet;
P_a ≥ 5 kW, η_T = 0.98 or 1 kW < P_a < 5 kW, η_T = 0.01 * P_a + 0.93 or P_a ≤ 1 kW, η_T = 0.94

C_m is the compensation factor to account for matching of components, with value 0.9 for fans without housing and 1 for fans with housing;

C_c is the part load compensation factor:
for a motor without a variable speed drive C_c = 1.0
for a motor with a variable speed drive and P_{ed} ≥ 5 kW then C_c = 1.04
for a motor with a variable speed drive and P_{ed} < 5 kW then C_c = -0.03 ln(P_{ed}) + 1.088.

In its target efficiency the Fan Regulation also implicitly uses the new ISO 12759 and AMCA 205 standard on FMEG, because it sets a different target for units up to 10 kW electric motor power input and units above 10 kW. Target values for category A,C seem less ambitious than for category B,D, but it must be taken into account that these are efficiencies based on total pressure, i.e. generally 10-15%-points higher than the efficiency values based on static pressure.

The table below gives a summary of the Fan Regulation and examples of minimum efficiency targets for several values of the electric motor power P (in kW). Values of P in the examples match those of CEXH, CHRV, AHU-S, AHU-M and AHU-L, given in Task 2.

Table 1-54 . Ecodesign Fan Regulation 327/2011, summary and examples

<table>
<thead>
<tr>
<th>fan type</th>
<th>cat.</th>
<th>press.</th>
<th>range P in kW</th>
<th>η_{target} =</th>
<th>N</th>
<th>N</th>
<th>P=</th>
<th>0.5</th>
<th>1</th>
<th>2.2</th>
<th>7.5</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial A, C static</td>
<td>P ≤ 10</td>
<td>2.74 ∙ ln(P) – 6.33 + N</td>
<td>36</td>
<td>2013</td>
<td>27</td>
<td>30</td>
<td>32</td>
<td>35</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>0.78 ∙ ln(P) – 1.88 + N</td>
<td>40</td>
<td>2015</td>
<td>31</td>
<td>34</td>
<td>36</td>
<td>39</td>
<td>41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P ≤ 10</td>
<td>2.74 ∙ ln(P) – 6.33 + N</td>
<td>50</td>
<td>2013</td>
<td>41</td>
<td>44</td>
<td>46</td>
<td>49</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>0.78 ∙ ln(P) – 1.88 + N</td>
<td>58</td>
<td>2015</td>
<td>49</td>
<td>52</td>
<td>54</td>
<td>57</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC without housing ** A, C static</td>
<td>P ≤ 10</td>
<td>4.56 ∙ ln(P) – 10.5 + N</td>
<td>58</td>
<td>2013</td>
<td>44</td>
<td>48</td>
<td>51</td>
<td>57</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>1.1 ∙ ln(P) – 2.6 + N</td>
<td>62</td>
<td>2015</td>
<td>48</td>
<td>52</td>
<td>55</td>
<td>61</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC with housing *** A, C static</td>
<td>P ≤ 10</td>
<td>4.56 ∙ ln(P) – 10.5 + N</td>
<td>58</td>
<td>2013</td>
<td>44</td>
<td>48</td>
<td>51</td>
<td>57</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>1.1 ∙ ln(P) – 2.6 + N</td>
<td>62</td>
<td>2015</td>
<td>48</td>
<td>52</td>
<td>55</td>
<td>61</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed flow A, C static</td>
<td>P ≤ 10</td>
<td>4.56 ∙ ln(P) – 10.5 + N</td>
<td>47</td>
<td>2013</td>
<td>33</td>
<td>37</td>
<td>40</td>
<td>46</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>1.1 ∙ ln(P) – 2.6 + N</td>
<td>50</td>
<td>2015</td>
<td>47</td>
<td>47</td>
<td>48</td>
<td>50</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross flow B, D total</td>
<td>P ≤ 10</td>
<td>1.14 ∙ ln(P) – 2.6 + N</td>
<td>13</td>
<td>2013</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 &lt; P</td>
<td>N</td>
<td>21</td>
<td>2015</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>21</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

35 AMCA 205. Energy efficiency classification for fans
36 Dynamic pressure (in Pa) is the pressure derived from the mass flow rate, the average gas density at the outlet and the fan outlet area.
The Commission expects an electricity saving potential of 5% in 2020 from this generic fan measure (34 TWh/a on a total of 660 TWh/a in baseline 2020).

Although the Ecodesign Fan Regulation promises to be a valuable generic instrument to eliminate the least efficient fans from the market, it is by no means a substitute for the regulation of energy consumption inside a specific application such as the mechanical ventilation unit, because

- It does not cover the role of controls and heat recovery, thus missing out on very important saving potential related to mechanical ventilation;

- Even when related on electricity consumption alone, the ambition level of a generic fan measure is governed by the economics of the “weakest application” in terms of payback-time and Life Cycle Costs, in order to avoid a “negative impact on the industry” (boundary condition of directive 2009/125/EC). In contrast, when the application is known—as is the case with mechanical ventilation—the ambition level can be specific and in this case much higher. For the application in non-residential ventilation units, where usually the category B,D (with outlet ducts) applies and cross-flow fans are not suitable, it seems that 5% is a conservative estimate. The potential could be increased by excluding forward curved and radial fans for this application.

- A generic fan measure uses generic test conditions. A specific application uses its own measurement standards, which take into account the specific design and (selection of) components used. For instance, using the same fan, there may be up to 50% electricity saving of the ventilation unit depending on the internal pressure drop of the casing, fan in/outlet, filters and the heat recovery unit (see also Task 5).

- Last but not least, the selection of the right fan, motor and drive in relation to the load profile of a ventilation unit may give a very different design than is evident from generic fan specifications. This is related to the so-called ‘fan-laws’, describing the non-linear relationship of the energy use, fan impeller and fan speed. This is explained in Task 5, i.e. showing that the best efficiency point (bep) of a generic fan test (usually at 70% of nominal pressure and flow rate) is often not the bep in operation. Depending on the application, it may e.g. be advantageous to choose a large impeller with a smaller (lower rpm) motor and fitting variable speed drive, especially if the fan is to operate in part load. According to the fan laws, a 10% increase of impeller diameter results in a 41% energy saving (fifth power correlation, c.p.). The fan rotational speed decrease of 20% leads to an almost 50% decrease in absorbed power (third power correlation, c.p.). These effects will often not show from a fan manufacturer’s catalogue, where the priority is usually to show a fan with the highest nominal flow rate at the lowest price.
4.1.3 Ecodesign Electric Motor Regulation No. 640/2009

The Ecodesign Commission Regulation No. 640/2009 on Motors > 750 W (and < 375 kW) was published d.d. 23.7.2009. Regulation No. 640/2009 stipulates that (brushless squirrel cage) fan motors have to reach IE2 level on the 16th of July 2011 and meet either the IE3 level or be equipped with a variable speed drive by 1 January 2015 (large motors 7.5-375 kW) respectively 1 January 2017 (all motors 0.75-375 kW).

Motors in ventilation units or ventilation fans are not part of the exemptions, and thus the regulation will apply in general. However, it applies only to electric single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motor that:

— has 2 to 6 poles,
— has a rated voltage of \( U_N \) up to 1 000 V,
— has a rated output \( P_N \) between 0.75 kW and 375 kW,
— is rated on the basis of continuous duty operation.

These single speed motors are rare in ventilation unit applications and thus the impact of the measure will be very limited on the products in scope.


On 19 May 2010, a recast of the Energy Performance of Buildings Directive was adopted by the European Parliament and the Council of the European Union in order to strengthen the energy performance requirements and to clarify and streamline some of the provisions from the 2002 Directive (2002/91/EC) it replaces. In November 2008, the Commission adopted the proposal for a recast of the Energy Performance of Buildings Directive. Throughout 2009, the proposal went through the approval process of the European Parliament and Council and a political agreement was achieved 17 November 2009. The recast proposal confirms the importance of effective implementation at the Member State level, the importance of Community-wide co-operation and the strong long-term commitment and role of the Commission itself to support such effective implementation. As the November 2008 Commission Communication for the original proposal states, buildings have significant untapped potential for cost effective energy savings "which, if realized, would mean that in 2020 the EU will consume 11 % less final energy." The magnitude of the potential savings is such that every effort must be made to achieve it.

Highlights:

- As of 31 December 2020 new buildings in the EU will have to consume 'nearly zero' energy and the energy will be 'to a very large extent' from renewable sources.

- Public authorities that own or occupy a new building should set an example by building, buying or renting such 'nearly zero energy building' as of 31 December 2018.

- The definition of very low energy building was agreed to: "nearly zero energy building means a building that has a very high energy performance, determined in accordance with Annex I. The nearly zero or very low amount of energy required should to a very significant level be covered by energy from renewable source, including renewable energy produced on-site or nearby"

- There is no specific target to be set for the renovation of existing building, but Member States shall following the leading example of the public sector by developing policies and take
measures such as targets in order to stimulate the transformation of buildings that are refurbished into very low energy buildings, and inform the Commission thereof in their national plans referred to in paragraph 1.

- The 1000m² threshold for major renovation has been deleted and this will take effect when the national regulations have been implemented and applied, probably at the beginning of 2014.

- Minimum requirements for components are introduced for all replacements and renovations, although for major renovations, the holistic calculation methodology is the preferred method with performance calculations based on component requirements allowed as a complement or alternatively

- A harmonised calculation methodology to push-up Member States’ minimum energy performance requirements towards a cost-optimal level is set out in the Directive in a definition and an annex, and will also be refined in a comitology process. Member States will have to justify to the Commission if the gap between current requirements and cost optimal requirements is more than 15%.

- A more detailed and rigorous procedure for issuing energy performance certificates will be required in Member States.

- Control systems will be required by MS to check the correctness of performance certification.

- Member States will be required to introduce penalties for non-compliance. Member States shall lay down the rules on penalties applicable to infringements of the national provisions adopted pursuant to this Directive and shall take all measures necessary to ensure that they are implemented. The penalties provided for must be effective, proportionate and dissuasive. Member States shall communicate those provisions to the Commission.

Relevant citations for ventilation units are

Recital 12.

(12) When setting energy performance requirements for technical building systems, Member States should use, where available and appropriate, harmonised instruments, in particular testing and calculation methods and energy efficiency classes developed under measures implementing Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (1) and Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (2), with a view to ensuring coherence with related initiatives and minimise, to the extent possible, potential fragmentation of the market.

Art. 2: Definitions

Ventilation is part of the ‘technical building system’ and explicitly mentioned as part of the energy performance of buildings

Art. 4 Setting of minimum energy performance requirements

These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation,...
Article 8 Technical building systems

System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.

The system requirements shall cover at least the following:

(a) heating systems;
(b) hot water systems;
(c) air-conditioning systems;
(d) large ventilation systems;
or a combination of such systems.

Article 15 Inspection of air-conditioning systems

Article 15 sets an obligation of the inspection air-conditioning systems >12 kW rated output regarding efficiency and sizing; air handling is not mentioned explicitly.

ANNEX I. Common general framework for the calculation of energy performance of buildings

3. The methodology shall be laid down taking into consideration at least the following aspects:

(c) air-conditioning installations;
(d) natural and mechanical ventilation which may include air-tightness;

4. For the purpose of the calculation buildings should be adequately classified into the following categories:

(a) single-family houses of different types;
(b) apartment blocks;
(c) offices;
(d) educational buildings;
(e) hospitals;
(f) hotels and restaurants;
(g) sports facilities;
(h) wholesale and retail trade services buildings;
(i) other types of energy-consuming buildings.

EPBD standards

Over 30 European Standards were produced in support of the EPBD under the following Technical Committees.

TC 89 Thermal performance of buildings and building components;
TC 156 Ventilation for buildings;
TC 169 Light and lighting;
TC 228 Heating systems in buildings;
TC 247 Building automation, controls and building management.

ISO/TC 163 *Thermal performance and energy use in the built environment.* is also now working in these areas.

The majority of the standards published by CEN/TC 89 are also global standards, either prepared under CEN/TC 89 lead or under ISO/TC 163 lead. (European standards prepared in cooperation with ISO are designated “EN ISO XXX”.)

### 4.1.5 Energy Labelling Directive 2010/30/EU (recast)

The recast Energy Labelling Directive 2010/30/EU was adopted by the European Parliament and Council the 19th May 2010. The directive introduces the possibility for new efficiency classes A+, A++ and A+++ on top of the existing A grade for the most energy-efficient household products.

The new directive extends the energy label to energy-related products in the commercial and industrial sectors, e.g. cold storage rooms and vending machines. A Commission working group will determine the energy classes and the specific products that will be labelled.

The extension of the scope from energy-using to energy-related products (including construction products) implies that the Directive covers any good having an impact on energy consumption during use. These products could not only consume energy but could also "have a significant direct or indirect impact" on energy savings. Examples are window glazing and outer doors.

Energy labelling requirements are already in force for a number of products and the Commission will adopt delegated regulations for energy labelling in parallel with the adoption of the Ecodesign regulations. The new labels will be mandatory for products placed on the market a defined time after the regulation has been published in the OJ.

According to the new Energy Labelling Directive, the layout of the energy efficiency label gives room to up to three new energy classes to reflect technological progress. However, the total number of classes will still be limited to seven. The labelling colour scheme will be adjusted accordingly, so that the highest energy efficiency class will remain dark green and the lowest energy efficient class will be red.

### 4.1.6 European Union Ecolabel Regulation 66/2010

The EU Ecolabel may be awarded to products and services which have a lower environmental impact than other products in the same group. The label criteria were devised using scientific data on the whole of a product’s life cycle, from product development to disposal.

The label may be awarded to all goods or services distributed, consumed or used on the Community market whether in return for payment or free of charge. It does not apply to medicinal products for human or veterinary use, or to medical devices.


**Award criteria**

The label shall be awarded in consideration of European environmental and ethical objectives. In particular:
• the impact of goods and services on climate change, nature and biodiversity, energy and resource consumption, generation of waste, pollution, emissions and the release of hazardous substances into the environment;
• the substitution of hazardous substances by safer substances;
• durability and reusability of products;
• ultimate impact on the environment, including on consumer health and safety;
• compliance with social and ethical standards, such as international labour standards;
• taking into account criteria established by other labels at national and regional levels;
• reducing animal testing.

The label cannot be awarded to products containing substances classified by Regulation (EC) No 1272/2008 as toxic, hazardous to the environment, carcinogenic or mutagenic, or substances subject to the regulatory framework for the management of chemicals.

Competent bodies

Member States shall designate one or more bodies responsible for the labelling process at national level. Their operations shall be transparent and their activities shall be open to the involvement of all interested parties.

They are specifically responsible for regularly checking that products comply with the label criteria. Their remit also includes receiving complaints, informing the public, monitoring false advertising and prohibiting products.

The procedure for award and use of the label

In order to be awarded the label, economic operators shall submit an application to:

• one or more Member State(s), which will send it to the competent national body;
• a third State, which will send it to the Member State where the product is marketed.

If the product complies with the label criteria, the competent body shall conclude a contract with the operator, establishing the terms of use and withdrawal of the label. The operator may then place the label on the product. The use of the label is subject to payment of a fee when the application is made, and an annual fee.

The European Union Ecolabelling Board (EUEB)

The Commission shall establish a committee representing the national competent bodies. The Commission shall consult the EUEB when developing or revising the award criteria and requirements of the label.

Context

Regulation (EC) No 1980/2000 is repealed. However, it shall continue to apply to contracts concluded before the current Regulation entered into force, until the date of expiry specified in the contracts.

4.1.7 Construction Products Regulation 305/2011/EU (recast)

Single market (art. 95) directive, laying down ‘essential requirements’ for construction products as a basis for CE marking. Essential requirements are part of the harmonized standards. Focus is on
harmonised product-information. The CPR, previously directive 89/106/EEC amended in 1993 and 2003, has recently been recast as a regulation, laying down harmonised conditions for the marketing of construction products.

As part of the Better Regulation initiative, the CPR provides more clarification of the concepts and the use of CE marking. It introduces simplified procedures, which the Commission states will reduce the costs incurred by enterprises, in particular small and medium enterprises (SMEs).

In the category “ventilation for buildings” there are currently 29 EN standards, including the standards mentioned in Chapter 2, published in the Official Journal as containing ‘essential requirements’ relating to the Construction Products Directive 89/106/ECC (predecessor of the current regulation). In commercial practice it appears from anecdotal information that manufacturers especially refer to conformity with CPR requirements for ventilation related to safety in the context of smoke control and high-temperature ventilation (fire-control, e.g. in parking garages).  

4.1.8 LVD - Low Voltage Directive 2006/95/EC

The Low Voltage Directive (LVD) 2006/95/EC is one of the oldest Single Market Directives adopted before the "New" or "Global" Approach. However, it does characterise both with a conformity assessment procedure applied to equipment before placing on the Market and with Essential Health and Safety Requirements (EHSRs) which such equipment must meet either directly or by means of harmonised standards.

The LVD ensures that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union. The Directive covers electrical equipment with a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment. For most electrical equipment, the health aspects of emissions of Electromagnetic Fields are also under the domain of the Low Voltage Directive.

For electrical equipment within its scope, the Directive covers all health and safety risks, thus ensuring that electrical equipment is safe in its intended use. Guidelines on application and Recommendations are available - including LVD Administrative Co-operation Working Group (LVD ADCO) documents and recommendations - as well as European Commission opinions within framework of the Directive.

In respect of conformity assessment, there is no third party intervention, as the manufacturer undertakes the conformity assessment. There are "Notified Bodies" which may be used to provide reports in response to a challenge by a national authority as to the conformity of the equipment.

4.1.9 EMC-D - Electromagnetic Compatibility 2004/108/EC

The main objective of the Directive 2004/108/EC of the European Parliament and of the Council, of 15 December 2004, on the approximation of the Laws of Member States relating to electromagnetic compatibility (EMC) is thus to regulate the compatibility of equipment regarding EMC:

• equipment (apparatus and fixed installations) needs to comply with EMC requirements when it is placed on the market and/or taken into service;

http://esearch.cen.eu/ search term “ventilation for buildings”
• the application of good engineering practice is required for fixed installations, with the possibility for the competent authorities of Member States to impose measures if non-compliance is established.

The EMC Directive first limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended.

4.1.10 MD - Machinery Directive 2006/42/EC

The Machinery Directive 2006/42/EC provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at European Union level. Machinery can be described as "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application".

Essentially performing a dual function, the Directive not only promotes the free movement of machinery within the Single Market, but also guarantees a high level of protection to EU workers and citizens. Being a "New Legal Framework" Directive, it promotes harmonisation through a combination of mandatory health and safety requirements and voluntary harmonised standards. Such directives apply only to products which are intended to be placed (or put into service) on the EU market for the first time.

The Machinery Directive 2006/42/EC was published on 9th June 2006 and it is applicable from 29th December 2009, replacing the Machinery Directive 98/37/EC.

The MD applies to mechanical ventilation products in ENTR Lot 6. The Machinery Directive, similar as the LVD, makes reference to (harmonised standards with) IP-rating for electric components (penetration of humidity and dust), prescribes flame retardants for plastic encasing of electric parts and gives guidance for smoke- and fire control (e.g. cut-out thermostat at high temperature levels).

4.1.11 Packaging Directive 2004/12/EC

The Packaging and Packaging Waste Directive is not included in CE-marking

• Transposed into National Law of Member States, eg.:
• NL - Packaging Convenant
• DE - Grüne Punkt system (Duales System Deutschlands - www.gruenerpunkt.de/index_js.html)
• UK - The Producer Responsibility Obligations (Packaging Waste) Regulations 1997 (as amended), and parallel statutory instruments in the devolved administrations (see note on packaging in UK section)
• Implications: Need to use similar methods/materials as other appliances to facilitate participation in existing compliance schemes. See chapters on national requirements for further details.

---

4.1.12 WEEE Directive 2002/96/EC

The WEEE Directive on Waste of electrical and electronic equipment prescribes minimum requirements for waste treatment and recycling.

It appears to apply to products in the scope of ENTR Lot 6, in as much as they can be classified as ‘Large household appliances’ with sub-categories ‘Air conditioner appliances’ and ‘Other fanning, exhaust ventilation and conditioning equipment’ (see WEEE Directive, Annex IB). For this category Member states shall ensure to reach the following targets:

\[ \text{the rate of recovery shall be increased to a minimum of } 80\% \text{ by an average weight per appliance,} \]
\[ \text{and component, material and substance reuse and recycling shall be increased to a minimum of } 75\% \text{ by an average weight per appliance;} \]

Several manufacturers of air handling units mention that the rules of 2002/96/EC apply. Whether exceptions apply, e.g. for very large units that can be considered as part of the building construction, is unknown.

The WEEE directive is currently (June 2012) under review.

4.1.13 RoHS Directive 2011/65/EU (recast of 2002/95/EC)

The RoHS Directive 2011/65/EU (recast of 2002/95/EC) on the Restriction of Hazardous Substances may be relevant for the electronics components (Pb) and flame retardants (PBB, PBDE) in plastics components. A point of attention is the maximum allowable concentration of lead (Pb) in copper (brass) and aluminium alloys.

In mechanical ventilation units, RoHS-compliances is especially relevant e.g. for flame retardants (no halogenated flame retardants in plastics parts), hazardous substances in the fan control unit (i.e. the electronics) and sensor –materials.

4.1.14 Existing voluntary agreements

The study team is not aware of any specific voluntary agreements at EU level for products in the scope that could be employed voluntary agreements as an equivalent to Ecodesign legislation.

There are voluntary certification programs, at national and international level, that are useful to this study as they give information of the technical characteristics of the products. Hereafter the Eurovent certification, acting at European level, is explained.

4.1.15 Eurovent Certification

Eurovent Certification Company in a third party organism that supplies public certified data on HVAC products to professionals. There are presently 19 certification programs defined. These are “Certify-all” programmes : when a manufacturer enters the scheme, he should declare all the products in its range (e.g. all chillers manufactured). Amongst certified products, chillers, rooftops and air handling units have an ad-hoc labeling system (with air conditioners below 12 kW using the official EU label). These labels are sometimes referred by Member States or regions legislations when no EU energy
efficiency class is available. These programs are described hereafter from information available on ECC website\textsuperscript{39}.

**Certification Air Handling Units (AHU)**

AHU definition Eurovent\textsuperscript{40}

“A double wall casing with at least a filter, a fan and a temperature controlling component delivering air to the building with minimum 1000m\textsuperscript{3}/h;

*Temperature controlling components are Heat recovery, Cooling coil, Heating coil, Humidifiers/Dehumidifiers*”

**Scope**

Participant must certify all models in the applied product ranges up to the maximum stated air flow. The minimum air flow rate must be under 25 000 m\textsuperscript{3}/h.

**Testing**

3.1 *Mechanical characteristics* :

European Standard prEN1886 : Ventilation for buildings - Air Handling Units - Mechanical performance (November 1997)

3.2 *Rating performances*

European Standard prEN13053 : Ventilation for buildings - Air Handling Units - Ratings and performance for units, components and sections (July 1999)

**Certified characteristics**

4.1 *Mechanical characteristics*

*The following mechanical characteristics are certified :*

- a - Casing strength
- b - Casing air leakage
- c - Filter bypass leakage
- d - Thermal transmittance of the casing
- e - Thermal bridging factor
- f - Acoustical insulation of casing

4.2 *Performance characteristics*

*The following mechanical characteristics are certified :*

- a - Air flow - Available static pressure - power input

\textsuperscript{39} http://www.eurovent-certification.com

\textsuperscript{40} Eurovent, Yannick Lu-Cotrelle, pers. comm., Oct. 2010.
b - Octave band in-duct sound power level

\( c \) - Airborne sound power level

\( d \) - Heating capacity*

\( e \) - Cooling capacity*

f - Heat recovery*

g - Pressure loss on water side*

* If standard features of the product range

**Eurovent energy efficiency of Air Handling Units**

A label system has been put in place. It is described hereafter.

The velocity of air (measured in the area of the filter section) was combined to the efficiency and the pressure losses of the heat recovery system, and the active power of fans, to define the efficiency of the unit, and a voluntary classification, issued in 2009. Units were grouped in three categories: 1) Units connected to outdoor air with a design temperature (winter time) below 9°C – classes A to <E; 2) Units with 100% circulation air and units connected to outdoor air with a design temperature (winter time) above 9°C – classes A\(_G\) to <E\(_G\); 3) Stand-alone extract units – classes A\(_A\) to <E\(_A\).

<\( E \) classes have no requirements. For classes A to E, the following table was defined, giving reference values to be used in calculations. In final check \( f \), the absorbed power factor, has to be inferior to \( f_{ref} \).

\[
\Delta p_x, \Delta p_y, \Delta p_z \text{ corrections were based on the following assumptions and correlations:}
\]

- The relationship between velocity in the cross section of the unit and internal static pressure drop is considered to be exponential to the power of 1.4.

- For pressure drop evaluation of the heat recovery section, the design air volume flows across the heat recovery for winter time shall be taken. Pressure drop increase due to condensation is not taken into account. Heat recovery efficiency figures for run around coil systems are based on fluid with 25% ethylene glycol and inlet temperatures 0°C, 22°C respectively.

- Weighting ratio between electric energy and thermal energy is 2 in Europe, meaning that 1 kWh of electric energy is equivalent to 2 kWh of primary thermal energy. The empirical formula for the equivalence between the efficiency and the pressure drop of a heat recovery system is:

\[
f = \frac{P_{sq} + P_{et}}{P_{sq-rdf} + P_{et-rdf}} \quad \text{(1)}
\]

\[
\Delta p_{air-side-rdf} = \left[ \frac{\Delta p_{\text{state}} - (\Delta p_x + \Delta p_y + \Delta p_z)}{450} \right]^{0.925} \times (a_{y-z} + 0.08)^{0.95} \quad \text{(2)}
\]

\[
\Delta p_x = \left( \Delta p_{\text{state}} - \Delta p_{\text{external}} \right) - \Delta p_{\text{HES}} \times \left[ 1 - \left( \frac{\nu_{ef}}{\nu_s} \right)^{1.4} \right] \quad \text{(3)}
\]

\[
\Delta p_y = \Delta p_{\text{HES}} - \Delta p_{\text{ref}} \quad \text{(4)}
\]

\[
\Delta p_z = (\gamma_{ref} - \gamma_s) \times \left( 1 - \frac{\nu_{ef}}{100} \right) \times [(-0.0035 \times t_{DA} - 0.79) \times t_{DA} + 81] \quad \text{(5)}
\]
system, as a function of the outdoor climate, has been derived from numerous energy consumption calculations all over Europe.

Table 1-55. Eurovent energy efficiency classes for AHU

<table>
<thead>
<tr>
<th>CLASS</th>
<th>Reference to be used in the calculations</th>
<th>Subgroup 1</th>
<th>Final check of class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All subgroups</td>
<td>Subgroup 1</td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>$v_{r,c} [m/s]$</td>
<td>$\eta_{r,c} [%]$</td>
<td>$\Delta P_{r,c} [Pa]$</td>
</tr>
<tr>
<td>A / AG / A†</td>
<td>1.8</td>
<td>75</td>
<td>220</td>
</tr>
<tr>
<td>B / BG / B†</td>
<td>2.0</td>
<td>66</td>
<td>230</td>
</tr>
<tr>
<td>C / CG / C†</td>
<td>2.2</td>
<td>57</td>
<td>170</td>
</tr>
<tr>
<td>D / DG / D†</td>
<td>2.5</td>
<td>47</td>
<td>125</td>
</tr>
<tr>
<td>E / EG / E†</td>
<td>2.8</td>
<td>37</td>
<td>100</td>
</tr>
<tr>
<td>&lt;E / &lt;EG / &lt;E†</td>
<td>No requirements</td>
<td>No requirements</td>
<td></td>
</tr>
</tbody>
</table>

For the preparation of this table, an amendment of EN13053 was necessary, in order to refine the velocity and heat recovery classes, so it was submitted to CEN/TC 116 in spring 2009.

Certification Air to Air Plate Heat Exchangers (AAHE)

Definition

2.1 Air to Air Plate or Tube Heat Exchanger

Heat Exchanger designed to transfer thermal energy (sensible or total) from one air stream to another without moving parts.

Heat transfer surfaces are in form of plates. This exchanger may have parallel flow, cross flow or counter flow construction or a combination of these.

2.2 Product Range

A family of products of different size built according to the same design and using the same selection procedure.

2.3 Dry efficiency

Ratio of dry temperature differences (without condensation):

$$\eta_t = \frac{t_{22} - t_{21}}{t_{11} - t_{21}}$$

with:

11 Warm air inlet
12 Warm air outlet
21 Cold air inlet
22 Cold air outlet

2.4 Wet efficiency
Ratio of wet temperature differences (with condensation):

\[ \eta_i = \frac{t_w^{22} - t_{w1}}{t_{w1} - t_w^{21}} \]

### 2.5 Pressure Drop
Loss in total pressure between the inlet and the outlet of a unit.

### 2.6 Internal Air Leakage
Air leakage between two air streams.

**Testing**

*Tests are conducted in accordance with:*

EN 308 "Heat exchangers - Test procedures for establishing performance of air to air and flue gases heat recovery devices".

Particular specifications shall be applied during the test according to Eurovent document 8/C/001-2005.

**Certified characteristics**

- *a* - Dry efficiency
- *b* - Wet efficiency
- *c* - Pressure drop

*Published data corresponds to a unit with 1 m width (without side wall), 200 Pa pressure loss and a density of 1.2 kg/m³.*

**Certification Air to Air Rotary Heat Exchangers (AARE)**

**Scope**

Eurovent Air to Air Rotary Heat Exchangers Certification Programme applies to all Rotary Heat Exchangers including casing.

Participants shall certify all models, if available, including:

- all classes:
  - condensation rotor / non hygroscopic
  - rotor enthalpy rotor / hygroscopic rotor
  - sorption rotor
- all rotor geometry (wave height, foil thickness)
- all sizes (rotor diameters and rotor depths)
- all materials
- all airflow rates
- all different types of sealing (if available)
The class “sorption rotor” has to fulfill specific additional requirements on the latent efficiency (see the section “Certified Characteristics”)

**Definition**

2.1 Rotary Heat Exchanger:

A Rotary Heat Exchanger is a device incorporating a rotating cylinder or wheel for the purpose of transferring energy (sensible or total) from one air stream to the other. It incorporates heat transfer material, a drive mechanism, a casing or frame, and includes any seals which are provided to retard the bypassing and leakage of air from one air stream to the other.

2.2 Product Range

The Certification Programme applies to the Rotary Heat Exchanger classes “Condensation Rotor/non hygroscopic rotor”, “Enthalpy Rotor/hygroscopic rotor” and “Sorption Rotor”.

**Testing**

_The following standards are used to test the rotors:_

- EN 308 (June 1997) “Heat exchangers – Test procedures for establishing performance of air to air and flue gases heat recovery devices”.

Particular specifications shall be applied during the test according to Eurovent document 8/C/002-2006.

**Ratings**

_Certified characteristics_

a. Sensible efficiency
b. Latent efficiency
c. Pressure drop

_The class “sorption rotor” has to fulfil specific additional requirements on the latent efficiency:_

_Under all tested conditions with nominal airflow rate the latent efficiency has to be at least 60% of the sensible efficiency. Rotors which have lower latent efficiency only can be certified in the class “enthalpy rotor / hygroscopic rotor”._

**Published data**

5.1 Rotor diameters are real outside diameters

5.2 Air velocities are calculated according to the free face area of the rotor (inside seals and without hub) and according to a density of 1.2 kg/m³
5.3 The nominal air flow is calculated according to the above defined velocity and a density of 1.2 kg/m³

5.4 Pressure drop is according to a density of 1.2 kg/m³

Certification Air Filters class F5-F9 (FIL)41

Scope
This Certification Programme applies to air filters elements rated and sold as "Fine Air Filters F5-F9" as defined in EN779.

Definition
2.1 Air Filter Element
A filter unit to clean air from particulate contamination comprising filter material including framing, supporting parts and gaskets, the total to be inserted into a filter housing device.

2.2 Performance Data
Single values out of the filter test report as carried out in accordance with EN 779.

2.3 Product Group
A product group is characterised by the following
* the same filter material
* the same basic construction (e.g. pocket filters, rigid pocket filters or flat sheet etc.)
* the same or lower media velocity: rated air-flow / min. net filter area; (does not have to be published, for info to EUROVENT CERTIFICATION only)
* the same filter class F5, F6, F7, F8 or F9
* published data available about: basic construction, filter media, filter class available via internet or other published sales brochures.

2.4 F-Filter Class: Class of fine air filters based on classification according to EN 779.

2.5 Initial Pressure Drop: Pressure drop of a new filter at the rated air-flow

Testing
Verification of performance characteristics shall be carried out in accordance with the European Standard:

EN 779.2002 or subsequently superseded: "Particulate air filters for general ventilation - Determination of filtration performance - without Annex A (discharge)."

Air filters are a relevant part of products in the scope of ENTR Lot 6, if not for any other reason because the energy consumption of the units is measured with the pressure drop over the filter. And given the fact that often the pressure drop is related to the filtration performance, it makes sense—in the interest of a "level playing field"—also to include the filtration effectiveness as an element of measures.
Ratings

Certified characteristics

The following performance characteristics shall be certified:

* Filter class: F5 up to F9
* Initial pressure drop $\Delta p_0$ in Pa, measured according to EN779 page 12/13
4.2 Subtask 1.3.2 - Legislation at Member State level

The relevant existing legislation on ventilation systems in the Member States has been scrutinized.

Regarding ventilation, Member State’s legislation that was found bases its requirements on the EU standards. Some countries have specific requirements regarding the construction of aeraulic systems, their efficiency and control. Where this information has been identified, it has been reported below country by country. Countries where no specific requirements for mechanical ventilation could be identified, i.e. in most Eastern- and Southern European Member States, are not discussed.

There are relatively few dedicated technical or efficiency requirements, the reason being that the requirements are generally set upon the total primary energy consumption of the building per square meters. Hence, ventilation systems as well as other end uses of the building are constrained without individual requirements on the components of the systems. The few exceptions where requirements have been identified are given hereafter.

4.2.1 Finland


4.1.2

A quantity of heating energy that corresponds to at least 30% of heating energy required for the heating of the ventilation system shall be recovered from the extract air of the ventilation system. A similar reduction in the need for thermal energy can be implemented by improving the thermal insulation of the building envelope, which shall be verified by relevant calculations.

It is permissible not to have heat recovery from extract air for certain individual areas of the building, and also without any corresponding reduction in energy consumption, provided that such heat recovery system can be shown to be inappropriate.

4.1.2.1

A mechanical supply and extract air system is normally equipped with heat recovery from the extract air, in which the heat exchanger’s supply air temperature efficiency shall be at least 50% in a test situation when the mass flow rates of the supply air and extract air are equal, and protection against freezing and removal of water condensed from the extract air is arranged in a reliable way.

The annual efficiency of the heat recovery equipment used in the calculations is the heat exchanger’s supply air temperature efficiency value multiplied by 0.6, unless proved to be otherwise by calculations.

4.1.2.2

Heat recovery system can be shown to be inappropriate for instance in cases where the exceptionally contaminated state of the extract air prevents the functioning of the heat recovery system or the temperature of the extract air is less than +15 °C during the heating season.

The Finnish regulation is representative of heat recovery legislation in the whole of Scandinavia. As regards electrical efficiency of ventilation systems in buildings, Scandinavian countries employ a minimum SFP of around 2 kW/(m³/s). Note that this applies to buildings as a whole.
4.2.2 France

1. General
The French Thermal Regulation\(^{42}\) (2005 for new buildings and 2007 for existing buildings) defines the minimum energy requirements for construction of new buildings and the retrofit of existing buildings. A new version is being prepared and shall enter into force in 2012.

New construction
The global primary energy consumption of the building which includes heating, cooling, hot water, ventilation and lighting, Cep (kWhpe/m².year) should be lower than the reference value Cepref allowed for the specific building characteristics and climate. The map of French climates for the thermal regulation is presented hereunder.

\(^{42}\) French Republic, Code of Construction law and habitation, articles L.111-9, R.111-6 et R.111-20 and application decrees, for new construction.

In addition, generic requirements apply to ventilation systems.

**Existing buildings**

For existing buildings, provisions are similar to new buildings for refurbishment of building with area larger than 1000 m², when the investment of the retrofit is larger than 25 % of the value of the building and if the building has been built after 1948. In all other cases, requirements component by component apply and do include minimum performance requirements for air conditioning and ventilation systems.

---

### 2. Air distribution systems

**New construction**

Reference characteristics

For dwellings, the reference system is a mechanically controlled exhaust system. Exhaust air handling units in kitchen have two speeds. The reference fan power is of 0.25 W / m³h⁻¹ and 0.4 W / m³h⁻¹ if the system is equipped of a F5 to F9 class filter. For dwellings with electric direct heating, the reference ventilation system can modulate the flow.

For buildings that are not dwellings, the reference ventilation system is a mechanical balanced ventilation system without heat recovery nor preheating. The impact of air leakage of the ventilation system is taken into account. The reference fan power is of 0.3 W / m³h⁻¹ and 0.45 W / m³h⁻¹ if the system is equipped of a F5 to F9 class filter.

**Energy consumption follow up**

For buildings that are not dwellings, whether the heated area is larger than 400 m², it should be installed a system to measure the time of operation of each handling unit.

**Existing buildings**

**Minimum requirements**

For dwellings, the maximum fan power allowed is of 0.25 W / m³h⁻¹ and 0.4 W / m³h⁻¹ if the system is equipped of a F5 to F9 class filter.

For buildings that are not dwellings, the reference fan power is of 0.3 W / m³h⁻¹ and 0.45 W / m³h⁻¹ if the system is equipped of a F5 to F9 class filter.

**Control**

For buildings that are not dwellings, whether the heated area is larger than 400 m², it should be installed a timer to stop the mechanical ventilation system during inoccupation periods.

---

### 4.2.3 Germany

EnEV 2009 regulates AHU’s >4000 m³/h. Mandatory: Minimum SFP4 level, automatic controls for humidity (if that is a function offered) and —if the flow rate exceeds 9 m³ per m² (net or building-) floor—area the air flow, insulation of piping and —new and at replacement— heat recovery at least at level H3. Applicable standards are EN 13779;2007 for SFP4 and EN 13053 for H3. For the constraints on operating hours DIN 18599-10 : 2007-02 applies. Pipe insulation (not relevant for ventilation systems) shall be in accordance with appendix 5.
Regulation
amending the German Energy Saving Ordinance (18.3.2009)\textsuperscript{43}

Section 15

Air-conditioning and other air-handling systems

(1) Upon installation in buildings of air-conditioning systems with a cooling capacity of more than twelve kilowatts and air handling systems for a volume power of delivery air of at least 4 000 cubic metres per hour, as well as upon replacement of central devices or air duct systems of such systems, these systems must be designed in such a way, that

1. the electrical power of the individual ventilators related to the delivery volume or
2. the weighted average value of the electric power of all delivery and exhaust air fans related to the relevant delivery volume does not exceed the threshold value of Category SFP 4 in accordance with DIN EN 13779:

2007-09 at design flow rate. The threshold value for Class SFP 4 can be increased by tolerances according to DIN EN 13779 : 2007-09 Part 6.5.2 for gas and HEPA filters as well as heat feedback components of Classes H2 or H1 in accordance with DIN EN 13053.

(2) Upon installation of systems in buildings in accordance with paragraph 1 sentence 1 and in the case of replacement of central controllers of such systems, if these systems are intended to directly change the humidity of the ambient air, these systems must be equipped with automatic regulating devices, in which separate target values for the humidification and dehumidification can be set and the directly measured humidity of the supply or exhaust air serves as a reference variable. If such devices are not present in existing systems in accordance with paragraph 1 sentence 1, the operator must upgrade in the case of air conditioning systems within six months of expiration of the relevant time limit in section 12 paragraph 3, in the case of other ventilation and air-conditioning systems with appropriate application of the time limits in section 12 paragraph 3.

(3) Upon installation of systems in buildings in accordance with paragraph 1 sentence 1 and in the case of replacement of central controllers or air duct systems of such systems, these systems must be furnished with devices for automatic regulation of flow rates depending on the thermal and material loads or for timed setting of the flow rates if the supply air rate of these systems per square metre of net floor area serviced exceeds nine cubic metres per hour, in residential buildings per square metre of building floor space serviced. Sentence 1 does not apply if increased supply air flow rates are required in the rooms serviced based on industrial or health protection or if load changes cannot be ascertained either by technical measurement or over the course of time.

\textsuperscript{43}http://www.zukunft-haus.info/fileadmin/zukunft-haus/energieausweis/Gesetze_Verordnungen/EnEV_2009 aktuelle nichtamtliche Lesefassung 180309 englisch Internetversion ohne Formulare.pdf
(4) If cooling distribution and cold water pipes and fittings belonging to systems within the meaning of paragraph 1 sentence 1 are initially installed or replaced in buildings, their heat absorption is to be limited in accordance with Appendix 5.

(5) If systems in line with paragraph 1 sentence 1 are installed in buildings or central controllers of such systems are replaced, these must be equipped with a device for heat recovery which at least corresponds to Class H3 in accordance with DIN EN 13053 : 2007-09. For the number of operating hours the general constraints on usage in accordance with DIN V 18599-10 : 2007-02 are decisive, and for the air flow rate it is the external air flow rate.

Table 1-56. Passiv Haus Institute. Certification of of “Passive House suitable component – heat recovery device”

<table>
<thead>
<tr>
<th>Passive House Institute (Germany). Criteria for certification heat recovery device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive House – comfort criterion</td>
</tr>
<tr>
<td>Efficiency criterion (heat)</td>
</tr>
<tr>
<td>The effective dry heat recovery must be higher than 75% with balanced mass flows</td>
</tr>
<tr>
<td>at external temperature between -15 and +10 °C and dry extract air (ca. 20 °C)</td>
</tr>
<tr>
<td>Electrical efficiency criterion</td>
</tr>
<tr>
<td>At the designed mass flow rate the total electrical power consumption of the ventilation device may not exceed 0.45 W per (m³/h) of transported supply air flow</td>
</tr>
<tr>
<td>Balancing and controllability</td>
</tr>
<tr>
<td>Outdoor air and exhaust air mass flows must be balanceable for the rated air flow rate, with controllability of at least 3 levels (basic ventilation 70-80%, standard ventilation 100%, increased ventilation 130%)</td>
</tr>
<tr>
<td>Sound absorption</td>
</tr>
<tr>
<td>Noise level in installation room &lt; 35 dB(A), in living areas &lt; 25 dB(A), in functional areas &lt; 30 dB(A)</td>
</tr>
<tr>
<td>Roomair hygiene</td>
</tr>
<tr>
<td>Outdoor filter at least F7, extract air filter at least G4</td>
</tr>
<tr>
<td>Frost protection</td>
</tr>
<tr>
<td>Frost protection for heat exchanger without supply air interruption, frost protection for an air heater in case of failure of the extract air fan or frost protection heater coil.</td>
</tr>
</tbody>
</table>

4.2.4 Ireland

1. General

The regulations that implement the EPBD impose calculated primary energy emission limits for new buildings and for those that undergo major refurbishment. These do not define explicit performance limits for systems or components. However, the need to meet the requirements places limits on system performance and also provides an incentive to go beyond minimum permitted levels.

2. Air distribution systems

Irish Building Regulations stipulate maximum allowable system specific fan powers.

For new buildings this is 2.0 W/l/s and for new installations or major changes in existing buildings, 3.0 W/l/s. Higher (unspecified) values are permitted when the air conditioning is primarily for process rather than personal comfort. This explicitly includes: large kitchens, large conference rooms, sports facilities and computer and communications rooms.
4.2.5 Netherlands

Current situation
The Building Regulations (Bouwbesluit 2003) contain the performance requirements on ventilation airflow rates and on Energy Performance of the overall building. The method for determining the energy performance of buildings is described in:

- NEN 5128:2004, “Energieprestatie van woonfuncties en woongebouwen – Bepalingsmethode” for new residential dwellings
- NEN 2916:2004, “Energieprestatie van utiliteitsgebouwen – Bepalingsmethode” for new built non residential buildings

For Existing Buildings, the energy performance can be determined with determined with the ISSO Guidelines for residential buildings (EPA-W) and non-residential buildings (EPA-U)44.

The method for determining the energy performance follows the holistic approach whereby the energy use of the building for the five functions heating, cooling, hot water, ventilation and lighting is calculated, assuming average occupation and average inhabitant behaviour, expressed in a single figure called the Energy Performance Coefficient (EPC). This approach implies that no specific performance requirements for the individual five functions applies, but that the overall energy performance of these combined functions is assessed. In this context stakeholder will try to find the cheapest way to comply with these EPC-requirements.

Currently there are energy performance requirements for new residential and non residential buildings. For existing buildings it is only mandatory that an Energy Performance Assessment with related Energy label can be presented when the building or dwelling is sold or rented.

The existing values for the EPC for new residential and non residential buildings (0.8, see table below) result in a market situation where ventilation systems with heat recovery and/or IAQ-control are a reasonably good alternative, but not strictly necessary to comply with the EPC-requirements. Alternative approaches (better DHW-efficiency, higher U-values, etc.) can still prove to be a cheaper way. With the expected higher values for residential buildings per jan. 1st 2011, the application of heat recovery and IAQ-control is expected to become more or less standard.

Table 1-57 Existing and expected values for the EPC of new buildings

<table>
<thead>
<tr>
<th>Function of the building*</th>
<th>Existing EPC-requirement</th>
<th>Expected EPC-requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Places of Assembly</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Prison</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Hospitals</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Other health care functions</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Offices</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Hotels</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Schools</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Sports</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Shops and supermarkets</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

* A non-residential building can have more functions (to be indicated as a percentage of overall building surface)

The applicable rating scale for energy labels for residential and non-residential are presented in the table below. With the current EPC requirements all new residential dwelling carry label A. Per 01-02-2011 the new residential dwellings will all have Energy label A+

44 ISSO ( Instituut voor Studie en Stimulering van Onderzoek op het gebied van gebouwinstallaties) is the Dutch knowledge centre for the building installation sector. URL: www.isso.nl.
Table 1-58. NL Rating scale Energy Labels for Residential and non residential buildings.

<table>
<thead>
<tr>
<th></th>
<th>A++</th>
<th>A+</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>≤ 0.50</td>
<td>0.51 - 0.70</td>
<td>0.71 – 1.05</td>
<td>1.06 – 1.30</td>
<td>1.31 – 1.60</td>
<td>1.61 – 2.00</td>
<td>2.01 – 2.40</td>
<td>2.41 – 2.90</td>
<td>&gt; 2.90</td>
</tr>
<tr>
<td>Non Residential</td>
<td>≤ 0.50</td>
<td>0.51 - 0.70</td>
<td>0.71 – 1.05</td>
<td>1.06 – 1.15</td>
<td>1.16 – 1.30</td>
<td>1.31 – 1.45</td>
<td>1.46 – 1.60</td>
<td>1.61 – 1.75</td>
<td>&gt; 1.75</td>
</tr>
</tbody>
</table>

**Future situation**

Currently the new standard NEN7120, “Energy performance of Buildings – Determination method” is being developed. This new standard will be applicable for all buildings (residential and non residential) both for existing and new ones; it will replace NEN5128 and NEN2916, and also the EPA-W and EPA-U methods from ISSO.

Simultaneously with this new NEN7120 standard, a new ventilation standard NEN8088 is being developed based on EN 15242. One of the purposes of this new ventilation paragraph will be the accommodation of the various new innovative ventilation systems that have been brought on the market in the Netherland, in which the energy performance evaluation of the various ventilation systems with their different heat recovery and controls solutions will play an important role.

**4.2.6 Poland**

In Poland minimum air flow rates are regulated in the Polish Standard PN-83 B-03430/Az3:2000 and are fairly in line with EU standards. Minimum energy requirements are in the MSHP, Decree of Minister of Spatial Planning and Housing MGPIB, Dec. 14 1994 r. (with amendments) Dziennik Ustaw. Nr. 15/1999 poz. 140. It makes heat recovery ventilation mandatory for systems > 10.000 m³/h, prescribes maximum leakage (<0.25% in plate heat exchangers, <5% in rotary wheels) and requires at least G4 filters for heat exchangers and F6 filters for systems with humidifiers. Ductwork should comply with maximum leakage coefficients (< 4.78 m³/(m².h) at 400 Pa overpressure). Design parameters for indoor air are given in PN-78/B-03421.

**4.2.7 Portugal**

1. **General**

The Portuguese national thermal regulation RCCTE (REGULAMENTO DAS CARACTERÍSTICAS DE COMPORTAMENTO TÉRMICO DOS EDIFÍCIOS) establishes the minimum energy efficiency requirements to reduce the HVAC energy needs.

This regulation applies to residential buildings and non-residential buildings with less than 1000 m² (usage area) and in which the HVAC system nominal cooling capacity installed is less than 25 kW. In the case of a collective residential building, each apartment must be considered separately. For non-residential buildings with more than 1000 m² another regulation is applied, the RSECE (REGULAMENTO DOS SISTEMAS ENERGÉTICOS DE CLIMATIZAÇÃO EM EDIFÍCIOS)

---


46 Additional market info Poland: 120 000 air-conditioning units (all types, including multi-splits) with avg. electricity consumption 3 kW were installed. Chillers: 2000 units with on average 60 kW power consumption.
RCCTE
The RCCTE is to be applied for new buildings and in case of retrofit if the retrofit cost is higher than the reference value (reference value = 630€/m²). The RCCTE defines the minimum thermal characteristics of the buildings shell such as: U values (W/m².K) of walls, roofs ..., cold bridges and the solar factor of windows.

It sets also the limits for heating/cooling needs, hot water heating needs and the total primary energy.

Heating nominal energy needs limit – Ni > Nominal heating energy needs – Nic
Cooling nominal energy needs limit – Nv > Nominal cooling energy needs – Nvc
Hot water nominal energy needs limit – Na > Nominal hot water energy needs – Nac
Total primary energy needs limit – Nt > Total primary energy needs – Ntc

Nominal cooling final useful energy needs (Nv) maximum value: Nv depends only of the local climate zone.

a) Zone V1 (north), Nv=16 kWh/m².year;
b) Zone V1 (south), Nv=22 kWh/m².year;
c) Zone V2 (north), Nv=18 kWh/m².year;
d) Zone V2 (south), Nv=32 kWh/m².year;
e) Zone V3 (north), Nv=26 kWh/m².year;
f) Zone V3 (south), Nv=32 kWh/m².year;
g) Azores, Nv=21 kWh/m².year;
h) Madeira, Nv=23 kWh/m².year.

Total annual primary energy needs maximum value (Nt): 0.9 (0.01 Ni + 0.01 Nv + 0.15 Na) (kgep/m².year)

The total annual primary energy needs calculation (Ntc) is calculated as follows.

Ntc = 0.1 (Nic/ηi)Fpui + 0.1(Nvc/ηv)Fpuv + Nac Fpua (kep/m².year )

Nic = (Qt + Qv – Qgu) / Ap (Final useful Heating energy needs)

Qt – conduction losses through building shell
Qv – ventilation losses
Qgu – thermal gains (internal and solar)

ηi – heating nominal efficiency
ηv – cooling nominal efficiency
Fpui - Conversion factor between useful energy and primary energy for the heating system
Fpuv - Conversion factor between useful energy and primary energy for the cooling system
Fpua - Conversion factor between useful energy and primary energy for the hot water system
Fpu electricity = 0.29 kgep/kWh
Fpu solid, liquid and gas fuels = 0.086 kgep/kWh

\[ \text{Nvc} = \frac{Qg \cdot (1 - \eta)}{A_p} \]

- \( Qg \) – total brut gains
- \( \eta \) - usage factor of energy gains
- \( A_p \) – usage area (m²)

\[ \text{Nac} = \frac{(Q_a / \eta_a - E_{solar} - E_{ren})}{A_p} \]

- \( Q_a \) – useful energy to heat hot water by conventional systems
- \( \eta_a \) – Efficiency of the hot water system
- \( E_{solar} \) – contribution of solar systems to hot water
- \( E_{ren} \) – contribution of any other renewable source to hot water

**RSECE**

The RSECE (REGULAMENTO DOS SISTEMAS ENERGÉTICOS DE CLIMATIZAÇÃO EM EDIFÍCIOS) is applied to non-residential buildings with more than 1000 m² and to HVAC system with a nominal cooling power higher than 25 kW.

The requirements of the RSECE include the following sections:

- Minimal quality of the building shell: \( U \), solar factor (with requirements identical to the RCCTE regulation).
- Minimum levels of Ventilation.
- Maximum power of HVAC systems to be installed: maximum of dynamic simulation (multizone) + 40 \%; simulations take into account sensible gains in non-permanent regime, building losses through conduction, internal gains, ventilation, occupants, infiltrations, radiation gains and as well loads due to the several components of the HVAC system, notably for the heating system components, ventilation components, air conditioning components, pumps, ventilators, dehumidification or terminal heating; calculation is made for each zone and for the simultaneous maximum of all zones where the cooling system works.
- Use renewable energies and cogeneration systems.
- Maintenance plans.
- Maximum primary energy consumption (heating/cooling, ventilation, pumps, lighting and all other equipments on the building) through a fixed Energy efficiency index (IEE – Indicador de eficiência energética) by building type. Once the IEE is calculated the value is compared to a table that contains the limit values for this index by building type.
Definition of the Energy efficiency index (IEE – Indicador de eficiencia energética)

\[
\text{IEE} = \text{IEEI} + \text{IEEV} + \frac{\text{Qout}}{\text{Ap}}
\]

Qout – Energy consumption from other processes than heating and cooling (kgep/year)
Ap – usage area (m²)
IEEI – heating energy efficiency (kgoe/m².year)
IEEV – cooling energy efficiency (kgoe/m².year)

\[
\text{IEEI} = \frac{\text{Qaq}}{\text{Ap}} \times \text{FCI}
\]

\[
\text{IEEV} = \frac{\text{Qarr}}{\text{Ap}} \times \text{FCV}
\]

Qaq– heating energy consumption (kgoe/year) Qarr– cooling energy consumption (kgoe/year)

FCI – Correction factor for heating
FCV – Correction factor for cooling

\[
\text{FCI} = \frac{\text{Ni1}}{\text{Niz}}
\]

\[
\text{FCV} = \frac{\text{Nv1}}{\text{Nvz}}
\]

Ni1/Nv1 - Maximal heating/cooling needs limits defined by the RCCTE for the reference climate zone (I1)
Niz/Nvz - Maximal heating/cooling needs limits defined by the RCCTE for the climate zone (z) of the building

NOTA: Conversion factor between useful energy and primary energy – (reference values for the existing Portuguese energetic mix) : Electricity – 0.29 kgoe/kWh, Solid, liquid and gas fuel – 0.086 kgoe/kWh
### Table 1-59. RSECE, Annex 11, Maximal heating and heating + cooling primary energy consumption values for tertiary buildings \( \text{kgep} = \text{kgoe}, \text{aquecimento} = \text{heating}, \text{arrefecimento} = \text{cooling} \)

<table>
<thead>
<tr>
<th>Tipo de actividade</th>
<th>Tipologia do edificio</th>
<th>Aquecimento e arrefecimento</th>
<th>Aquecimento</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kgep/m² ano</td>
<td>kgoe</td>
</tr>
<tr>
<td>Comercial ............</td>
<td>Hipermercados...........</td>
<td>110</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Vendas por prazo.......</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Supermercados..........</td>
<td>70</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Centros comerciais.....</td>
<td>95</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Pequenas lojas.........</td>
<td>35</td>
<td>31</td>
</tr>
<tr>
<td>Serviço de refeições</td>
<td>Restaurantes...........</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Pastelarias............</td>
<td>140</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>Pronto a comer.........</td>
<td>170</td>
<td>159</td>
</tr>
<tr>
<td>Hotéis ...............</td>
<td>Hotéis de 4 ou mais estrelas</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Hotéis de 3 ou menos estrelas</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>Entretenimento .......</td>
<td>Cinemas e teatros......</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Discoteclas............</td>
<td>40</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Bingo e clubes sociais</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Clubes desportivos com piscina</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Clubes desportivos sem piscina</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Serviços .............</td>
<td>Escritórios............</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Sedes de bancos e seguradoras</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Salas de bancos e seguradoras</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Comunicação............</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Bibliotecas............</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Museus e galerias.......</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Tribunais, ministérios e câmaras municipais</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Estabelecimentos prisionais...</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Escolas ...............</td>
<td>Estabelecimentos de ensino</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Hospitais .............</td>
<td>Estabelecimentos de saúde com internamento</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Estabelecimentos de saúde sem internamento</td>
<td>30</td>
<td>21</td>
</tr>
</tbody>
</table>

For new buildings, the heating and cooling energy consumption are calculated by simulation methods:

- Buildings with \( 500 \text{ m}^2 < \text{area} < 1000 \text{ m}^2 \) - a simplified method is applied
- Buildings with area \( >1000 \text{ m}^2 \) - detailed simulation is used. It can be made a simulation zone by zone and then to add the results each hour based on the EN ISO 13790 standard.

For existing buildings the global energy consumption should be determined, in normal operation, through periodic energy audits (following the SCE - methodology). In case that the nominal consumption exceeds the maximum defined value, an energy reduction plan should be put in place, and the renovation should occur in the maximum delay of 3 years.

New buildings with less than 1000 m² and with a HVAC system of more than 25 kW should respect the primary energy consumption requirements (heating/cooling, ventilation, pumps, lighting, all equipment consuming energy) and they should not exceed by 80 % the maximum energy requirements for heating and cooling as defined by the RCCTE.

However the existing buildings with less than 1000 m² and with a HVAC system larger than 25 kW do not have any energy consumption limit.

Residential buildings affected by this regulation should not exceed 80 % of the maximum energy needs for heating and cooling as defined by the RCCTE.
This is the main legislation of interest for the Lot 6 study since it contains the requirements on the HVAC systems and components. In the following sections, main requirements on systems are described.

### 2. Air distribution systems

All elements providing transportation of fluids should have motors with the minimum ranking IE2.

### 3. Heat recovery and free cooling

Heat recovery and free-cooling
- It is mandatory* to recover the extracted air energy, in a heating station, with a minimum efficiency of 50% if the extracted air thermal power is superior to 80 kW.
- In “All Air” HVAC systems with a flow of more than 10 000 m³/h, it is mandatory* the installation of equipments allowing free-cooling.

* If economically viable.

### 4.2.8 Spain

The Regulation on Indoor Heating/Air-conditioning Systems (Reglamento de Instalaciones Térmicas en los Edificios – RITE) lays down the conditions that must be met by systems intended to provide thermal comfort and hygiene by providing heating, air-conditioning, and hot water, so as to achieve a rational use of energy. The requirements have been promulgated in the Royal Decree 1027/2007. This decree is to be revised in 2012 since the RITE also creates an obligation to revise and update energy efficiency requirements on a regular basis (at least once every 5 years). Autonomous regions may introduce additional requirements and part of the decisions are also of their responsibility as the frequency of the inspection of cooling generators.

### 1. General

The RITE applies to all air conditioning (in its broader acceptance) systems in human occupied buildings, for new installation or refurbishment (while it leads to a modification of the installed systems).

In addition of the process of the design, certification, maintenance, inspection ... of these installations, it defines the following requirements for these installations:
- technical requirements,
- hygiene and health requirements,
- energy efficiency requirements.

### 2. Ventilation and air distribution systems

Ventilation is mandatory in human occupied buildings. The RITE defines different control classes for IAQ tat are described in the table below. Classes C5 and C6 are mandatory in Cinemas, theaters and other rooms with high occupancy levels. It means that ventilation should be controlled a function of the number of people or of the CO2 or VOC concentration.

47 Source: [http://www.idae.es/](http://www.idae.es/)

---

ENTR LOT 6, FINAL REPORT TASK 1 VENTILATION SYSTYEMS, 14.06.2012
Table 1-60. RITE, classification of IAQ control in buildings

<table>
<thead>
<tr>
<th>Categoría</th>
<th>Tipo</th>
<th>Descripción</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDA-C1</td>
<td>Manual</td>
<td>El sistema funciona continuamente</td>
</tr>
<tr>
<td>IDA-C2</td>
<td>Control manual</td>
<td>El sistema funciona manualmente, controlado por un interruptor</td>
</tr>
<tr>
<td>IDA-C3</td>
<td>Control por tiempo</td>
<td>El sistema funciona de acuerdo a un determinado horario</td>
</tr>
<tr>
<td>IDA-C4</td>
<td>Control por presencia</td>
<td>El sistema funciona por una señal de presencia (encendido de luces, infrarrojos, etc.)</td>
</tr>
<tr>
<td>IDA-C5</td>
<td>Control por ocupación</td>
<td>El sistema funciona dependiendo del número de personas presentes</td>
</tr>
<tr>
<td>IDA-C6</td>
<td>Control directo</td>
<td>El sistema está controlado por sensores que miden parámetros de calidad del aire interior (CO2 o VOCs)</td>
</tr>
</tbody>
</table>

Air duct pressure losses

The leakage rate is defined in prEN 15727:2010 using the following equations:

\[ f = c \cdot p^{0.65} \]

Where:

- \( f \) is the leakage ratio in \( \text{dm}^3 / (\text{s.m}^2) \)
- \( p \) the static pressure in Pa
- \( c \) the coefficient that defines the leakage rate class.

4 classes of leakage are defined as reported in the table below:

Table 1-61. RITE, air leakage classes

<table>
<thead>
<tr>
<th>Clase</th>
<th>Coeficiente c</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.027</td>
</tr>
<tr>
<td>B</td>
<td>0.009</td>
</tr>
<tr>
<td>C</td>
<td>0.003</td>
</tr>
<tr>
<td>D</td>
<td>0.001</td>
</tr>
</tbody>
</table>

The air duct should be of class B or higher (C or D).

In addition, the maximum admissible pressure losses by components of the aeraulic systems are defined below (NOTA: the following corrections should be considered, heat recovery from 100 to 260 Pa):

\[ \text{NOTA: the following corrections should be considered, heat recovery from 100 to 260 Pa} \]
Table 1-62. RITE, aeraulic system individual components maximal pressure loss authorized

1. Las caídas de presión máximas admisibles serán las siguientes:

<table>
<thead>
<tr>
<th>Component</th>
<th>Maximal Pressure Loss (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baterías de calentamiento</td>
<td>40</td>
</tr>
<tr>
<td>Baterías de refrigeración en seco</td>
<td>60</td>
</tr>
<tr>
<td>Baterías de refrigeración y deshumidificación</td>
<td>120</td>
</tr>
<tr>
<td>Recuperadores de calor</td>
<td>80 a 120</td>
</tr>
<tr>
<td>Atenuadores solares</td>
<td>60</td>
</tr>
<tr>
<td>Unidades territoriales de aire</td>
<td>40</td>
</tr>
<tr>
<td>Elementos de difusión de aire</td>
<td>40 a 200</td>
</tr>
<tr>
<td>Rejillas de retorno de aire</td>
<td>20</td>
</tr>
<tr>
<td>Secciones de filtración</td>
<td>Menor que la caída de presión admitida por el fabricante, según tipo de filtro</td>
</tr>
</tbody>
</table>

Filters

- A prefilter is mandatory.
- Except for fresh air inlet filters, the relative humidity of air in a filter should be lower than 90%.
- For heat recovery units, an F6 or more efficient filter should be installed.

Table 1-63. RITE, filter classes to be installed as a function of the type of air and its quality

<table>
<thead>
<tr>
<th>Filtración de partículas</th>
<th>F6</th>
<th>F6</th>
<th>F6</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ids 1</td>
<td>F7</td>
<td>F6</td>
<td>F6</td>
<td>G4</td>
</tr>
<tr>
<td>Ids 2</td>
<td>F7</td>
<td>F6</td>
<td>F6</td>
<td>G4</td>
</tr>
<tr>
<td>Ids 3</td>
<td>F7</td>
<td>F6</td>
<td>F6</td>
<td>G4</td>
</tr>
<tr>
<td>Ids 4</td>
<td>F6/GF/F9*</td>
<td>F6/GF/F9*</td>
<td>F6</td>
<td>G4</td>
</tr>
</tbody>
</table>

Filtros finales

<table>
<thead>
<tr>
<th>ODA 1</th>
<th>F9</th>
<th>F8</th>
<th>F7</th>
<th>F6</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODA 2</td>
<td>F9</td>
<td>F8</td>
<td>F7</td>
<td>F6</td>
</tr>
<tr>
<td>ODA 3</td>
<td>F9</td>
<td>F8</td>
<td>F7</td>
<td>F6</td>
</tr>
<tr>
<td>ODA 4</td>
<td>F9</td>
<td>F8</td>
<td>F7</td>
<td>F6</td>
</tr>
<tr>
<td>ODA 5</td>
<td>F9</td>
<td>F8</td>
<td>F7</td>
<td>F6</td>
</tr>
</tbody>
</table>

* Se deberá prever la instalación de un filtro de gas o un filtro químico (GF) situado entre las dos etapas de filtración. El conjunto de filtración F6/GF/F9 se pondrá, preferentemente, en una Unidad de Retratamiento de Aire (UPA).*

Fan products

SFP is limited to 750 W/(m³/s) for supply and exhaust ventilation systems, and to 2000 W/(m³/s) for air conditioning systems.

For fan with flow rates larger than 5 m³/s, they should be equipped with an indirect metering and control means. (NOTA: electronic variable frequency drive is advised by authorities for the control)
Air duct insulation for cooling systems
The same requirement as for pipes applies. Below 70 kW rated cooling capacity, a minimum insulation thickness of 30 mm for indoor ducts and 50 mm for outdoor ducts is acceptable (insulation coefficient for 10 K being of 0.04 W/(m.K)).

3. Heat recovery and free cooling
Free cooling
When the installed rated cooling capacity is higher than 70 kW, a free cooling system on air is mandatory.
- for all air systems, maximum speed of exhaust and inlet air in the air handling unit should be limited to 6 m.s⁻¹. The mixing section efficiency should be higher than 75 %.
- For mixed systems (with water and air): for water cooled systems, the heat rejection media should be used ; for air cooled chillers, free cooling should be provided by an air/water coil located in parallel with the chiller evaporator.

Heat recovery
Heat recovery is mandatory when installing a cooling system with fresh air flow rate superior to 0.5 m³. s⁻¹. On the exhaust air flow, an adiabatic cooler should be installed. Minimum efficiency of the heat recovery system and maximum pressure drop are given in the table below as a function of the number of working hours of the installation and of the fresh air intake.

Table 1-64 . RITE, heat recovery minimum efficiency and maximum pressure drop

<table>
<thead>
<tr>
<th>Horas anuales de funcionamiento</th>
<th>Caudal de aire exterior (m³/s)</th>
<th>≥ 0,6...1,5</th>
<th>&gt; 1,5...3,0</th>
<th>&gt; 3,0...6,0</th>
<th>&gt; 6,0...12</th>
<th>&gt; 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Pa</td>
<td>%</td>
<td>Pa</td>
<td>%</td>
<td>Pa</td>
</tr>
<tr>
<td>≤ 2.000</td>
<td>40</td>
<td>100</td>
<td>44</td>
<td>120</td>
<td>47</td>
<td>140</td>
</tr>
<tr>
<td>&gt; 2.000...4.000</td>
<td>44</td>
<td>140</td>
<td>47</td>
<td>160</td>
<td>52</td>
<td>180</td>
</tr>
<tr>
<td>&gt; 4.000...6.000</td>
<td>47</td>
<td>160</td>
<td>50</td>
<td>180</td>
<td>55</td>
<td>200</td>
</tr>
<tr>
<td>&gt; 6.000</td>
<td>50</td>
<td>180</td>
<td>55</td>
<td>200</td>
<td>60</td>
<td>220</td>
</tr>
</tbody>
</table>

4. Monitoring and Energy Audit
Maintenance
Maintenance is mandatory. Points to be checked are specified as well as the frequency of these verifications.

Monitoring
For systems serving several users, the installation should be equipped with a system enabling to partition the energy consumption.
- Above 20 kW, fans and pumps should also register the number of working hours as well as compressors above 70 kW cooling capacity.
- Above 400 kW, the thermal energy should also be measured and sub-metering of the electric consumption of the plant is mandatory.
4.2.9 United Kingdom

1. UK General

The UK regulations that implement the EPBD impose calculated carbon emission limits for new buildings and for those that undergo major refurbishment. These do not define explicit performance limits for systems or components. However, the need to meet the requirements places limits on system performance and also provides an incentive to go beyond minimum permitted levels.

Other parts of the regulations contain explicit performance requirements. In particular, there are performance requirements for ventilation heat recovery equipment and various aspects of mechanical ventilation systems.

This information is contained in the “Non-domestic Building Services Compliance Guide: 2010 Edition” which, strictly speaking, applies to England and Wales but, in practice, is recognised in Scotland and Northern Ireland. Tables of minimum requirements below and much of the text are taken from that document. Strictly speaking the document only provides guidance offers recommendations that are likely to be acceptable to building control departments. In practice, its contents are the normal means of demonstrating compliance.

More demanding performance levels are required for some products for eligibility for Enhanced Capital Allowances (ECAs) – accelerated depreciation for tax purposes. ECA may also be claimed for some components of products such as motors and drives, and compact heat exchangers.

2. UK Air Distribution Systems

The “Non-domestic Building Services Compliance Guide:2010 Edition” contains minimum specific fan powers different types of newly-installed ventilation systems. It also contains recommendations for duct and air handling unit leakage. The requirements differ between new buildings and existing buildings.

2.1 Scope

The guidance applies to the following types of air distribution system:

- central air conditioning systems;
- central mechanical ventilation systems with heating, cooling or heat recovery;
- all central systems not covered by the above two types;
- zonal supply systems where the fan is remote from the zone, such as ceiling void or roof-mounted units;
- zonal extract systems where the fan is remote from the zone;
- local supply and extract ventilation units such as window, wall or roof units serving a single area (eg toilet extract);
- other local ventilation units, eg fan coil units and fan assisted terminal VAV units.

2.2 Definitions

48 Compliance Guide ref (not yet published)
Air conditioning system means a combination of components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity and air cleanliness.

Ventilation system means a combination of components required to provide air treatment in which temperature, ventilation and air cleanliness are controlled.

Central system means a supply and extract system which serves the whole or major zones of the building.

Local unit means an unducted ventilation unit serving a single area.

Zonal system means a system which serves a group of rooms forming part of a building, ie a zone, where ducting is required.

Demand control is a type of control where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicator for the need of ventilation.

Specific fan power of an air distribution system (SFP) means the sum of the design circuit-watts of the system fans that supply air and exhaust it back outdoors, including losses through switchgear and controls such as inverters (ie the total circuit-watts for the supply and extract fans), divided by the design air flow rate through that system.

The specific fan power of an air distribution system should be calculated according to the procedure set out in EN BS 13779:2007\(^{49}\) Annex D Assessing the power efficiency of fans and air handling units – Calculating and checking the SFP, SFP\(_E\) and SFP\(_V\).

\[
\text{SFP} = \frac{P_{sf} + P_{ef}}{q}
\]

where:

- SFP is the specific fan power demand of the air distribution system (W/l/s);
- \(P_{sf}\) is the total fan power of all supply air fans at the design air flow rate, including power losses through switchgear and controls associated with powering and controlling the fans (W);
- \(P_{ef}\) is the total fan power of all exhaust air fans at the design air flow rate including power losses through switchgear and controls associated with powering and controlling the fans (W);
- \(q\) is the design air flow rate through the system, which should be the greater of either the supply or exhaust air flow (l/s). Note that for an air handling unit, \(q\) is the largest supply or extract air flow through the unit.

*External system pressure drop* means the total system pressure drop excluding the pressure drop across the air handling unit (AHU).

### 2.3 Criteria

Air distribution systems in new and existing buildings should meet the following minimum standards:

- a) air handling systems should be capable of achieving a specific fan power at 25 % of design flow rate no greater than that achieved at 100 % design flow rate;

---

\(^{49}\) EN BS 13779:2007 *Ventilation for non-residential buildings – Performance requirements for ventilation and room-conditioning systems.*
b) in order to aid commissioning and to provide flexibility for future changes of use, reasonable provision would be to equip with variable speed drives those fans that are rated at more than 1100 W and which form part of the environmental control system(s), including smoke control fans used for control of overheating. The provision is not applicable to smoke control fans and similar ventilation systems only used in abnormal circumstances;

c) In order to limit air leakage, ventilation ductwork should be made and assembled so as to be reasonably airtight. Ways of meeting this requirement would be to comply with the specifications given in:

- HVCA DW144\textsuperscript{50}. Membership of the HVCA specialist ductwork group or the Association of Ductwork Contractors and Allied Services is one way of demonstrating suitable qualifications; or
- British Standards such as BS EN 1507:2006\textsuperscript{51}, BS EN 12237:2003\textsuperscript{52} and BS EN 13403:2003\textsuperscript{53}.

d) in order to limit air leakage, air handling units should be made and assembled so as to be reasonably airtight. Ways of meeting this requirement would be to comply with Class L2 air leakage given in BS EN 1886:1998\textsuperscript{54};

e) the specific fan power of air distribution systems at the design air flow rate should be no worse than in Table 36 for new buildings and in Table 39 for existing buildings;

f) where the primary air and cooling is provided by central plant and an air distribution system which includes the additional components listed in Table 37, the allowed specific fan powers may be increased by the amounts shown in Table 37 to account for the additional resistance;

g) pressure drops for air distribution systems in new buildings should not generally exceed the values given in Table 36. Exceptions may be made for certain systems such as those with high velocities needed for long throws over 20m;

h) a minimum controls package should be provided in new and existing buildings as in Table 38.

Table 1-65. UK Maximum specific fan powers and pressure drop in air distribution systems in new buildings

<table>
<thead>
<tr>
<th>System type</th>
<th>Maximum SFP, W/l/s</th>
<th>Maximum external system pressure drop, Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central mechanical ventilation system including heating and cooling</td>
<td>1.8</td>
<td>400 supply 250 extract</td>
</tr>
<tr>
<td>Central mechanical ventilation system including heating only</td>
<td>1.6</td>
<td>400 supply 250 extract</td>
</tr>
<tr>
<td>All other central mechanical ventilation systems</td>
<td>1.4</td>
<td>400 supply 250 extract</td>
</tr>
<tr>
<td>Zonal supply system where the fan is remote from the zone, such as ceiling void or roof mounted units</td>
<td>1.2</td>
<td>200</td>
</tr>
</tbody>
</table>

\textsuperscript{50} Ductwork Specification DW/144 Specifications for sheet metal ductwork – Low, medium and high pressure/velocity air systems (Appendix M revision 2002), HVCA, 1998.

\textsuperscript{51} BS EN 1507:2006 Ventilation for buildings – Sheet metal air ducts with rectangular section – Requirements for strength and leakage.

\textsuperscript{52} BS EN 12237:2003 Ventilation for buildings – Ductwork – Strength and leakage of circular sheet metal ducts.

\textsuperscript{53} BS EN 13403:2003 Ventilation for buildings – Non-metallic ducts – Ductwork made from insulation ductboards.

\textsuperscript{54} BS EN 1886:1998 Ventilation for buildings – Air handling units – Mechanical performance.
### Table 1-66. UK Extending SFP for additional components

<table>
<thead>
<tr>
<th>Component</th>
<th>SFP, W/l/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional return filter for heat recovery</td>
<td>+0.1</td>
</tr>
<tr>
<td>HEPA filter</td>
<td>+1.0</td>
</tr>
<tr>
<td>Heat recovery – thermal wheel system</td>
<td>+0.3</td>
</tr>
<tr>
<td>Heat recovery – other systems</td>
<td>+0.3</td>
</tr>
<tr>
<td>Humidifier/dehumidifier (air conditioning system)</td>
<td>+0.1</td>
</tr>
</tbody>
</table>

Notes:

* The rating weighted average is calculated by the following formula

\[
P_{\text{mains.1}} \cdot SFP_1 + P_{\text{mains.2}} \cdot SFP_2 + P_{\text{mains.3}} \cdot SFP_3 + \ldots
\]

where \( P_{\text{mains}} \) is useful power supplied from the mains, W.

### Table 1-67. UK Minimum controls for air distribution systems in new and existing buildings from BS EN 15232:200740

<table>
<thead>
<tr>
<th>System type</th>
<th>Minimum controls package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central mechanical ventilation system including heating, cooling or heat recovery</td>
<td>Air flow control at the room level</td>
</tr>
<tr>
<td></td>
<td>Time control</td>
</tr>
<tr>
<td></td>
<td>Air flow control at the air handler level</td>
</tr>
<tr>
<td></td>
<td>On/off time control</td>
</tr>
<tr>
<td></td>
<td>Heat exchanger defrosting control</td>
</tr>
<tr>
<td></td>
<td>With defrosting control – during cooling periods a control loop enables to warranty that the air temperature leaving the heat exchanger is not too</td>
</tr>
</tbody>
</table>

---

ENTR LOT 6, FINAL REPORT TASK 1 VENTILATION SYSTEMS, 14.06.2012
### Table 1-68. UK Minimum controls for air distribution systems in new and existing buildings from BS EN 15232:2007

<table>
<thead>
<tr>
<th>System type</th>
<th>Minimum controls package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zonal system</td>
<td>Air flow control at the room level On/off time control</td>
</tr>
<tr>
<td></td>
<td>Air flow control at the air handler level No control</td>
</tr>
<tr>
<td></td>
<td>Supply temperature contro No control</td>
</tr>
<tr>
<td>Local system</td>
<td>Air flow control at the room level On/off</td>
</tr>
<tr>
<td></td>
<td>Air flow control at the air handler level No control</td>
</tr>
<tr>
<td></td>
<td>Supply temperature control No control</td>
</tr>
</tbody>
</table>

### Table 1-69. UK Maximum specific fan powers in existing buildings

<table>
<thead>
<tr>
<th>System type</th>
<th>Maximum SFP, W/l/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central balanced mechanical ventilation system including heating and cooling</td>
<td>2.2</td>
</tr>
<tr>
<td>Central balanced mechanical ventilation system including heating only</td>
<td>1.6</td>
</tr>
<tr>
<td>All other central balanced mechanical ventilation systems</td>
<td>1.8</td>
</tr>
<tr>
<td>Zonal supply system where the fan is remote from the zone, such as ceiling void or roof mounted units</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Zonal extract system where the fan is remote from the zone | 0.6  
Zonal supply and extract ventilation units such as ceiling void or roof units serving a single room or zone with heating and heat recovery | 2.0  
Local balanced supply and extract ventilation system such as wall/roof units serving a single area with heating and heat recovery | 1.8  
Local supply or extract ventilation units such as window/wall/roof units serving a single area (eg toilet extract) | 0.5  
Other local ventilation supply and/or extract units | 0.6  
Fan assisted terminal VAV unit | 1.2  
Fan coil units (rating weighted average*) | 0.6  

Notes:
* The rating weighted average is calculated by the following formula:

\[ \frac{P_{\text{mains.1}} \cdot SFP_{1} + P_{\text{mains.2}} \cdot SFP_{2} + P_{\text{mains.3}} \cdot SFP_{3} + \ldots}{P_{\text{mains.1}} + P_{\text{mains.2}} + P_{\text{mains.3}} + \ldots} \]

where \( P_{\text{mains}} \) is useful power supplied from the mains, W.

3. UK Heat Recovery Equipment

There are minimum performance requirements for new installations in new or existing buildings. In addition, these products can be eligible for Enhanced Capital Allowances if they satisfy more demanding requirements.\(^{55}\)

3.1 Minimum performance requirements

Air supply and extract ventilation systems including heating or cooling should be fitted with a heat recovery system. The application of a heat recovery system is described in 6.5 of BS EN 13053:2006\(^{56}\). The methods for testing air-to-air heat recovery devices are given in BS EN 308:1997\(^{57}\).

The minimum dry heat recovery efficiency with reference to the mass flow ratio 1:1 should be no less than given in Table 40.

**Table 1-70 . UK Minimum dry heat recovery efficiency for heat exchangers in new and existing buildings**

<table>
<thead>
<tr>
<th>Heat exchanger type</th>
<th>Dry heat recovery efficiency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate heat exchanger</td>
<td>50</td>
</tr>
<tr>
<td>Heat pipes</td>
<td>60</td>
</tr>
<tr>
<td>Thermal wheel</td>
<td>65</td>
</tr>
</tbody>
</table>

\(^{55}\) Note that the minimum performance requirements shown are new values for 2010, while the ECA values are from 2009. In some cases the former are more demanding than the latter, but this is likely to be corrected by revision to the ECA values.

\(^{56}\) BS EN 13053:2006 Ventilation for buildings – Air handling units – Rating and performance for units, components and sections.

\(^{57}\) BS EN 308:1997 Heat exchangers – Test procedures for establishing the performance of air to air and flue gases heat recovery devices.
3.2 Enhanced Capital Allowances

ECA Performance criteria

Products must have:

- A net sensible effectiveness at the product’s maximum rated air flow under balanced flow conditions that is greater than or equal to the values set out in Table 1 below.
- A pressure drop across each side of the heat exchanger(s) within the product at the product’s maximum rated air flow that is less than the values set out in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1-71 . UK Performance requirements for air-to-air recovery products.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product category</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1 Plate heat exchangers</td>
</tr>
<tr>
<td>2 Rotating heat exchangers</td>
</tr>
<tr>
<td>3 Run-around coils</td>
</tr>
<tr>
<td>4 Heat pipe heat exchangers</td>
</tr>
</tbody>
</table>

ECA REQUIRED TEST PROCEDURES

All products must be tested in accordance with the relevant procedures and test conditions in one of the following standards:

- BS EN 308:1997 “Heat Exchanger: Test procedures for establishing performance of air to air and flue gases heat recovery devices”.
- JIS B 8628: 2003, “Air to air heat exchanger”.
- Other equivalent test standards where the resulting performance data can be scientifically proven, using the methodologies in ANSI/ASHRAE Standard 84-2008 “Method of Testing Air-to-Air Heat/Energy Exchangers”, to be equivalent to that obtained under BS EN 308:1997. Where the net sensible effectiveness should be calculated using the formulae in Appendix C3 of AHRI 1060:2005, and the test data collected when rating the product’s performance in heating mode at the test conditions specified in the selected standard.

Where the product is not tested in accordance with AHRI 1060: 2005, then the Exhaust Air Transfer Ratio (EATR) may be determined using the internal exhaust air leakage rate obtained under section 5.3 of BS EN 308: 1997, or the carryover mass flow rate obtained under section 5.4 of BS EN 308: 1997 (as appropriate), or the leaking rate obtained under section 3.1.5 (b) of JIS B 8628: 2003.

For run-around coils, EATR value of zero should be used when calculating net sensible effectiveness.

Where products are too large to be been tested at their maximum rated air flow under the standard test conditions specified in AHRI 1060: 2005, BS EN 308: 1997 or JIS B 8628: 2003, then performance data obtained at other test conditions may be extrapolated using validated models (or correlations), in accordance with the methodology outlined in Appendix D of ANSI/ASHRAE Standard 84-2008.
4.3 Subtask 1.3.3 - Third Country Legislation

Third country legislation is shortly described. Investigation regards requirements on ventilation products, link between building codes and requirements on equipment and other relevant information regarding the life cycle of these systems.

4.3.1 USA

Introduction
The United States is currently the largest energy producer and consumer in the world (http://www.eia.doe.gov/emeu/international/contents.html). In 2007, the US used about 100 quadrillion (quad) BTU or 29 PWh of energy, representing 21% of the world total (this comes out to 337 million BTU or 355 GJ per capita). 30% of US primary energy was imported. By contrast, the EU-27 consumed 77 quadrillion BTU (23 PWh, or 16% of world total), of which 56% was imported. On a per capita basis, the EU-27 energy intensity (166 GJ) is less than one-half of the US value (337 GJ).

The United States Department of Energy (USDOE) compiles and reports energy statistics according to four broad categories, which include: industrial, transportation, commercial and residential buildings. The residential sector includes living quarters for private households, while the commercial sector includes service-providing facilities and equipment (e.g., businesses, government & other institutions). According to recent statistics, the partition of energy use by sector is 33%, 28%, 17% and 21%, respectively, for industrial, transportation, commercial and residential buildings. Together, residential and commercial properties account for nearly 40% of the total US annual energy use. A further breakdown of total building energy consumption by end use is presented in Table 1 (additional information may be found in the Buildings Energy Data-book; http://buildingsdatabook.eren.doe.gov/). Figure 1 shows US carbon equivalent emissions for base year 2008.
In the US, more than half of commercial building energy use and operational costs is allocated to heating, cooling and ventilating activities. Commercial systems differ from residential ones in a number of important ways. While most residential homes and apartments rely on operable windows (airing) and structure-related infiltration (air leaks) for fresh air, commercial buildings are subject to minimum (mandatory) ventilation requirements (e.g., ASHRAE 62.1) and minimum energy performance standards and design (prescriptive) decisions concerning the use of heating/cooling technologies (e.g., ASHRAE 90.1), which are aimed at promoting a pleasant working environment for occupants and achieving indoor air quality (IAQ) compliance. With increasing building size, heating, ventilating, and air conditioning (HVAC) needs are increasingly dominated by the use of air conditioning to reject heat from lighting systems, equipment, and people working in the building. The ability to introduce in a building a large amount of outdoor air with the mechanical system allows the use of outdoor air instead of conditioned-air whenever the heating load can be satisfactorily met using the cool outdoor air flow ("free" cooling). This "economizer" mode uses the fan more and the refrigeration compressor less, resulting in significant energy savings and avoided environmental pollution (e.g., carbon emissions). The impact of the economizer varies with climate, being greatest in regions with mild to cooler temperatures, larger diurnal temperature variations and lower air humidity (see BASE study results presented later on in this document).
Table 1-72. Energy breakdown by end use in US building sector in 2006, % of total (primary)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>20%</td>
<td>26%</td>
<td>12%</td>
</tr>
<tr>
<td>Space cooling</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
</tr>
<tr>
<td>Ventilation</td>
<td>3%</td>
<td>–</td>
<td>7%</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>6%</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>Water heating</td>
<td>10%</td>
<td>12%</td>
<td>6%</td>
</tr>
<tr>
<td>Electronics (incl., computers)</td>
<td>10%</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td>Lighting</td>
<td>18%</td>
<td>12%</td>
<td>25%</td>
</tr>
<tr>
<td>Cooking</td>
<td>3%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Appliances</td>
<td>12%</td>
<td>10%</td>
<td>13%</td>
</tr>
</tbody>
</table>


(Web-links:)

Standard 62.1-2007 publication ➔ [http://www.ashrae.org/technology/page/132](http://www.ashrae.org/technology/page/132), and


**Purpose**

The aim of this standard is to specify minimum ventilation rates and other requirements necessary to achieve “acceptable indoor air quality (IAQ) conditions” that minimize adverse health effects. By acceptable IAQ is meant that building occupants are not at a significant risk of being exposed to any known indoor air pollutants at harmful concentrations and that the majority of people (e.g., at least 80%) find the air quality to be acceptable. The ASHRAE Standard 62.1-2007 is the latest incarnation of Standard 62.1, which was first published in 1973, with subsequent revisions/updates in 1981, 1989, 1999, 2001, and every third year thereafter. The standard 62.1 is due to be updated by the end of the year 2010. The 2007 edition combines Standard 62.1-2004 and eight approved addenda to the 2004 edition. In response to changes in knowledge, experience and technology, Standard 62.1 is continuously revised by means of addenda, which undergo a public review process aimed at reaching a consensus among interested parties before it is considered for approval by the ASHRAE and ANSI Board of Directors. Addenda that have been approved are published periodically, every 18 months.

**Scope**

Standard 62.1-2007 applies to all indoor spaces intended for human use, except living areas in single family homes or low-rise multi-family apartment buildings of less than three-stories above ground – for these structures, instead, the requirements in ASHRAE 62.2-2007 would apply. Other exceptions include interior spaces in road vehicles and aircraft. For laboratory, industrial and healthcare facilities, additional safety and environmental regulatory codes and guidelines based on prevailing workplace conditions may still apply (e.g., regulations and guidelines imposed by the Occupational Safety and Health Administration).

The provisions of Standard 62.1 apply to new or new portions of buildings and their systems and changes to systems in existing buildings. The goal is to design a ventilation system (Figure 2) that meets minimum air quality standards that are perceived as acceptable to the majority of building occupants and that are meant to protect human health by limiting the accumulation and exposure
to indoor air contaminants. Although the standard is not intended to be applied retroactively as a mandatory regulation or code, the provisions may also be used to “improve” the indoor air quality in existing buildings. Consideration or control of thermal comfort is within the scope of ASHRAE Standard 90.1-2007.

Figure 1-11. Ventilation system diagram (Source: ASHRAE 62.1-2007)

Report overview
The report for Standard 62.1-2007 consists of nine sections, plus nine appendices, covering requirements for ventilation design, air-cleaning system design, construction and system start-up (commissioning) and operation and maintenance. The standard does not prescribe specific ventilation rates to achieve acceptable indoor air quality for spaces that contain secondhand smoking (Environmental Tobacco Spaces – ETS), but a number of mandatory requirements are specified in Section 5.18 to keep ETS zones separate from ETS-free areas (separated physically & airflow-wise).

Chapter 4 (“Outdoor air quality”) covers requirements dealing with:
- “Regional air quality” compliance with US national ambient air quality standards for the geographic area of the building site (EPA NAAQS criteria are available at http://www.epa.gov), and
- “Local air quality” assessment to identify local pollution sources of contaminants of potential concern that may enter the building during normal hours of operation.

Documentation summarizing the findings and conclusions regarding the acceptability of outdoor air quality shall be provided to and reviewed with building owners.

Chapter 5 (“Systems and equipment”) covers several topics, including, for example, design characteristics and decisions affecting the following:
- “natural ventilation systems”
- “ventilation air distribution systems” (prescriptive criteria for air balancing and plenum systems)
• “Ventilation system controls” (e.g., mechanical ventilation systems shall include controls that enable fan operation whenever spaces are occupied; and shall maintain the minimum outdoor airflow requirements as listed in Table 5)

• “Outdoor air intakes” (provisions for managing rain and snow entrainment into the system, for avoiding rain intrusion into the airstream and for preventing bird nesting within outdoor air intake)

• “Dehumidification systems” (e.g., interior relative humidity shall be limited to less than 65% at conditions specified in Sec. 5.10.1; and when mechanical air-conditioning systems are dehumidifying, the design minimum outdoor air supply rate shall be greater than the maximum exhaust airflow to prevent system imbalances that may lead to unwanted outward air leakage from conditioned spaces to unconditioned areas or to the outdoors – building “ex-filtration”)

• “Airstream surfaces, Building envelope and Interior surfaces” (e.g., airstream surfaces shall be designed and constructed to prevent biological growth and to be resistant to erosion; pipes, ducts and other surfaces within buildings whose surface temperature may fall below the local dew point shall be insulated; exterior joints, seams or penetrations in the building envelope shall be caulked, weather-stripped and sealed to limit the uncontrolled inward leakage of airflow and moisture or entry of contaminants to conditioned spaces from unconditioned areas or from the outdoors – building “in-filtration”; etc.)

• “Local capture of contaminants and Combustion air” (e.g., the discharge from non-combustion equipment shall be vented outdoors; fuel burning appliances shall have an adequate supply of air for complete combustion and for combustion product removal; and contaminants generated by vented equipment shall be exhausted to the outdoors)

• “Particulate Matter (PM) removal” (PM filters or air cleaners shall be placed upstream of all cooling coils (Fig. 2) or other devices with wetted surfaces used to treat supply airflow and shall have a Minimum Efficiency Reporting Value, MERV, of at least 6, as rated according to ANSI/ASHRAE Standard 52.2), and

• “Air classification and recirculation” (Sec. 5.17 covers air quality classifications based on “subjective criteria” for return, transfer and exhaust airflows. There are four air quality classifications, ranging from low contaminated air with little or no sensory irritation intensity and offensive odor (Class 1), to highly objectionable fumes or gases, or dangerous levels of particles or bio-aerosols, or gases at harmful concentrations (Class 4). “Class 2” air is defined as air having a moderate contaminant concentration with mild sensory irritation intensity or mild offensive odor; although Class 2 air may not be harmful, it is unsuitable for transfer and recirculation to other building spaces. This section also covers air “re-designation” (Sec. 5.17.2) and air recirculation limits for minimum ventilation requirements (Sec. 5.17.3)).

Additional prescriptive provisions are provided for (a) drain pans, (b) finned-tube coils and heat exchangers, (c) humidifiers and water spray systems, (d) access for inspection, cleaning and maintenance and (e) buildings with attached parking garages (e.g., buildings with attached garages shall limit the transfer of vehicular exhaust air to human occupied spaces by (i) maintaining the garage pressure below that of the adjacent building or (ii) use of a vestibule to provide an airlock between the garage and the adjacent building, or (iii) any other means to prevent air transfer of contaminants between adjacent structures).

Chapter 6 (“Procedures”) is concerned with provisions for mechanically powered equipment, such as motor-driven fans and blowers, used in the design of building ventilation systems. Ventilation refers to the process of supplying or removing air from a building space for the purpose of managing contaminant, humidity and temperature levels within that space or “breathing zone”. Breathing zone is that region of an occupied space that lies between 3 to 72 inches (7.5 to 180 cm) above the
floor and more than 2 feet (60 cm) away from the walls or from any local air-conditioning equipment. Two design approaches or “procedures” are described in the standard documentation.

- The “Ventilation rate procedure” is a prescriptive based approach for determining design outdoor air intake flow rates based on space type, occupant density, size of conditioned floor area, zone air distribution effectiveness (i.e., the effectiveness of air mixing in a space for a given air supply and return configuration; cf. Table 6.2 on p.16 of the report) and system ventilation efficiency (i.e., the efficiency of a system at delivering outdoor air from the intake point to an individual breathing zone; cf. Table 6.3 p.16 of the report). Section 6.2, along with the supplemental information provided in Appendix A, outlines the steps for computing outdoor air intake requirements for (a) “breathing zone” of the occupiable building space, (b) single-zone systems, (c) 100% outdoor air systems and (d) multiple-zone re-circulating systems. Regarding air re-circulation limits, the provisions outlined in Sec. 5.17.3 shall prevail.

Minimum requirements for breathing zone ventilation and system exhaust flow rates are provided below in Tables 5 and 6, respectively. The mandatory outdoor air intake required at the breathing zone accounts for both occupant related contaminants (e.g., odors) and area related sources, such as building materials, furnishings and contaminant emissions due to non-occupant activities and processes. The breathing zone outdoor airflow shall be determined in accordance with the provisions specified in Sec. 6.2.2 (see footnote to Table 5). Furthermore, the system shall include dynamic rest controls to account for varying operating conditions, including changes in occupancy load, variations in system ventilation efficiency, or changes in supply outdoor air fraction (proportion of outdoor air included in total design supply air flow) due to economizer use or exhaust air makeup.

Outdoor air treatment before delivery to occupied spaces is required when NAAQS limits for particulate matter or ozone are exceeded, except for systems supplying air to enclosed parking garages, warehouses, storage rooms, janitor’s closets, trash rooms, recycling areas and shipping, receiving and distribution areas. Standard 62.1-2007 does not specify a mandatory minimum ventilation rate in smoking areas, although such areas shall have higher ventilation rates and shall employ additional air cleaning devices compared to no-smoking areas.

- The “Indoor Air Quality (IAQ) procedure” is a performance based approach to designing a building and its ventilation system. Minimum design ventilation rates for achieving “acceptable” IAQ standards are based on both scientific considerations that would maintain indoor contaminant concentrations at or below a “threshold” value that would limit the potential harmful effects to human health and public perception, on the part of building occupants and/or visitors, of what constitutes an acceptable air quality level. Appendix B provides some contaminant concentration guidelines that are provided solely on the basis as reference values. It should be noted that ASHRAE does not select or recommend default values. For particulate matter with an aerodynamic diameter of 10 microns or less (PM$_{10}$), the proposed “target concentration limit” or “concentration of interest” is 50µg/m$^3$. That is, the accumulated inhalation exposure due to PM$_{10}$ indoor concentrations less than 50µg/m$^3$ should not pose a significant increase in the risk of adverse health effects in the “general” population (there will, of course, be variations in susceptibility among individuals). For the purpose of this procedure, perceived IAQ acceptability does not include occupant dissatisfaction due to thermal discomfort, noise and vibration, lighting and psychological stressors. The design level of acceptability is achieved when a majority consensus is established among building occupants (e.g., at least 80% of people agree or perceive that the indoor air quality is acceptable or better).

Sec. 6.3.1.4 discusses several ventilation design approaches to determine space and supply airflows, including supply outdoor air intake, and other design parameters deemed relevant.
by the building designer. Option “a”, for example, discusses the “mass balance analysis” approach for ventilation systems serving a single space (details are provided in Appendix D). Compliance with the IAQ procedure requires the submittal of a “summary design” report including the following information: (a) an analysis of contaminant sources, (b) choice of target concentration limits and references for these limits, (c) the design approach used to achieve acceptable IAQ and (d) any background or justification for the design approach selected.

According to Sec. 2.9 in ASHRAE Standard 62.1-2007 (p.3): “Acceptable indoor air quality may not be achieved in all buildings meeting the requirements of this standard for one or more of the following reasons:

a) because of the diversity of sources and contaminants in indoor air;
b) because of the many other factors that may affect occupant perception and acceptance of IAQ;
c) because of the range of the susceptibilities in the population; and
d) because outdoor air brought into the building may be unacceptable or may not be adequately cleaned.”
### Table 6-1: Minimum Ventilation Rates in Breathing Zone

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_p$ (cfm/person)</th>
<th>Area Outdoor Air Rate $R_a$ (cfm/ft²)</th>
<th>Default Values</th>
<th>Notes</th>
<th>Combined Outdoor Air Rate (see Note 5)</th>
<th>Air Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L/s-person</td>
<td>L/s·m²</td>
<td>#/1000 ft² or #/100 m²</td>
<td>cfm/person</td>
<td>L/s-person</td>
<td></td>
</tr>
<tr>
<td><strong>Correctional Facilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
<td>0.6</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Dayroom</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>Guard stations</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Booking/waiting</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td><strong>Educational Facilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daycare (through age 4)</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Daycare sickroom</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Classrooms (ages 5–8)</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Classrooms (age 9 plus)</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>Lecture classroom</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
<td>65</td>
<td>8</td>
</tr>
<tr>
<td>Lecture hall (fixed seats)</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td>Art classroom</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Science laboratories</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>University/college laboratories</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Wood/metal shop</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Computer lab</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Media center</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Music/theater/dance</td>
<td>10</td>
<td>5</td>
<td>0.06</td>
<td>0.3</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>Multi-use assembly</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td><strong>Food and Beverage Service</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restaurant dining rooms</td>
<td>7.5</td>
<td>3.8</td>
<td>0.18</td>
<td>0.9</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Cafeteria/fast-food dining</td>
<td>7.5</td>
<td>3.8</td>
<td>0.18</td>
<td>0.9</td>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td>Bars, cocktail lounges</td>
<td>7.5</td>
<td>3.8</td>
<td>0.18</td>
<td>0.9</td>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break rooms</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Coffee stations</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Conference/meeting</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>Corridors</td>
<td>–</td>
<td>–</td>
<td>0.06</td>
<td>0.3</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Storage rooms</td>
<td>–</td>
<td>–</td>
<td>0.12</td>
<td>0.6</td>
<td>B</td>
<td>–</td>
</tr>
<tr>
<td><strong>Hotels, Motels, Resorts, Dormitories</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom/living room</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Barracks sleeping areas</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Laundry rooms, central</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
<td>0.6</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Laundry rooms within dwelling units</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
<td>0.6</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Lobbies/prefunction</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Multipurpose assembly</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>120</td>
<td>6</td>
</tr>
</tbody>
</table>
Note, $Breathing\ zone\ outdoor\ airflow = R_p \times Zone\ population + R_a \times Zone\ floor\ area$; zone population is the maximum number of people expected to occupy the zone during normal usage, whereas zone floor is the net occupied floor area. Zone outdoor airflow is Breathing zone outdoor airflow divided by the Zone air distribution effectiveness (cf. Table 6.2 in ASHRAE report). Source: ASHRAE 62.1-2007

Table 1-74. Minimum Ventilation Rates in Breathing Zone (cont.)

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_p$</th>
<th>Area Outdoor Air Rate $R_a$</th>
<th>Notes</th>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cfm/person L/s-person</td>
<td>cfm/h2 L/s-m2</td>
<td></td>
<td>Operator Density (see Note 4)</td>
</tr>
<tr>
<td>Office Buildings:</td>
<td></td>
<td></td>
<td></td>
<td>#/1000 ft² or #/100 m²</td>
</tr>
<tr>
<td>Office space</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Reception areas</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Telephone/data entry</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Main entry lobbies</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Miscellaneous Spaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank vaults/safe deposit</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Computer (not printing)</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Electrical equipment rooms</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Elevator machine rooms</td>
<td>-</td>
<td>-</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Pharmacy (prep. area)</td>
<td>5</td>
<td>2.5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Photo studios</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Shipping/receiving</td>
<td>-</td>
<td>-</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Telephone closets</td>
<td>-</td>
<td>-</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Transportation waiting</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Warehouses</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Public Assembly Spaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditorium seating area</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Places of religious worship</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Courtrooms</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Legislative chambers</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Libraries</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Lounges</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Museums (children’s)</td>
<td>7.5</td>
<td>3.8</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Museums/galleries</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
</tr>
</tbody>
</table>
### Table 1-75. Minimum Ventilation Rates in Breathing Zone (cont.)

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_p$</th>
<th>Area Outdoor Air Rate $R_a$</th>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cfm/person L/s-person</td>
<td>cfm/ft² L/s·m²</td>
<td>Occuptant Density (see Note 4)</td>
</tr>
<tr>
<td>Sports and Entertainment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports arena (play area)</td>
<td>–</td>
<td>0.30</td>
<td>1.5</td>
</tr>
<tr>
<td>Gym, stadium (play area)</td>
<td>–</td>
<td>0.30</td>
<td>1.5</td>
</tr>
<tr>
<td>Spectator areas</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
</tr>
<tr>
<td>Swimming (pool &amp; deck)</td>
<td>–</td>
<td>0.48</td>
<td>2.4</td>
</tr>
<tr>
<td>Discourse floors</td>
<td>20</td>
<td>10</td>
<td>0.06</td>
</tr>
<tr>
<td>Health clubs/athletic</td>
<td>–</td>
<td>10</td>
<td>0.06</td>
</tr>
<tr>
<td>Health clubs/weight rooms</td>
<td>20</td>
<td>10</td>
<td>0.06</td>
</tr>
<tr>
<td>Bowling alley (seating)</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
</tr>
<tr>
<td>Gambling casinos</td>
<td>7.5</td>
<td>3.8</td>
<td>0.18</td>
</tr>
<tr>
<td>Game arcades</td>
<td>7.5</td>
<td>3.8</td>
<td>0.18</td>
</tr>
<tr>
<td>Stages, studios</td>
<td>10</td>
<td>5</td>
<td>0.06</td>
</tr>
</tbody>
</table>

**GENERAL NOTES FOR:**
1. Related requirements: The rates in this table are based on all other applicable requirements of this standard being met.
2. Snuffing: This table applies to no-smoking areas. Rates for smoke-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.
3. Air density: Volumetric airflow rates are based on an air density of 0.075 lb/ft³ (1.2 kg/m³), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density, but such adjustment is not required for compliance with this standard.
4. Default occupant density: The default occupant density shall be used when actual occupant density is not known.
5. Default combined outdoor air rate (per person): This rate is based on the default occupant density.
6. Unlisted occupancies: If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities, and building construction shall be used.
7. Health care facilities: Flow rates shall be determined in accordance with Appendix E.

**ITEM SPECIFIC NOTES FOR TABLE:**
A. For high school and college libraries, use values shown for Public Assembly Spaces—Libraries.
B. Rate may not be sufficient when stored materials include those having potentially harmful emissions.
C. Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.
D. Rate does not include special exhaust for stage effects, e.g., dry ice vapor, smoke.
E. When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.
F. Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, and one additional person for each additional bedroom.
G. Air from one residential dwelling shall not be mechanically transferred to any other space outside of that dwelling.

**Source:** ASHRAE 62.1-2007
### Table 1-76 . Minimum Exhaust Rates

#### TABLE 6-4 Minimum Exhaust Rates

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>Exhaust Rate, cfm/unit</th>
<th>Exhaust Rate, cfm/ft²</th>
<th>Notes</th>
<th>Exhaust Rate, L/s/unit</th>
<th>Exhaust Rate, L/s·m²</th>
<th>Air Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas</td>
<td>–</td>
<td>0.50</td>
<td>B</td>
<td>–</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Art classrooms</td>
<td>–</td>
<td>0.70</td>
<td>–</td>
<td>3.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Auto repair rooms</td>
<td>–</td>
<td>1.50</td>
<td>A</td>
<td>–</td>
<td>7.5</td>
<td>2</td>
</tr>
<tr>
<td>Barber shops</td>
<td>–</td>
<td>0.50</td>
<td>–</td>
<td>2.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Beauty and nail salons</td>
<td>–</td>
<td>0.60</td>
<td>–</td>
<td>3.0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Cells with toilet</td>
<td>–</td>
<td>1.00</td>
<td>–</td>
<td>5.0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Copy, printing rooms</td>
<td>–</td>
<td>0.50</td>
<td>–</td>
<td>2.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Darkrooms</td>
<td>–</td>
<td>1.00</td>
<td>–</td>
<td>5.0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Educational science laboratories</td>
<td>–</td>
<td>1.00</td>
<td>–</td>
<td>5.0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Janitor closets, trash rooms, recycling</td>
<td>–</td>
<td>1.00</td>
<td>–</td>
<td>5.0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Kitchenettes</td>
<td>–</td>
<td>0.30</td>
<td>–</td>
<td>1.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Kitchens—commercial</td>
<td>–</td>
<td>0.70</td>
<td>–</td>
<td>3.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Locker/dressing rooms</td>
<td>–</td>
<td>0.25</td>
<td>–</td>
<td>1.25</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Locker rooms</td>
<td>–</td>
<td>0.50</td>
<td>–</td>
<td>2.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Paint spray booths</td>
<td>–</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>–</td>
<td>4</td>
</tr>
<tr>
<td>Parking garages</td>
<td>–</td>
<td>0.75</td>
<td>C</td>
<td>3.7</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pet shops (animal areas)</td>
<td>–</td>
<td>0.90</td>
<td>–</td>
<td>4.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Refrigerating machinery rooms</td>
<td>–</td>
<td>–</td>
<td>F</td>
<td>–</td>
<td>–</td>
<td>3</td>
</tr>
<tr>
<td>Residential kitchens</td>
<td>50/100</td>
<td>–</td>
<td>G</td>
<td>25/50</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>Soiled laundry storage rooms</td>
<td>–</td>
<td>1.00</td>
<td>F</td>
<td>–</td>
<td>–</td>
<td>5</td>
</tr>
<tr>
<td>Storage rooms, chemical</td>
<td>–</td>
<td>1.50</td>
<td>F</td>
<td>–</td>
<td>7.5</td>
<td>4</td>
</tr>
<tr>
<td>Toilets—private</td>
<td>25/50</td>
<td>–</td>
<td>E</td>
<td>12.5/25</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>Toilets—public</td>
<td>50/70</td>
<td>–</td>
<td>D</td>
<td>25/35</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>Woodwork shop/classrooms</td>
<td>–</td>
<td>0.50</td>
<td>–</td>
<td>2.5</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

A. Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B. When combustion equipment is intended to be used on the plugging surface additional dilution ventilation and/or source control shall be provided.
C. Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.
D. Rate is for water closet and/or urinal. Provide the higher rate when periods of heavy use are expected to occur, e.g., toilets in theaters, schools, and sports facilities. The lower rate may be used otherwise.
E. Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during annual hours of use, the lower rate may be used. Otherwise use the higher rate.
F. See other applicable standards for exhaust rate.
G. For continuous system operation, the lower rate may be used. Otherwise use the higher rate.

**Source:** ASHRAE 62.1-2007

---


**Purpose**

The objective of this standard is to provide “Minimum Energy Performance Standards” (MEPS) and requirements for the “energy efficiency design” of buildings except low-rise residential buildings. Standard 90.1 was first issued in 1975, and has since been revised six times (1980, 1989, 1999, 2001, 2004 and 2007). The Energy Policy Act (EPAct) of 1992 made Standard 90.1-1989 “the law of the land”. Since then, the standard has been widely adopted across the United States and has become a point of reference in building and energy codes around the world. Starting with the 2001 edition, the standard has been published every third year to coincide with the release of updated regulatory building codes (such as those published by the International Energy Conservation Code, IECC).
The standard is due to be updated again by the end of December 2010; and if all goes as planned, the new regulations should go into effect in the United States by 2013. The main goal of the 2010 edition is a 30% energy reduction relative to the 2004 version of the standard, which would imply a building Energy Use Intensity (energy consumption per unit surface area) of 33.000 BTU/yr per square foot, or about 12 W per square meter (down from 53.000 BTU/yr-ft²). According to the Energy Policy Act of 2005, all US government buildings are now required to be at least 30% more energy efficient than the specification outlined in Standard 90.1. Since the baseline is continuously updated, the EPAct of 2005 sets a moving target relative to the ASHRAE standard.

Starting in 1999, the ASHRAE Board of Directors placed the standard on “continuous maintenance”, meaning the standard is now changed on an ongoing basis through the use of addenda, which are subject to public review, comment and consensus building among all interested parties. Addenda become part of the standard, and equipment manufacturers, for example, are obliged to meet the new specifications, upon the final approval and publication by the Board of Directors. All approved addenda and errata by a given date are included in the next standard version. Forty-four approved addenda were added to Standard 90.1-2004 when the 2007 edition was released. Over twenty additional addenda have been approved since the release of 90.1-2007, and several more are presently in the review/resolution/approval process (http://www.ashrae.org/technology/page/132).

Scope

This standard applies to new or new portions of buildings and their systems and to new systems in existing buildings. The standard does not apply, however, to single family houses or multi-family structures of less than three-stories above ground (ASHRAE 90.2 covers low-rise buildings), nor does it apply to manufactured homes (mobile or modular) and buildings that do not use electricity or fossil fuel. Equipment whose primary energy use is for industrial, manufacturing or commercial processes, are also outside the scope of this standard.

Provisions of Standard 90.1 apply to building envelope, provided the heating demand is greater than or equal to 3.4 BTU/h-ft² (10.7 W/m²) or the sensible cooling load is at least 5 BTU/h-ft² (15.8 W/m²), heating, ventilation and air-conditioning systems, service water heating, lighting, electric motors and belt drives and other equipment in conjunction with building operation. This standard is not intended to bypass norms of safety or circumvent health and environmental requirements.

HVAC mandatory provisions and prescriptive requirements

The report for Standard 90.1-2007 consists of twelve sections, plus seven appendices. Chapter 6 covers heating, ventilation and air-conditioning requirements for new buildings, additions to existing buildings and alterations to existing HVAC systems. All new or replacement HVAC systems must comply with the standard, except as noted in the documentation. Compliance is not required, for example, when (a) the equipment is being relocated, modified or repaired but not replaced; (b) replacement would require extensive modification of existing systems and replacement involves like-for-like equipment, or (c) HVAC to a building addition is provided by an existing HVAC system.

Compliance paths

The standard provides for three pathways of compliance (Figure 1-12). The “Simplified Approach” option applies to buildings with a gross floor area less than 25.000 ft² (2.300 m²) and a building height less than two stories. In addition, the installed HVAC system must meet all requirements as stated in Section 6.3.2. For example, (a) heating and cooling demand must be provided by a single zone, air- or evaporatively-cooled, unitary packaged or split HVAC system complying with the “mandatory” minimum energy efficiency standards (MEPS) (note, a building designer or building owner can always exceed these basic conditions); (b) an air economizer must be installed, unless the system cooling efficiency exceeds by a sufficient margin the MEPS requirements (cf. Table 6.3.2 on p.31); and (c) simultaneous heating and cooling of occupied spaces or reheating for humidity control does not occur. Furthermore, compliance with the standard requires submission of “record
drawings”, “manuals” and evidence of “system balance”. These submittals (Section 6.7) should include, for example: (a) location and performance data for each piece of equipment, (b) configuration of duct and pipe distribution system (incl. size and design flow rates), (c) size and options of each piece of equipment, (d) operation and maintenance manuals, incl. at least one service provider, (e) detailed narrative and diagrams of how each piece of equipment is intended to operate, incl. recommended setpoints, maintenance and calibration notes, and (f) evidence that system controls are in proper working condition. “Completion requirements” are a necessary part of any path for demonstrating compliance with the standard.

In the “Mandatory – Prescriptive Approach” option, compliance is established when the prospective HVAC system design satisfies both “Mandatory” and “Prescriptive” provisions, as outlined, respectively, in Sections 6.4 and 6.5 of the standard and verified through supporting documentation (completion requirements). In the “Mandatory – Energy Cost Budget Method” (Chapter 11), the building designer is allowed to tradeoff between various building systems and components as long as the building annual total energy cost for the prospective design is no more than the equivalent cost for a design based on the “prescriptive” path. Verification of energy cost savings requires the use of simulation software that can model building energy consumption. Approved computerized methodologies include BLAST, TRACE and DOE-2 software (http://gundog.lbl.gov/dirsoft/d2whatis.html).

**Load calculations**

For the purpose of sizing equipment and systems, heating and cooling loads are determined using accepted engineering standards.

**Controls**

(i) Zone heating or cooling is controlled thermostatically.

(ii) A temperature range or “dead band” of at least 5 F (2.8 C) will be established such that simultaneous heating and cooling within a given zone will not occur or will be kept to a minimum.

(iii) HVAC systems not intended to operate continuously or having a
design heating/cooling capacity less than 15,000 BTU/h (<4.5 kW) shall be equipped with “off-hour” controls, including automatic or manual start and stop, setback, zone isolation and optimum start controls.

(iv) Both outdoor air supply and exhaust systems shall be equipped with motorized dampers that will shut when the airflow is off.

(v) Fans with motors greater than 0.75 hp (= 0.5 kW) shall be shut off when not required.

(vi) Systems providing humidification and de-humidification capability to a given zone shall not operate simultaneously.

(vii) Demand control ventilation is required for spaces larger than 500 ft² (46 m²), an occupant density greater than 40 people per 1000 ft² (43 persons per m²) and served by systems with one or more of the following: an air-side economizer, automatic outdoor air damper control, or a design outdoor airflow in excess of 3,000 ft³ (85 m³). One notable exemption are exhaust air energy recovery systems complying with Sec. 6.5.6.1.

### HVAC system construction and insulation

- (i) All supply and return ducts and plenums shall be thermally insulated and sealed. Insulation shall be protected from damage due to sunlight, wind, moisture and equipment maintenance.
- (ii) Piping shall be thermally insulated.
- (iii) All ductwork that is designed to operate at static pressures in excess of 3 inches water column shall be leak tested.

### Prescriptive criteria

**Economizers**

Cooling systems with fans must be equipped with an air or water economizer. An economizer is not required, for ex., when (a) systems operate 20 hours or less a week, (b) systems operate in warm to very hot, humid environments identified by climate zones 1a, 2a, 3a and 4a (see tables and figures in Normative Appendix B of ASHRAE 90.1-2007 report for zone definitions; climate zone equivalents for international locations are available at [http://www.ashrae.org/technology/page/938](http://www.ashrae.org/technology/page/938)), (c) system size is below a climate zone specific threshold cooling capacity (e.g., in a hot but dry climate, an economizer is not required if system size is below 135,000 BTU/h or 39 kW; cf. Table 6.5.1 on p.36), or (d) system efficiency meets or exceeds the minimum efficiency for that type of system listed in Table 6.3.2 (cf. p.31).

(i) An air economizer shall modulate the outdoor and return air dampers to supply up to 100% outdoor air for cooling purposes. Economizer controls shall be integrated with other mechanical cooling components and operation shall not be determined solely by mixed air temperature. Means to relieve excess outdoor air intake will be provided to avoid over pressurizing the building.

(ii) When outdoor air can no longer reduce cooling demand, an air
economizer shall reduce the outdoor intake to a minimum quantity needed to maintain a healthy indoor environment. Control will be based on outdoor air temperature, relative humidity and outdoor air enthalpy.

(iii) Water economizers shall be capable of cooling supply air by indirect evaporation and providing up to 100% of cooling load when outdoor air temperatures are below 50 F (10 C) dry bulb or 45 F (7 C) wet bulb.

<table>
<thead>
<tr>
<th>Simultaneous heating and cooling limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generally speaking, simultaneous heating and cooling of air and water flow streams is not permitted, although there are special circumstances when it may be allowed. This requirement applies to air systems with thermostatic and humidistatic controls and to hydronic systems supplying heated or chilled water (Sec. 6.5.2).</td>
</tr>
<tr>
<td>(i) Zone thermostatic controls shall prevent reheating, recooling or mixing of air streams that have previously been cooled or heated by either mechanical means or by economizer usage. Exceptions are permitted when the re-conditioned airstream volume is less than the larger of: (a) 30% of the zone design peak supply rate, (b) 0.4 ft³/min per ft² of conditioned space, (c) the volume of outdoor air required to meet the ventilation requirements in Section 6.2 of ASHRAE 62.1-2007, and (d) any higher rate for which the energy penalty for reheating/recooling the air is offset by the lower energy demand due to reduced outdoor air intake. Another exception is allowed when at least 75% of the reheat energy is provided by on-site heat recovery systems or solar energy.</td>
</tr>
<tr>
<td>(ii) The simultaneous heating and cooling of fluids in hydronic systems shall be limited. In a “two-pipe changeover system” that uses a common supply system for delivering heated and chilled water, for example, shall be designed to allow a dead band of at least 15 F (8 C), based on outdoor temperature, between changeover from one mode to the other. At the changeover point, the heating and cooling supply temperatures must not be more than 30 F (17 C) apart, and the system must operate in one mode for at least four hours before switching to the other.</td>
</tr>
<tr>
<td>In a “three-pipe system”, a common return for both heated and chilled water shall not be allowed.</td>
</tr>
<tr>
<td>(iii) Systems with humidistatic controls may simultaneously heat and cool airstreams provided the system is capable of reducing supply airflow volume up to 50% or more below design specification, while still meeting ASHRAE 62.1-2007 requirements. There are other exceptions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air system design and control</th>
</tr>
</thead>
<tbody>
<tr>
<td>An HVAC system having a total fan system motor nameplate horsepower greater than 5 hp (3.7 kW) shall not exceed at “full load” fan system design conditions the maximum fan motor size as determined by the relationships indicated below. The “full load fan power limitation” applies to supply, return, relief, and exhaust fans, and to fan-powered terminal boxes associated with heating &amp; cooling systems.</td>
</tr>
</tbody>
</table>
**Constant volume system** (*full load power limitation*)

\[
\text{hp} \leq 0.0011 \times \text{CFM}_S \quad \text{(allowable nameplate motor)}
\]

\[
\text{bhp} \leq 0.00094 \times \text{CFM}_S + A \quad \text{(allowable fan system bhp)}
\]

**Variable volume system** (*full load power limitation*)

\[
\text{hp} \leq 0.0015 \times \text{CFM}_S \quad \text{(allowable nameplate motor)}
\]

\[
\text{bhp} \leq 0.0013 \times \text{CFM}_S + A \quad \text{(allowable fan system bhp)}
\]

\(\text{CFM}_S\) is the maximum design airflow rate to conditioned spaces served by the system in cubic feet per minute; \(\text{hp}\) is the maximum combined motor nameplate horsepower, \(\text{bhp}\) is the maximum combined fan brake horsepower and \(A\) is a pressure drop adjustment factor, which compensates for pressure increases due to ducts, filters, gas-phase air cleaners, heat recovery devices, sound attenuation sections, etc.

(i) For each fan, the selected fan motor shall be no larger than the first available motor size greater than the “\(\text{bhp}\)” rating.

(ii) Individual exhaust fans with a motor nameplate horsepower less than 1 hp and fans exhausting air from fume hoods are exempt.

(iii) Hospital and laboratory systems that use exhaust/return fans to maintain space pressure relationships needed for a healthy and safe indoor environment may use variable air volume fan power specification.

(iv) “Part-load fan power limitation” (Sec. 6.5.3.2.1). Individual VAV fans with motors greater than 10 hp shall meet one of the following criteria:
(a) the fan shall be driven by a mechanical or electrical variable speed drive, (b) the fan shall be a vane-axial fan with variable pitch blades, or (c) fan motor demand shall be no more than 30% of design wattage at 50% of design air volume when static pressure is \(\frac{3}{4}\) of total design static pressure.

(v) “Fan pressure optimization” (Sec. 6.5.3.2.3). For air systems that use direct digital control of individual zoned boxes that report to the central control panel, the static pressure set-point shall be reset based on the zone requiring the most pressure. That is, the static pressure is reduced until the damper position on the critical VAV box is nearly wide open.
PRESCRIPTIVE CRITERIA (CONT.)

| Energy recovery | (i) Individual fan systems with a design supply air capacity exceeding 5000 ft$^3$ or 140 m$^3$, of which the “outdoor air fraction” (defined as the ratio of the outdoor air supply divided by the design supply airflow) is 70% or more, shall have an energy recovery system with at least 50% energy recovery efficiency. That is, the change in the enthalpy of the outdoor air supply is equal to 50% of the difference between the enthalpies of the outdoor air and return air at design conditions.

(ii) Provisions shall be made to control or bypass the heat recovery unit so as not to interfere with air economizer operation.

(iii) Exceptions include (a) systems serving spaces that are un-cooled or not heated above 60 F (15 C), (b) systems involved in the removal of toxic fumes or dust (e.g., paint), (c) commercial kitchen hoods used for grease vapor and smoke removal and (d) systems when more than 60% of the preheat energy is already supplied by other on-site recovered heat sources, e.g., by solar energy.

(iv) A condenser heat recovery system shall be installed for service hot water heating provided the facility is operational around the clock, the design service hot water load is at least 1,000,000 BTU/h (290 kW) and the installed heat rejection capacity of the water cooled system exceeds 6,000,000 BTU/h (1,760 kW). Furthermore, the heat recovery system shall either have a 60% recovery efficiency of the peak heat rejection load or be capable of preheating service hot water draw to 85 F (29 C) at peak design conditions.

Select addenda to 90.1-2007

(Web-link: http://www.ashrae.org/technology/page/132)

Addendum “h”

This addendum revises and adds a new exception to Section 6.5.2.1 (Simultaneous Heating and Cooling Limitation – Zone Controls) that takes advantage of the energy savings potential of Direct Digital Controls (DDC) and alleviates a common problem that arises when the maximum reheated airflow that is currently permitted in the 2007 standard is insufficient to meet peak heating demand, unless a very high supply air temperature is maintained. At high supply air temperatures, a portion of the supply airflow is circulated directly to the return duct (a phenomenon identified as “short-circuiting”), which in turn leads to poor occupant comfort and ventilation effectiveness. The new proposal would alleviate this situation by increasing the amount of reheated air from the current limit of 30% of the zone design peak supply rate to the new maximum of 50%, provided the reconditioned volume of air in dead band is limited to 20% of design peak flow rate (down from 30%).
Addendum “n”

This revision extends the usage of variable air volume (VAV) fans for application to large scale, single zone units – VAV fan control for multiple-zone systems is already a requirement in the standard. Requirements, to take effect on January 1st, 2012, apply to unitary (packaged) equipment and air-handling units having a cooling capacity in excess of 110,000 BTU/h (32.3 kW). The provision can be met using either two-speed motors or variable-speed drives on the supply fan(s). To prevent/reduce coil frosting, the minimum fan speed is set at 67% of design specification.

Addendum “p”

Addendum corrects the fan power limitation deficiencies of Standard 90.1-2004 concerning fan systems exhausting air from fume hoods in a laboratory setting.

Addendum “ad”

This addendum provides a procedure for validating (certifying) manufacturer’s performance efficiency claims for liquid-to-liquid heat exchangers.

4.4 Discussion and guidance

All legislation discussed in paragraph 4.1 applies wholly or partially to the products in the scope, or—in the case of the Ecodesign, Ecolabel and Energy Label Directives—may apply to these products in the future. Every sub-paragraph then explains in detail the way in which certain aspects of the products in the scope may be affected. The amount of detailed explanation is proportionate to how critical the legislation is for the products in the scope. For instance, packaging, WEEE, RoHS are not critical, because packaging of installation products strapped on (re-usable) pellets is never signalled as a source of large savings; the high metal content of the product ensures high collection and recycling rates and the use of hazardous substances is mainly dealt with by specialist suppliers and not by the unit manufacturer themselves. On the other hand, the Fan Regulation and new elements in the Energy Performance of Building may be very important for the design of possible Ecodesign measures for the products in the scope.

As regards Voluntary Agreements, there is no agreement that could be employed as a substitute for legislation under the Ecodesign directive. The Eurovent certification (the Eurovent “energy label”) has been described in great detail, because it may be relevant for policy makers whether—on top of this initiative—a proper EU Energy Label would be required.

Legislation on mechanical ventilation systems in especially non-residential buildings, discussed in paragraph 4.2, is scarce. Only Germany and, up to a degree, the UK address requirements for these products. Instead, most national legislation regulates the overall ventilation performance and overall energy efficiency for ventilation in a building, without specifying how it should be realised through individual mechanical ventilation units. For that reason, the US specifications in the paragraph on third country legislation may be helpful in as much as it shows where a more product- and system-specific approach could lead. But it also shows that in the US ventilation and air-conditioning are still very much interrelated, whereas in the EU the overriding trend is towards a split between the ventilation function and the space cooling/heating function.
5 Scope and saving potential for collective & non-residential ventilation systems (first estimate)

The scope of the Ventilation in this study is the non-residential & collective residential sector.

The total building-volume in the European Union is around 250 billion m³. An estimated 140 billion m³ of this volume -- sheds, stables, garages, some warehouses, etc. -- is permanently unheated. The remaining 110 billion m³ has a heating system of some sorts. Taking into account the heating characteristics of each subsector, it is estimated that the average (24/7) indoor temperature of this building volume is 18 °C during the heating season.

The average European heating season is around 7 months (ca. 5000 hours), during which time the average outdoor temperature is on average 6.5 °C. In other words, there is a temperature difference between indoor and outdoor temperature of 11.5 °C. Around 2.5 °C out of this temperature difference is supplied by solar gains (sun coming through windows) and internal heat production of appliances and people. This leaves 9 °C to be supplied by an active heating system.

The infiltration and ventilation characteristic of a building is often expressed as the ratio between the hourly air exchange in m³/h and the building volume in m³. For instance, assuming this ratio is 0.8 m³/m³.h it means that for every m³ of building volume 0.8 m³ of fresh air is needed per hour. For the 110 billion m³ of heated building-volume, during 5000 hours per heating season ca. 440.000 billion m³ (0.44 x 10¹⁵ m³) of fresh air will penetrate the buildings and will have to be heated.

The specific heat, i.e. the energy needed to heat 1 m³ of air by 1 degree Celsius (°C) or Kelvin (K), amounts to around 0.33 Wh/m³.K. Given the net indoor-outdoor temperature difference of 9 °C (9 K), it can now be calculated how much energy the heating system has to deliver, i.e.

\[ 0.44 \times 10^{15} \text{ m}^3 \times 9 \text{ K} \times 0.33 \text{ Wh/m}^3.K = 1.3 \times 10^{15} \text{ Wh} = \text{ca. 1300 TWh} \]

In Europe most of space heating is done by a central heating boiler and the total systems efficiency, including all losses, is not more than 60%.

This means that around 2166 TWh (in Gross Calorific Value GCV of the fuel) is needed to compensate for the infiltration and ventilation losses of all heated European buildings. Expressed in peta-joules (1 PJ= 1015 Joules= 0.277 TWh) this amounts to ca. 8000 PJ.

In order to know how much carbon emissions are involved in producing this 8000 PJ of heat the fuel mix has to be known. In Europe, for space heating the dominant fuel is natural gas, some oil, district heat and electricity. On average the emissions per PJ are 0.0577 million tonnes of CO₂ equivalent (“Mt CO₂ eq.”). Thus the 8000 PJ of heating energy causes some 460 Mt CO₂ eq..

This is a huge figure, equivalent to one-third of all space heating energy and 11 % of all EU-27 carbon emissions. Although at this stage it is only a rough estimate, it certainly shows the importance of being able to recover a part of the waste heat involved and to ventilate only when and as much as needed.

But the amount of energy mentioned is certainly not fully within the scope of the underlying study, for a number of reasons:

1. It includes at least 25% (0.2 m³/m³.h) infiltration losses, i.e. air that is penetrating through openings in window frames, doors, etc., without a willful intervention of the user. These 115 Mt CO₂ may be tackled through building regulations (Energy Performance of Buildings measures), but they are not part of Ecodesign measures relating to ventilation systems. On
the other hand, if infiltration diminishes beyond a certain threshold the ventilation requirements will have to increase in order to guarantee a minimum Indoor Air Quality and in that sense some projection of the development of infiltration losses may be relevant for the outcome of the study;

2. Of the remaining 345 Mt CO$_2$ related to strict ventilation losses, already now—especially in Northern Europe—around 8% (28 Mt CO$_2$ eq.) is recovered by the use of heat recovery systems;

3. This study relates to collective residential ventilation (flats, apartment blocks) and ventilation in non-residential buildings. Residential ventilation of individual dwellings, accounting for almost 30% of the total (93 Mt CO$_2$), is excluded (part of DG ENER Lot 10). Also agricultural buildings (greenhouses, some stables) as well as specialized industrial & mining ventilation applications—together perhaps accounting for 5% of the total (17 Mt CO$_2$)—are excluded.

All in all, the scope of the study is limited to around 3600 PJ of heating energy, resulting in 207 Mt CO$_2$ equivalent.

The main saving potential will come from better controls (ventilation when and where needed) and from waste heat recovery. Recovery will never be 100%, but even when taking into account efficiency degradation in time, a long-term saving potential on heating energy of around 3000 PJ (170 Mt CO$_2$ equivalent) should be possible\textsuperscript{58}. For saving on electricity and heating it is important that probably around 40-50% or more can be saved through better controls.

On the downside, the saving on heating energy will come at a price in terms of an increase of electric energy for the extra fans (and controls) that will be needed for the waste heat recovery. When assuming a total pressure drop of 900 Pa\textsuperscript{59}, a volume of 45 billion m$^3$/h\textsuperscript{60} and two fans (one supply- and one exhaust fan) the additional net power for mechanical ventilation—at the best available technology—will amount to

\[ 900 \text{ Pa} \times 12.5 \text{ mln. m}^3/\text{s} \times 2 = 22.500 \times 10^6 \text{ W} = 22.5 \text{ GW} \]

Given an average fan+motor+drive efficiency of about 70%\textsuperscript{61} and ideally the equivalent of 2200 full-load operating hours per year\textsuperscript{62} this results in around 2200 x 22.5/70% = 49.500 GWh= ca. 50 TWh of electric energy consumption per year. At 0.43 Mt CO$_2$ equivalent per TWh electric energy this means carbon emissions of around 22 Mt CO$_2$ eq.. Of course, these would not all be additional energy consumers, because in many instances they could be replacing existing extraction fans. Still, with the realization of full waste heat recovery an extra 14 Mt CO$_2$ emissions from fans and controls could be the penalty to expect at full ventilation waste heat recovery in the EU. The net carbon saving potential in the scope would thus be around 150 Mt CO$_2$ equivalent.

The possible credit for achieving such a long term target should be shared with other measures. As regards the extra fan energy, the measures on motors (>750W) and fans (>125W) in Lot 11 should make it possible that the penalty of the extra fans is not 12 Mt CO$_2$, but probably more like 10 Mt

\textsuperscript{58} Kaup, Dr., Study on energy-efficiency of air-handling units (AHU) at Birkenfeld Environmental Campus, Trier University of Applied Sciences, paper, 2010. Dr. Kaup mentions a heat transfer efficiency of

\textsuperscript{59} Kaup (see Annex ) mentions an average AHU at 1050 Pa (at 14 000 m$^3$/h) pressure drop. This includes the pressure drop of heating/cooling coil (assumed to be around 200-250 Pa), which is excluded from the pure ventilation scope, but only partially (40%) includes the ca. 170 Pa for the waste heat recovery. In total, a pressure drop of 900 Pa is assumed for the pure ventilation (and coarse filter) function.

\textsuperscript{60} 0.45 m$^3$/m$^2$.h for full load ventilation x 110 billion m$^2$

\textsuperscript{61} Kaup mentions 54% average AHU system efficiency with best values close to 70%. Compare: Average rooftop fan system efficiency is at 30%.

\textsuperscript{62} 12h/day at 80%, night at 20%. 6 days/week in heating season of 30 weeks. Total 2160 full-load hours/year. Note that this a relatively ideal case, which assumes a good control regime and natural ventilation outside the heating season. Currently, it is not unusual –especially when heating/cooling is part of the AHU-- to have systems running 12h/day at full load, 12h/night at half load, all year around (6570 full-load hours).
CO\textsubscript{2}. This would increase the saving potential to 160 Mt CO\textsubscript{2} eq., but not fully due to measures that can be expected from the scope of this study. Of course, the underlying study would implicitly cover the electricity consumption of fans <125 W when they are an integrated part of the ventilation system.

On the heating side, 40% of the saving on heating energy, some 70 out of 170 Mt CO\textsubscript{2} eq., is due to efficiency losses in the heating system. With a fully efficient heating system, the ventilation would require 1800 PJ and cause ‘only’ 100 Mt CO\textsubscript{2} eq. emissions per year. Efficiency improvement of heating systems is the subject of ENER Lot 1, 10, 15, 20 and 21 and ENTR Lot 6. If all goes according to plan a 20-25% efficiency improvement should be achieved on heating systems in 2020. This means that some 17 Mt CO\textsubscript{2} eq. should be partitioned to heating measures.

All in all, the truly unique share of the long-term saving potential that is in the scope of this study will be around 130-135 Mt CO\textsubscript{2} eq..

Finally, in particular for this new product group of well-controlled waste heat recovery ventilation that is aiming at the building industry, the significance of “long term” should be stressed. Although there are good products for the existing building stock, it is still a product that will take several decades to reach an 80-90% of its saving potential and realistically a market penetration of 30-40% of the building stock by 2020 would be an enormous achievement. Thus, for EU energy and carbon policy targets aiming at 2020 a savings contribution of no more than 40-50 Mt CO\textsubscript{2} eq. and 700-900 PJ/year is what can be expected.

Figure 1-13. Split-up of 110 bln. m\textsuperscript{3} heated volume equivalent at 18°C indoor temperature in the EU.
References

Standards


ISO 12759:2010, Fans -- Efficiency classification for fans. 2010


EN 13141-8:2006, Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of unducted mechanical supply and exhaust
ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room. March 2006 (currently being revised, Nov. 2010)

EN ISO 3741:1999, Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms. 1999
EN ISO 3744:1994, Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane. 1994
EN ISO 3746:1995, Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane. 1995
EN ISO 5136:2003, Acoustics — Determination of sound power radiated into a duct by fans and other air-moving devices — In-duct method. 2003
EN 779 :2003, Particulate air filters for general ventilation - Determination of the filtration performance.(currently under review ; latest publication prEN 779 :2009)
EN 1822:2009, High efficiency air filters (EPA, HEPA and ULPA) – Parts 1 to 5 (Part 1 : Determination of the filtration performance)

EN 14134:2004, Ventilation for buildings - Performance testing and installation checks of residential ventilation systems.
EN 12599 : 2000, Ventilation for buildings - Test procedures and measuring methods for handing over installed ventilation and air conditioning systems (standard under revision, Nov. 2010)
EN 1507: 2006, Ventilation for buildings - Sheet metal air ducts with rectangular section - Requirements for strength and leakage
EN 12237: 2003, Ventilation for buildings - Ductwork - Strength and leakage of circular sheet metal ducts

Voluntary agreements


Community legislation


Ecodesign requirements for industrial fans, Regulatory Committee document, July 2010.

DIRECTIVE 2010/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (recast)

DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits


**Member State and extra-EU legislation**


Part 7: Final energy demand of air-handling and air-conditioning systems for non-residential buildings

Part 10: Boundary conditions, climatic data

GERMANY, Gesetz zur Förderung Erneuerbarer Energien im Wärmebereich (Erneuerbare-Energien-Wärmegesetz – EEWärmeG)*), enforced 1.1.2009

GERMANY, Passiv Haus Institute. Certification of Passive House suitable component – heat recovery device


NETHERLANDS - NPR 5129, Energy performance of residential functions and residential buildings - Calculation program (EPW) with handbook, Nederlands Normalisatieinstituut - Normcommissie 351 074 "Klimaatbeheersing in gebouwen", 04.2005

POLAND, MSHP, Decree of Minister of Spatial Planning and Housing MGPiB, Dec. 14 1994 r. (with amendments) Dziennik Ustaw. Nr. 15/1999 poz. 140.


SPAIN, Regulation on Indoor Heating/Air-conditioning Systems (Reglamento de Instalaciones Térmicas en los Edificios – RITE), promulgated in Royal Decree 1027/2007


Other


List of figures

Figure 1-1 . Balanced unit, with heat recovery (winter operation) .......................................................... 8
Figure 1-2 . Study scope with respect of related measures and studies .................................................. 8
Figure 1-2 . Exhaust ventilation units (exhaust) ...................................................................................... 14
Figure 1-4 . Left: LHRV fancoil integrated in floor or ceiling: with central heating & cooling + local ventilation (‘Fassaden-belüftung’, Schüco). Right: Larger CHRV unit, 1000-4000 m³/h. (StorkAir). .......................................................... 15
Figure 1-5 . Upper left: Very large (100.000 m³/h) AHU with heat recovery (project Gemini/Kamen, Howatherm). Upper right: Rooftop AHU with heat recovery (Hoval). Below: heat exchangers for waste heat recovery. Below left: Cross-flow plate heat exchanger. Below right: Rotary wheel (Hoval) ............................................................................................................ 16
Figure 1-6 . Examples of fan absorbed power versus airflow ............................................................... 65
Figure 1-7 Driven Fan efficiency (ηtot) classification system for B-wheel fans, with or without fan housing [ISO 12759] ....................................................................................................................... 79
Figure 1-8 Driven Fan efficiency (ηtot) classification system for other fans (axial, F-wheel, T-wheel, or mixed flow fans). [ISO 12759] ........................................................................................................... 79
Figure 1-9 : Map of France climates (source French Thermal Regulation 2005) .................................... 108
Figure 1-10 . US greenhouse gas emissions in 2008 (http://www.eia.doe.gov/oiaf/1605/ggrpt/) ... 130
Figure 1-11 . Ventilation system diagram (Source: ASHRAE 62.1-2007) .............................................. 132
Figure 1-12 . ASHRAE 90.1-2007 compliance paths .......................................................................... 141
Figure 1-13 . Split-up of 110 bln. m³ heated volume equivalent at 18°C indoor temperature in the EU. ............................................................................................................................................. 149

List of tables

Table 1-1 . EN classification of type of air .......................................................................................... 22
Table 1-2 . EN classification of extract and exhaust air ................................................................. 22
Table 1-3 . EN classification of outdoor air ...................................................................................... 23
Table 1-4 . EN classification of indoor air quality ............................................................................ 23
Table 1-5 . EN leakage classification according to the pressurisation test method ................ 24
Table 1-6 . EN leakage classification according the tracer gas method ........................................ 24
Table 1-7 . EN leakage classification EN 13141-8 ........................................................................... 25
Table 1-8 . EN filter bypass leakage classification EN 13141-8 ......................................................... 25
Table 1-9 . EN coarse filter classification .......................................................................................... 25
Table 1-10 . EN fine filter classification ............................................................................................ 26
Table 1-11. EN classification of SPI values (residential units) .............................................................. 27
Table 1-12. EN classification of SFP values (non-residential) ................................................................. 27
Table 1-13. EN classification of thermal efficiency/ temperature ratio for HR units (EN 13141-7/-8). 28
Table 1-14. EN classification of energy efficiency for HR units (EN 13053) .......................................... 28
Table 1-15. EN classification of humidity ratio for HR units ............................................................... 29
Table 1-16. EN classification of standby power for residential ventilation units ................................. 29
Table 1-17 — Classes of average air velocity levels inside the casing ............................................... 29
Table 1-18. EN classification of control types for ventilation units ..................................................... 30
Table 1-19. EN classification of sound power levels for ventilation units ............................................ 30
Table 1-20. EN classification of sound transmitting resistance for ventilation units ........................... 31
Table 1-21. Overview of EN design - performance - and test standards on Ventilation Units ............. 32
Table 1-22 Examples of recommended ventilation rates for non-residential buildings for three categories of pollution from buildings itself. Rates are given per person (for diluting bio effluents from people) and per m² floor area (for dilution of buildings emissions) (acc. Table B.3 of annex B) .................................................................................................................................................... 34
Table 1-23. Examples of recommended ventilation rates for different types of non-residential buildings with default occupancy density for three categories of pollution from buildings itself. If smoking is allowed the last column gives the additional required ventilation rates (acc. Table B.2 of annex B). ..................................................................................................................................... 34
Table 1-24. Examples of recommended CO2 concentrations above outdoor concentrations for energy calculations and demand control (acc. Table B.4 of annex B) ............................................................................................................................................................................. 35
Table 1-25. Example of ventilation rates for residences (assuming complete mixing and at continuous operation of ventilation during occupied hours) (acc. Table B.5 of annex B) ......... 36
Table 1-26. Example of recommended design criteria for the humidity in occupied spaces if (de-) humidification systems are installed (acc table B.6 annex B) .......................................................................................................................... 37
Table 1-27. Examples of recommended design A-weighted sound pressure levels (EN 15251, Table E.1, annex E) ...................................................................................................................................................... 37
Table 1-28. Key outdoor air pollutants .................................................................................................. 40
Table 1-29. Recommended minimum filter classes .............................................................................. 40
Table 1-30. Recommendations on removal of extract air .................................................................... 40
Table 1-31. Design values for air extract rates ..................................................................................... 41
Table 1-32. Design values for air extract rates ..................................................................................... 41
Table 1-33. Examples for pressure drops for specific components in air handling systems (acc. table A.8 of EN13779) .......................................................................................................................... 44
Table 1-34. Rates of outdoor or transferred air per unit floor area (net area) for rooms not designed for human occupancy ................................................................................................................................. 44
Table 1-35. CO2-levels in rooms ......................................................................................................... 45
Table 1-36. Rates of outdoor air per person CO2-levels in rooms ....................................................... 45
Table 1-37. Calculated ventilation air flow rates for CO2 removal from a bedroom and related humidity /condensation risk at bedroom air temperature of 16 °C. ................................. 50
Table 1-38. Calculated ventilation air flow rates for CO$_2$ removal from a living room and related humidity/condensation risk at bedroom air temperature of 16 °C ............................................................ 51

Table 1-39. Calculated ventilation air flow rates for a bathroom; Extracted air at 100% RH and 22 °C 52

Table 1-40. Calculated ventilation air flow rates for a bathroom; Extracted air at 70% RH and 22 °C 52

Table 1-41. Calculated ventilation air flow rates for a WC ................................................................. 53

Table 1-42. Assumptions for level 2 (Table 2, page 10 of EN 15665) ................................................. 54

Table 1-43. Assumptions for level 3 (Table 3, page 14 of EN 15665) ................................................ 55

Table 1-44. Typical values for indoor duct leakages ............................................................................. 62

Table 1-45. Typical values for indoor AHU leakages ........................................................................... 63

Table 1-46. Default values for Rf;r ......................................................................................................... 65

Table 1-47. Example of fan power ratio in relation to airflow ratio and airflow control principle .... 66

Table 1-48. EN classification of nominal temperature ratio for HR units ........................................... 70

Table 1-49. Tolerances AHU technical parameters ............................................................................. 71

Table 1-50. Classes of power consumption of drives (fans) ............................................................... 72

Table 1-51. EN 13503. Table 9. Maximum final pressure drop for filters ........................................... 74

Table 1-52. Coefficients a & b depend on fan type & size ..................................................................... 78

Table 1-53. Examples for pressure drops for specific components in air handling systems (acc. table A.8 of EN13779). EXTRACT from table 1-33 ................................................................. 84

Table 1-54. Ecodesign Fan Regulation 2010, summary and examples ............................................. 90

Table 1-55. Eurovent energy efficiency classes for AHU .................................................................... 102

Table 1-56. Passiv Haus Institute. Certification of of “Passive House suitable component – heat recovery device......................................................................................................................... 111

Table 1-57. Existing and expected values for the EPC of new buildings ........................................ 112

Table 1-58. NL Rating scale Energy Labels for Residential and non residential buildings ............... 113

Table 1-59. RSECE, Annex 11, Maximal heating and heating + cooling primary energy consumption values for tertiary buildings (kgep = kgoe, aquecimento = heating, arrefecimento = cooling) ...117

Table 1-60. RITE, classification of IAQ control in buildings ............................................................. 119

Table 1-61. RITE, air leakage classes .................................................................................................... 119

Table 1-62. RITE, aeraulic system individual components maximal pressure loss authorized......... 120

Table 1-63. RITE, filter classes to be installed as a function of the type of air and its quality........... 120

Table 1-64. RITE, heat recovery minimum efficiency and maximum pressure drop ..................... 121

Table 1-65. UK Maximum specific fan powers and pressure drop in air distribution systems in new buildings ......................................................................................................................... 124

Table 1-66. UK Extending SFP for additional components .............................................................. 125

Table 1-67. UK Minimum controls for air distribution systems in new and existing buildings from BS EN 15232:200740 ....................................................................................................................... 125

Table 1-68. UK Minimum controls for air distribution systems in new and existing buildings from BS EN 15232:2007147 ....................................................................................................................... 126
Table 1-69. UK Maximum specific fan powers in existing buildings ................................................... 126
Table 1-70. UK Minimum dry heat recovery efficiency for heat exchangers in new and existing buildings ........................................................................................................................................ 127
Table 1-71. UK Performance requirements for air-to-air recovery products ........................................ 128
Table 1-72. Energy breakdown by end use in US building sector in 2006, % of total (primary) ........ 131
Table 1-73. Minimum Ventilation Rates in Breathing Zone .................................................................. 136
Table 1-74. Minimum Ventilation Rates in Breathing Zone (cont.) .................................................... 137
Table 1-75. Minimum Ventilation Rates in Breathing Zone (cont.) .................................................... 138
Table 1-76. Minimum Exhaust Rates .................................................................................................. 139
**Acronyms**

*This list contains the acronyms and symbols from all Task Reports*

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/7</td>
<td>All the time, i.e. 24 hours a day during 7 days a week</td>
</tr>
<tr>
<td>@</td>
<td>at</td>
</tr>
<tr>
<td>€</td>
<td>Euro</td>
</tr>
<tr>
<td>AC</td>
<td>1. Air Conditioning  2. Alternate Current</td>
</tr>
<tr>
<td>AHRI</td>
<td>Air-Conditioning, Heating, and Refrigeration Institute</td>
</tr>
<tr>
<td>AHU</td>
<td>Air Handling Unit</td>
</tr>
<tr>
<td>AIVC</td>
<td>Air Infiltration and Ventilation Centre</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration, and Air-Conditioning Engineers (standard)</td>
</tr>
<tr>
<td>AV</td>
<td>Surface Area/Volume (ratio)</td>
</tr>
<tr>
<td>BC</td>
<td>Backward Curved (fan impeller, a.k.a. 'B-wheel')</td>
</tr>
<tr>
<td>BEP or bep</td>
<td>Best Efficiency Point</td>
</tr>
<tr>
<td>BFC</td>
<td>Bypass Flow rate Control</td>
</tr>
<tr>
<td>BPO</td>
<td>Bypass Options</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>BSRIA</td>
<td>Building Services Research and Information Association</td>
</tr>
<tr>
<td>CAV</td>
<td>Constant Air Volume</td>
</tr>
<tr>
<td>CBS</td>
<td>Centraal Bureau voor de Statistiek (Netherlands statistics office)</td>
</tr>
<tr>
<td>CEN</td>
<td>Comité Européen de Normalisation (French: European Committee for Standardization)</td>
</tr>
<tr>
<td>CENELEC</td>
<td>Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)</td>
</tr>
<tr>
<td>CHRV</td>
<td>Central Heat Recovery Ventilation</td>
</tr>
<tr>
<td>CHW</td>
<td>Chilled Water</td>
</tr>
<tr>
<td>CN8</td>
<td>Combined Nomenclature (at eight digit level)</td>
</tr>
<tr>
<td>COP</td>
<td>Coefficient of Performance, synonymous for efficiency but used when efficiency can be &gt;100% due to not-accounted external energy sources (e.g. with heat pump)</td>
</tr>
<tr>
<td>CPD</td>
<td>Construction Products Directive (predecessor of CPR)</td>
</tr>
<tr>
<td>CPR</td>
<td>Construction Products Regulation</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DIN</td>
<td>Deutsche Industry Norm</td>
</tr>
<tr>
<td>DMU</td>
<td>Decision Making Unit</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>EATR</td>
<td>Exhaust Air Transfer Ratio (UK)</td>
</tr>
<tr>
<td>EC</td>
<td>Electronically Commutating (motor); European Community</td>
</tr>
<tr>
<td>ECA</td>
<td>Enhanced Capital Allowance</td>
</tr>
<tr>
<td>ECBCS</td>
<td>Energy Conservation in Buildings and Community Systems (an IEA Implementing Agreement)</td>
</tr>
<tr>
<td>EEIG</td>
<td>European Economic Interest Grouping</td>
</tr>
<tr>
<td>EHA</td>
<td>Exhaust air, i.e. airflow discharges to the atmosphere</td>
</tr>
<tr>
<td>EHVA</td>
<td>European Ventilation Hygien Association</td>
</tr>
<tr>
<td>EN</td>
<td>European Norm</td>
</tr>
<tr>
<td>ENER</td>
<td>European Commission, Directorate General Energy</td>
</tr>
<tr>
<td>EnEV</td>
<td>EnergieEinsparungsVerordnung</td>
</tr>
<tr>
<td>ENTR</td>
<td>European Commission, Directorate General Enterprise</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency (US)</td>
</tr>
<tr>
<td>EPAct</td>
<td>Energy Policy Act (US)</td>
</tr>
<tr>
<td>EPC</td>
<td>Energie Prestatie Coefficient (Netherlands)</td>
</tr>
<tr>
<td>ErP</td>
<td>Energy-related Products</td>
</tr>
<tr>
<td>ETA</td>
<td>Extract air, i.e. the airflow leaving the treated room</td>
</tr>
<tr>
<td>ETS</td>
<td>Environmental Tobacco Spaces (US); Emissions Trading System (EU)</td>
</tr>
<tr>
<td>EuP</td>
<td>Energy-using Products</td>
</tr>
<tr>
<td>EUROSTAT</td>
<td>Statistical Office of the European Union</td>
</tr>
<tr>
<td>EUROVENT</td>
<td>European Committee of Air Handling and Refrigeration Equipment Manufacturers</td>
</tr>
<tr>
<td>EVIA</td>
<td>European Ventilation Industry Association</td>
</tr>
<tr>
<td>FBC</td>
<td>Flow Balance Control</td>
</tr>
<tr>
<td>FC</td>
<td>Forward Curved (fan impeller, a.k.a. 'F-wheel')</td>
</tr>
<tr>
<td>FCU</td>
<td>Fan Coil Unit</td>
</tr>
<tr>
<td>FGK</td>
<td>Fachinstitut Gebaude-Klima e.V.</td>
</tr>
<tr>
<td>FIT</td>
<td>Filter Indicator Type</td>
</tr>
<tr>
<td>FMEG</td>
<td>Fan &amp; Motor Efficiency Grade (–)</td>
</tr>
<tr>
<td>FRC</td>
<td>Flow Rate Control</td>
</tr>
<tr>
<td>FRV</td>
<td>Flow Rate Variations</td>
</tr>
<tr>
<td>GBP</td>
<td>Great Britain Pound</td>
</tr>
<tr>
<td>GF</td>
<td>Ground Floor</td>
</tr>
<tr>
<td>HEPA</td>
<td>High-Efficiency Particulate Air (filter)</td>
</tr>
<tr>
<td>HR</td>
<td>Heat Recovery</td>
</tr>
<tr>
<td>HR</td>
<td>Heat Recovery</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>HRV</td>
<td>Heat Recovery Ventilation</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating Ventilation and/or Air-Conditioning</td>
</tr>
<tr>
<td>HWS</td>
<td>Hot Water Service</td>
</tr>
<tr>
<td>IAQ</td>
<td>Indoor Air Quality</td>
</tr>
<tr>
<td>IDA</td>
<td>Indoor air, i.e. air in the treated room or zone</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IEE</td>
<td>Indicador de Eficiencia Energética (Portugal)</td>
</tr>
<tr>
<td>INIVE</td>
<td>International Network for Information on Ventilation and Energy Performance</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
</tr>
<tr>
<td>JIS</td>
<td>Japanese Industrial Standard</td>
</tr>
<tr>
<td>LEA</td>
<td>Leakage, i.e. unintended airflow through leakage paths in the system</td>
</tr>
<tr>
<td>LHRV</td>
<td>Local Heat Recovery Ventilation</td>
</tr>
<tr>
<td>LT</td>
<td>Low Temperature</td>
</tr>
<tr>
<td>LTHW</td>
<td>Low Temperature Hot Water</td>
</tr>
<tr>
<td>LVD</td>
<td>Low Voltage Directive</td>
</tr>
<tr>
<td>MD</td>
<td>Machine Directive</td>
</tr>
<tr>
<td>MEErP</td>
<td>Methodology for Ecodesign of Energy-related Products</td>
</tr>
<tr>
<td>MEEuP</td>
<td>Methodology for Ecodesign of Energy-using Products</td>
</tr>
<tr>
<td>MEPS</td>
<td>Minimum Energy Efficiency Standard</td>
</tr>
<tr>
<td>NEN</td>
<td>Nederlands Normalisatie-Instituut (Netherlands Standards Institute)</td>
</tr>
<tr>
<td>NF</td>
<td>Norme Française (French Standard)</td>
</tr>
<tr>
<td>NTPF</td>
<td>Nominal Temperature Performance Factor (-)</td>
</tr>
<tr>
<td>ODA</td>
<td>Outdoor air, i.e. air entering the system or opening from outdoors before any air treatment</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturers</td>
</tr>
<tr>
<td>prEN</td>
<td>pre European Norm (draft standard)</td>
</tr>
<tr>
<td>PRODCOM</td>
<td>European Comunity Industry Production (statistics of industrial production)</td>
</tr>
<tr>
<td>RCCTE</td>
<td>Regulamento das Caracteristicas de Comportamento Térmico dos Edifícios (Portugal)</td>
</tr>
<tr>
<td>REHVA</td>
<td>Federation of European heating, ventilation and air-conditioning associations</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency (a.k.a. 'wireless”)</td>
</tr>
<tr>
<td>RH</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>RITE</td>
<td>Reglamento de Instalaciones Térmicas en los Edificios (Spain)</td>
</tr>
<tr>
<td>RLT</td>
<td>Herstellerverband Raumlufttechnischer Geräte</td>
</tr>
<tr>
<td>RoHS</td>
<td>Restriction of Hazardous Substances (directive)</td>
</tr>
<tr>
<td>RSECE</td>
<td>Regulamento dos Sistemas Energeticos de Climatização em Edifícios (Portugal)</td>
</tr>
<tr>
<td>RT</td>
<td>Réglementation Thermique (France)</td>
</tr>
</tbody>
</table>
SEC  Secondary air, i.e. airflow taken from a room and returned to the same room after any treatment
SFP  Specific Fan Power (in W per m³/s)
SI   Système International d’unités
SPI  Specific Power Input (in W per m³/s or m³/h)
SUP  Supply air, i.e. airflow entering the treated room, or air entering the system after any treatment
TFP  Type of Frost Protection
ToR  Terms of Reference
TRA  Transferred air, i.e. indoor air which passes from the treated room to another treated room
UF   Upper Floor(s)
USDOE United States Department of Energy (also ‘DOE’ or ‘DoE’)
VAT  Value Added Tax
VAV  Variable Air Volume
VHK  Van Holsteijn en Kemna (author)
VRF  Variable Refrigerant Flow
VSD  Variable Speed Drive (a.k.a. ASD, Adjustable Speed Drive)
WEEE Waste of Electric and Electronic Equipment (directive)
WFD  Waste Framework Directive

*Common parameter denominators in this report*

A   Surface (in m²)
c   Specific heat (in J/dm³.K or J/kg.K)
C   Generic for ‘coefficient’ or ‘constant’ (-)
Eff or η Efficiency (-)
h   Height (in m)
P   Power (in W)
q   Flow rate (in m³/s or m³/h)
Q   Energy or heat (in Joule or kWh)
R   Rate (in other reports reserved for Reynolds number)
t   Time (s or h) (also used for temperature
V   Air velocity (in m/s); Volume (in m³)
x   absolute humidity (g/kg air)
Δp Pressure difference (in Pa)
ΔT Temperature difference (in K)
ε Efficiency (for local ventilation efficiency) or 'coefficient of performance' (-)
θ or T Temperature (in °C)
ρ Density (in kg/dm³)

Units used in this report
bhp brake horse power, unit for power (745.7 W)
BTU British Thermal Unit, unit for energy (0.293 Wh)
BTU/h British Thermal Unit per hour, unit for power (0.293 W)
BTU/h-ft² BTU per hour and square feet, (≈3.147 W/m²)
°C Degree Celsius, unit of temperature
cf or ft³ cubic feet, US unit for volume (0.028316847 m³)
cfm cubic feet per minute, US unit for flow rate (1.69865 m³/h)
CO₂ eq. Carbon dioxide equivalent, unit for Greenhouse Gas Emissions (usually over 100 years, Global Warming Potential-100)
dB(A) Decibel, unit of A-weighted equivalent sound pressure
eq. equivalent
g gramme, ISO-unit of mass
h hour, also used as 'height' denominator
hp horse power, unit for power (745.7 W)
J Joule, SI-unit of energy
K (Degree) Kelvin, unit of temperature (0 K= -273 °C)
l or ltr litre (10⁻³ m³),
m, m², m³ meter, square meter, cubic meter; SI-units of length, surface, volume
Pa Pascal, SI-unit of pressure
s Second, SI-unit of time
sq ft or ft² square feet, unit for surface (0.0929 m²)
V Volt, unit for electric voltage
W Watt, unit of power
Wh Watt hour, unit of energy ( 1 Wh= 3.6 kJ)
country denominators

EU27  European Union with 27 Member States (compared to EU25, EU15, etc.)
AT    Austria
BE    Belgium
BU    Bulgaria
CY    Cyprus
CZ    Czech Republic
DE    Germany
DK    Denmark
EE    Estonia (also EST)
EL    Greece (also GR)
EI    Ireland (also IRE)
ES    Spain
EST   Estonia (preferably EE)
FI    Finland (also FIN)
FIN   Finland (preferably FI)
FR    France
GR    Greece (preferably EL)
HU    Hungary
IRE   Ireland (preferably EI)
IT    Italy
LT    Lithuania
LV    Latvia
LU    Luxemburg
MT    Malta
NL    Netherlands
PL    Poland
PT    Portugal
RO    Romenia
SI    Slovenia
SK    Slovakia
SV    Sweden
UK    United Kingdom
Numerical prefixes etc.

n    nano, 10^{-9}
\mu  micro, 10^{-6}
m    milli, 10^{-3}
k    kilo, 10^{3}
M    Mega, 10^{6}
G    Giga, 10^{9}
T    Tera, 10^{12}
P    Peta, 10^{15}

bln. Billion, 10^{9}
mln. Million, 10^{6}