INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and community systems programme

A Review of International Ventilation, Airtightness, Thermal Insulation and Indoor Air Quality Criteria

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AIVC

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This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme.

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Belgium, Denmark, Germany, Greece, Finland, France, Netherlands, New Zealand, Norway, Sweden, United Kingdom and the United States of America.

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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods, as well as air quality and studies of occupancy.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial.

To date the following have been initiated by the Executive Committee (completed projects are identified by *):

I	Load Energy Determination of Buildings*
II	Ekistics and Advanced Community Energy Systems*
III	Energy Conservation in Residential Buildings*
IV	Glasgow Commercial Building Monitoring*
V	Air Infiltration and Ventilation Centre
VI	Energy Systems and Design of Communities*
VII	Local Government Energy Planning*
VIII	Inhabitant Behaviour with Regard to Ventilation*
IX	Minimum Ventilation Rates*
X	Building HVAC Systems Simulation*
XI	Energy Auditing*
XII	Windows and Fenestration*
XIII	Energy Management in Hospitals*
XIV	Condensation*
XV	Energy Efficiency in Schools*
XVI	BEMS - 1: Energy Management Procedures*
XVII	BEMS - 2: Evaluation and Emulation Techniques*
XVIII	Demand Controlled Ventilating Systems*
XIX	Low Slope Roof Systems*
XX	Air Flow Patterns within Buildings*

XXI	Thermal Modelling*
XXII	Energy Efficient Communities*
XXIII	Multizone Air Flow Modelling (COMIS)*
XXIV	Heat Air and Moisture Transfer in Envelopes*
XXV	Real Time HEVAC Simulation*
XXVI	Energy Efficient Ventilation of Large Enclosures*
XXVII	Evaluation and Demonstration of Domestic Ventilation Systems
XXVIII	Low Energy Cooling Systems
XXIX	Daylight in Buildings
XXX	Bringing Simulation to Application
XXXI	Energy Related Environmental Impact of Buildings
XXXII	Integral Building Envelope Performance Assessment
XXXIII	Advanced Local Energy Planning
XXXIV	Computer-Aided Evaluation of HVAC System Performance
XXXV	Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings (HYBVENT)
XXXVI	Retrofitting in Educational Buildings - Energy Concept Adviser for Technical Retrofit Measures.
XXXVII	Low Exergy Systems for Heating and Cooling of Buildings.
XXXVIII	Solar Sustainable Housing
XXXIX	High Performance Thermal Insulation Systems (HiPTI)
XXXX	Commissioning of Building HVAC Systems for Improved Energy Performance

Annex V Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre was established by the Executive Committee following unanimous agreement that more needed to be understood about the impact of air change on energy use and indoor air quality. The purpose of the Centre is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

The Participants in this task are Belgium, Denmark, Finland, Franc e, Germany, Greece, Netherlands, New Zealand, Norway, Sweden, United Kingdom and the United States of America.

Disclaimer

The standards, codes of practice, regulations and requirements contained and used within this document have all been supplied and verified by the relevant AIVC country representatives or nominated country experts. All queries regarding the data should be directed to the relevant country representative, whose contact details can be found on the AIVC web site (**www.AIVC.org**). No responsibility or liability can be accepted for any claims arising through the use of the information contained within this publication.

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Scope

The purpose of this review is to provide a reference document to all those involved in building ventilation and air leakage research and practice. This review attempts to summarise available airtightness, minimum ventilation rate and indoor air quality requirements, standards, codes of practice and regulations. It also attempts to determine the nature and type of thermal insulation requirements and the rationale behind the data outlined in this report. Attempts have also been made to normalise the data, where appropriate to enabl e comparisons to be undertaken.

1. Introduction

In each country the definition and relative importance of standards, requirements, codes of practice and regulations often have different and subtle interpretations. In some countries the terminology is also different, such as the use of the word Decree. In answer to the obvious dilemma that surrounds such an international comparison of such documents, a rationale of standards is presented in Appendix H, in which different countries have outlined their own use of the terminology and its relative hierarchy to enable not only a comparison of values where applicable, but also relating their relative level of importance and impact.

A similar comparison was undertaken as part of the European TipVent Project in which the overall context of standards and regulations was examined. As stated in their report, the different levels of standardisation show that different approaches are possible and in many cases, achieving similar results which inevitably makes criteria hard to compare. Interpretations and definitions can differ greatly between countries, for example the word “standard” rarely means the same thing in any two countries. The authors of the TipVent report cite the Dutch standard, which consists mainly test methods and the Swiss SIA standard, which contains everything from requirements to test procedures and sometimes even solutions as an example. Apart from harmonised international standards units too are expressed in a wide variety of ways, which also hinders the comparison process. The applicability of criteria also varies, throughout most of Europe the same standards are used nationwide (for example in France and Sweden). Whilst in other countries requirements may vary according to the climatic region, or specific regions, for example standards specific to the German speaking part of Europe, Germany, Austria and Switzerland. Although these standards may stay the same the regulations may vary between the states (i.e. Bundesländer, Kantone). With national standards and regulations the requirements are adapted to local situations and may be much more stringent. This can lead to problems with stringent standards becoming possible for advanced areas, while situations tend to become very complex and difficult to survey if every municipality has its own regulation. Such countries have tried therefore to harmonise their standards on a high level.

The development of harmonised European standards and regulations also has to allow for regional needs and variety at the same time, CEN TC 156 “Ventilation in Buildings” is an example. Standardisation is undertaken at various levels, whilst the standards do not vary, the regulations can be different.Where standards vary regionally or for climatic reasons, public or private bodies are responsible for standardisation. As well as governmental bodies, which are responsible for law and regulations, most countries also have an official body which is responsible for standardisation. This body may be a public national institute for standardisation like in France (AFNOR) or a public authorised private institution like in Switzerland (SIA) and in the United Kingdom (BSI). In most cases national standardisation organisations develop the standards in close co-operation with the main public, private or semi-private institutions and industry in their respective countries. These institutions are mainly industry- and research associations and institutes. (A list of standard issuing organization is given in Appendix F)

Ventilation is standardised on very different technological levels, the most important codes are the building code and the energy code, but other standards for components and for testing methods, material standards or the health- and environmental codes are also addressed. The range of standards and regulations which influence the performance of ventilation systems is very wide.

Standards and Regulations are in most countries a complex structure of interacting instruments, constantly referencing or repeating and citing each other. Due to very different procedures for the development of the standards and regulations the status of many criteria may sometimes be unclear: Is it in force or not? Is it updated? The authors of the TipVent report conclude that due to the very complex standardisation procedure evident in some countries, a paradox exists, the legislation (which is commonly believed to be slow) produces new requirements before the standards are updated.

This report therefore brings together criteria from a wide variety of sources relating to whole building and component airtightness levels, minimum ventilation rate criteria for dwellings, schools and offices, indoor air quality criteria and thermal insulation levels, and tries to compare then where possible. A true and thorough comparison is not possible, due to the many differences outlined in this section, however this document provides a compendium of current criteria which can be used as a source of information and reference.

2.0 Building and Component Airtightness

Roulet (1991) highlights the fundamentals behind airtightness measurement, as well as the main techniques used to undertake air leakage testing on whole buildings and their components. The section below has been taken from this report, all references cited appear at the end of this chapter.

The main reason for conducting building airtightness measurements is to characterize the leakage of the building fabric in the absence of climatic or other variable parameters influencing the results. Therefore the building (or part of the building or a particular component) is pressurized or depressurized in order to create a pressure difference large enough to minimize influences from wind and temperature differences, on the results. This pressure differential is built up and maintained by means of a fan, forcing an air flow through the envelope or component to be evaluated. This amplified air flow can be put in evidence by both qualitative (visualization, etc.) as well as quantitative (measurement of the air flow for a given pressure difference) techniques in order to assess the leakage locations, areas and characteristics.

The following general models can be used for the characterization of the air leakage:

The power law:

$$q = C\Delta p^n$$

and the quadratic law:

$$\Delta p = aq^2 + bq + c$$

where:

q is the volume air flow rate through the leakage site [m^3/s];
Δp is the pressure difference across the leakage site [Pa];
n is the flow exponent ($0.5 \leq n \leq 1$);
C is the air flow coefficient [$m^3 s^{-1} Pa^{-n}$], and

a and b are coefficients representing respectively the turbulent and laminar parts of the quadratic law [$Pa\ s/m^3$ and $Pa\ s^2/m^6$].

c is an optional constant representing the zero-flow pressure difference [Pa]. Note that including this constant ensures that the quadratic curve fit is not forced through the origin, as is the case with the power curve fit.

Equations (2.1) and (2.2) can also be written in terms of mass air flow rates.

The purpose of quantitative pressurization measurements is to determine these coefficients and exponents of either of the above models describing the air flow through the envelope or component.

It is useful to perform a complete error analysis before (and of course also after) carrying a measurement with any of the techniques described below. Since the leakage characteristic is not linear, surprising causes of errors can be revealed by such a study, and knowledge of this allows improvement of the measurement technique, and therefore confidence in the results [Herrlin and Modera, 1988;Fürbringer and Roulet 1991].

2.1 Methods for Whole Building Evaluation

2.1.1 DC Pressurization,

a. External Fan

The majority of measurements in this category have been performed in small residential buildings. The technique usually involves replacing an external door with a panel containing a powerful, variable speed fan. A correctly designed panel will not require the existing door to be removed from its hinges. Initially developed and used as a research tool, several commercial blower doors are now available. These can be adjusted to fit snugly into any domestic door frame. Air flow through the fan creates an artificial, uniform, static pressure within the building. Internal and external pressure taps are made and a manometer is used to measure the induced pressure differential across the building envelope. It has become common practice to test buildings up to a pressure difference of 50 Pa.

Some means must also be provided to enable the volumetric flow rate through the fan to be evaluated. The aim of this type of measurement is to relate the pressure differential across the envelope to the air flow rate required to produce it. In general the higher the flow rate required to produce a g iven pressure difference, the less airtight the building.

The air flow required to produce a given pressure difference under pressurization (air flow in) will not necessarily be identical to the flow required to produce the same pressure differential under depressurisation (air flow out). This difference is due, in the main, to the fact that certain building elements can act as flap valves. For example, some types of window will be forced into their frames under pressurisation while the reverse will be true for evacuation. This implies that the actual leakage area of the building envelope will be a function of the type of test conducted. Baker, Sharples, and Ward,(1986) suggest that, in addition to this effect, the asymmetric geometry of some cracks with respect to the flow direction may explain significant changes in leakage characteristics with no associated change in leakage area. This type of crack may occur around casement windows where one leg of an L-shaped crack may be longer than the other. Hence, ideally, the fan and flow measuring mechanism must be reversible.

Theoretically there is no limit to the size of building which can be examined with DC pressurisation. However, the maximum volume of enclosure which may be pressurized is governed by the overall airtightness of the structure and the size of the available fan. Even if large fans are available, in large leaky structures it may be possible to only achieve a limited range of pressure differentials. Several researchers have used trailer mounted fans with maximum flow capacities of about 25 m^3/s to examine buildings with volumes in the region of 50 000 m^3 (see, for example, [Shaw, 1981].

b. Internal Fan

Because of the size and cost of trailer mounted equipment and the inherent difficulties of transportation and required manpower, other techniques have been developed for the examination of large buildings. One method is to create the required pressure differential using the building's existing air handling system. This technique relies on the building possessing a suitable mechanical ventilation system which can be adjusted to meet the needs of the measurement. Essentially, the supply fans are operated while all return and extract fans are turned off. All return dampers must be closed so that the air supplied to the building can only leave through the leakage sites.

The analysis of measurements results proceeds along the same lines as that for small buildings, but because of the large building volume it may not be possible to achieve a pressure dif ference of 50 Pa. Persily and Grot 1986, for example, compared the results of several building measurements by quoting the volume flow rate at a pressure difference of 25 Pa.

DC pressurization is subject to the disturbing influence of natural pressure fluctuations created by the wind. Hence most measurements in a DC pressurization test are made at pressure differentials far above those created by natural forces. This may lead to inaccuracy if the results are extrapolated to lower pressure differentials.

2.1.2 AC Pressurisation

AC pressurisation is a technique which allows building airtightness to be examined at similar pressure differentials with minimal interference from climatic forces. In this technique a small varying pressure difference is created across the building envelope, which is distinguishable from naturally occurring pressure fluctuations. Because of this, air flow through the envelope, induced by the applied pressure differential, can be evaluated [Modera and Sherman, 1985].

In practice a piston is used to create a continuous harmonic change in the internal volume of the building under test. This creates a time-varying pressure difference across the envelope. The airtightness of the building affects the amplitude and phase of the pressure change due to the harmonic volume change.

By measuring the amplitude of the pressure response inside the building and the phase relationship between this pressure and the velocity of the piston, the air flow through the envelope can be evaluated. The effects of air leakage sites are evident using this method, however large openings (such as open windows, which should anyway be closed during the test) can go undetected. This technique is not currently in use.

2.1.3 Pulse pressurisation

Methods avoiding the installation of heavy instruments could be useful, even if they are not very accurate. Such a method is even patented (Yuil, 1985) but was not widely diffused.

Based upon the theory of pressure evolution in a leaky cavity, a decay technique that could be used to quantify the leakage was developed and tested [Sherman and Modera, 1988]. The pressure is suddenly enhanced in the measured volume, e.g. by slamming the entrance door. The leakage characteristics are identified by fitting the measured pressure decay to theoretical values.

2.2 Quantitative Determination of Building Component Airtightness

The most accurate way for determining component leakage is testing the component in the laboratory. This is a standardized procedure for windows and doors in many countries (see section 2.3). This procedure is not at all appropriate for testing walls or roof components in real buildings, therefore other techniques for use on site have been developed.

The leakage characteristics of individual enteral buildings components can be evaluated from site measurements. In its simplest form this consists of sealing a chamber over the interior face of the building component. Air is supplied to or extracted from the chamber at a rate required to maintain a specified static pressure difference across the specimen. The resultant air flow through the specimen and the specified pressure difference are recorded.

This test is made more accurate if the pressure in the room containing the component is balanced to that in the collection chamber. This pressure balancing can be performed by using a secondary or auxiliary fan located in the room envelope. A fan is used to depressurise the room to a given pressure differential and another fan is adjusted to maintain a zero pressure difference between the collection chamber and the room. The leakage flow through the target area is then measured at Q. The increase in accuracy is due to the elimination of unwanted leakage between the collecting chamber and the rest of the room.

Whole house fan pressurization may also he used for evaluating the leakage path distribution by selectively sealing different potential leakage paths (using, for example, plastic sheeting or sticky tape) and measuring the resulting changes in air flow rate. The fraction of the total air leaking through the sealed components of the building envelope can then be deduced. Further components may be sealed and pressurisation repeated, hence this technique is often known as reductive sealing. As the components will be generally sealed from the inside, it is preferable that an over-pressure rather than an under-pressure be created within the building. Pressurisation will tend to force the seal onto the component while a negative pressure will tend to act against the seal making it less airtight.

Site measurements of component leakage can also be made by using a pressure compensating flow rate meter (e.g. [Phaff, 1987]). This device operates on the zero pressure principle whereby the resistance of the measuring instrument is compensated by means of an integral fan. This type of equipment was originally developed for measuring the flow rate at the supply and exhaust grilles of mechanical ventilation systems. When correctly adjusted the presence of the device does not influence the air flow and therefore the flow rate can be determined directly.

For this particular application a collection chamber is placed over the area where the cracks are situated and a flow meter is placed over an opening in the box. By compensating the pressure difference the air flow through the cracks is evaluated. The collection chamber does not need to be airtight, since at nearly zero pressure differential, unwanted leak flows will be minimal.

The building is pressurized in the normal way and a shield of hardboard is placed in the opening of an internal door. The flow meter is placed over an opening in the shield and at pressure compensation the air flow through office room facade is indicated. Bypass flows trough adjacent internal walls will be minimal near pressure compensation. However large internal leaks may make it impossible to see when compensation is reached.

Building component airtightness measurements can be performed under controlled laboratory conditions. A test chamber is used, into which various test specimens are fitted. The air flow through and the pressure difference across the test specimen can be accurately determined under laboratory conditions. This type of test enables large numbers of specimens to be examined under similar conditions. The results of such tests are often reported in terms of leakage per unit area or leakage per unit crack length. It must be noted that laboratory based measurements may produce significantly different results to site evaluations of seemingly identical components. This is mainly due to the fact that laboratory workmanship may be under closer control than that on site.

The air leakage through the whole surface of individual external or internal walls can be evaluated using a technique known as balanced fan pressurization. This method is particularly appropriate for large multi-cell buildings such as apartment blocks or multi-family dwellings. For example consider one apartment in a multi apartment building. The apartment will have a single external wall with up to five other walls being shared with adjoining corridors or apartments. If a normal fan pressurisation test is performed, the measured leakage will include the leakage to several internal zones. If however the pressure in these other zones is balanced with that in the main test zone, i.e. zero pressure difference across internal walls, then no air leakage will occur through internal flow paths and only the leakage to the external environment will be evaluated.

In order to achieve this pressure balance each surrounding zone must be pressurised along with the main measurement zone. Thus more than one set of fan pressurization equipment is required for this type of test. Also control procedures are needed in order to maintain zero pressure differences where required. The technique is not limited to multi-compartment buildings but it may also be used in a variety of other situations. For example, in a row of terraced houses, one house is pressurized in the normal manner whilst the adjacent houses are balanced to the same pressure. This enables the leakage through the external walls of the dwelling to be separated from the leakage through the partition walls.

Table 2.1 Overview of Current Airtightness Levels in Standards and Regulations (References are contained in Appendix A)

Country	Whole Building	Components	
		Windows	Doors
Belgium	***These are only recommendations, no obligations*** <3ach at 50Pa for dwellings with balanced mechanical vent. <1ach when heat recovery devices are used.		
Denmark			0.50 dm^3.s/m at 50Pa
Finland		Class 1 <0.5 $m^3/h.m^2$ at 50 Pa Class 2 0.5-2.5 $m^3/h.m^2$ at 50 Pa Class 3 >2.5 $m^3/h.m^2$ at 50 Pa	
France	The reference value in the air flow under 4 Pa, divided by the area of the envelope (and so expressed in $m^3/(h.m^2)$). The reference values vary from 0.8 to 2.5 depending on the type of construction. If no engagement is taken on a given value, a default value can be applied by adding 0,5 to the reference one.	Class A1 20-60 $m^3/h.m^2$ at 100Pa ClassA2 7-20 $m^3/h.m^2$ at 100Pa Class A3 <7 $m^3/h.m^2$ at 100Pa	Class A1 20-60 $m^3/h.m^2$ at 100Pa ClassA2 7-20 $m^3/h.m^2$ at 100Pa Class A3 <7 $m^3/h.m^2$ at 100Pa
Germany		The standard classifies windows by exposure level and gives acceptable air permeability values for each group under pressure over the range 10 to 1000Pa pressure Difference 1-20 $m^3/h.m$ length of crack over pressure diff 10 to 1000 Pa	
Italy	18.12.75 specifies a recommendation for an envelope air leakage value for schools; the infiltration rate across 1 square metre of exterior envelope should not exceed 10m3/h at a pressure difference of 10mm of water (98Pa). It also gives prescribed air changes rates of between 1.5 - 5.0ACH for rooms in school buildings.	1.4 – 4.0 $m^3/h.m$ at 50 Pa air flow rate per unit length of opening. 4.8 – 31 $m^3/h.m^2$ at 50 Pa air flow rate per unit area of window.	
Netherlands	**Standard NEN 2687 requirements** **Class 1 Max** 100-200 dm^3/s at 10Pa (1.4-2.24ach at 10Pa) Class 1 Min 30-50dm^3/s (0.4-0.72 ach at 10Pa) **Class 2 Max** upto 80 dm^3/s (0,72-1.15 ach at 10 Pa) In Building Decree the maximum air leakage of buildings is 200 dm^3/s at 10Pa tested according to NEN 2686 test method	2.5 dm^3/s per m length of crack at 75Pa 0.5 dm^3/s per 100 mm of frame section. **(NEN 2636)**	
New Zealand		0.6-4.0 dm^3/s per m length of joint at 150 Pa 2.0-17 $dm^3/s.m^2$ windows area at 150Pa.	
Norway	**Detached and undetached houses** 4 ach at 50 Pa **Other buildings two storeys high or less** 3 ach at 50 Pa **Other buildings >2 storeys high** 1.5 ach at 50 Pa		
Sweden	The building envelope shall be so airtight that the average air leakage rate at a pressure difference of 50 Pa does not exceed 0.8 l/s per m² for dwellings and 1.6 l/s m² for other spaces.		

Switzerland	**New Buildings** upper limit 0.75 m^3/h.m^2 Recommended limit 0.5 m^3/h.m^2 **Refurbished or modified buildings** upper limit 1.5 m^3/h.m^2 Recommended limit 1 m^3/h.m^2	0.2 m^3/h at 1 Pa (when n=0.66) (a) 5.65 m^3/h.m at 150 Pa (b) 8.95 m^3/h.m at 300 Pa (c) 14.25 m^3/h.m at 600 Pa	
United Kingdom	According to CIBSE TM23 2000 Not in Building regs yet) **Air Leakage index** **Dwellings** 15.0 m^3.h.m^2 at 50Pa (Good practice) 8 m^3.h.m^2 at 50Pa (best practice) **Dwellings (with whole house balanced mech. Vent)** 8.0 (GP) – 4.0 (BP) m^3.h.m^2 at 50Pa **Nat Vent. Offices** 10.0 (GP)- 5.0(BP) m^3.h.m^2 at 50Pa **Offices with Mech. Vent.** 5.0(GP)-2.5 (BP) m^3.h.m^2 at 50Pa **Superstores** 5.0(GP)-2.0 (BP) m^3.h.m^2 at 50Pa **Industrial** 15.0(GP)-2.0 (BP) m^3.h.m^2 at 50Pa	1.22-6.2 m^3/h.m of joint opening at 50Pa	
United States of America	Normalised leakage range taken from measurements at 4Pa ELA for whole of USA. From <0.1-1.60 (from ASHRAE 119-1988 (RA)Apped.B ACH≈LN. therefore <0.1-1.6ach) Note: Standard requires no part of the US to be tighter than 0.28 (only a small part of upper Midwest) Mostly the tightness requirement is 0.4.	Windows are 0.3 cfm per m^2 of window area, when tested by ASTM E28 **ASHRAE Standard 90.1-99** gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400.. Air leakage shall not exceed 5 l/s.m^2 for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products. ***ASHRAE 90.2-1999.*** (a) aluminium windows shall be 0.37cfm/ft of sash crack (b) PVC windows shall be either 0.37cfm/ft of sash crack, or 0.375 cfm/ft of area sash crack. (c) wood windows shall be 0.34 cfm/ft of sash crack, as specified in ANSI/WWDA I.S 2 87 (d) The requirement for manufactured housing windows shall be 0.50 cfm/ft^2 of window area. The air infiltration rate requirement for windows not covered by any of the listed references shall be 0.34 cfm/ft of sash crack. The requirement for fixed windows shall be0.34 cfm/ft^2 of window area.	**ASHRAE Standard 90.1-99** gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400.. Air leakage shall not exceed 5 l/s.m^2 for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products. **Sliding Doors** (a) Aluminium sliding doors 0.37cfm/ft^2 of door area (b) PVC sliding doors either 0.37cfm/ft^2 of door crack, 0.375 cfm/ft^2 of door area. (c) wooden sliding doors shall be 0.34 cfm/ft^2 of door area, (d) manufactured housing sliding doors shall be 0.50 cfm/ft^2 of door area, **Swinging Doors** The infiltration rate shall not exceed 0.5 cfm/m^2 of door area except for manufactured housing swinging doors. The requirement for these shall be 1.0 cfm/ft^2 of door area.

2.3 Whole Buildings

In the previous section the techniques used to pressurise buildings have been outlined. This section aims to compare the whole building airtightness requirements, standards etc currently adopted by specific countries. Currently Belgium, France, Italy, Netherlands, Norway, Sweden, Switzerland, and the United States of America have criteria to limit whole building air leakage. The United Kingdom is currently in the process of updating their Building Regulations to include for the first time whole building airtightness levels. These recommendations and standards are outlined in Appendix A, and have been summarised in Table 2.2.

Table 2.2 Whole building airtightness requirements

Country	Whole Building Airtightness
Belgium	***These are only recommendations, no obligations*** <3ach at 50Pa for dwellings with balanced mechanical vent. <1ach when heat recovery devices are used.
France	The reference value in the air flow under 4 Pa, divided by the area of the envelope (and so expressed in $m^3/(h.m^2)$). The reference values vary from 0.8 to 2.5 depending on the type of construc tion. If no engagement is taken on a given value, a default value can be applied by adding 0,5 to the reference one.
Italy	18.12.75 specifies a recommendation for an envelope air leakage value for schools; the infiltration rate across 1 square metre of exterior envelope should not exceed $10m^3/h$ at a pressure difference of 10mm of water (98Pa). It also gives prescribed air changes rates of between 1.5 - 5.0ACH for rooms in school buildings.
Netherlands	**Standard NEN 2687 requirements** **Class 1 Max** 100-200 dm^3/s at 10Pa (1.4-2.24ach at 10Pa) Class 1 Min 30-50dm^3/s (0.4-0.72 ach at 10Pa) **Class 2 Max** upto 80 dm^3/s (0,72-1.15 ach at 10 Pa) In Building Decree the maximum air leakage of buildings is 200 dm3/s at 10Pa tested according to NEN 2686 test method
Norway	**Detached and undetached houses** 4 ach at 50 Pa **Other buildings two storeys high or less** 3 ach at 50 Pa **Other buildings >2 storeys high** 1.5 ach at 50 Pa
Sweden	The building envelope shall be so airtight that the average air leakage rate at a pressure difference of 50 Pa does not exceed 0.8 l/s per m² for dwellings and 1.6 l/s m² for other spaces.
Switzerland	**New Buildings** upper limit 0.75 $m^3/h.m^2$ Recommended limit 0.5 $m^3/h.m^2$ at 4Pa **Refurbished or modified buildings** upper limit 1.5 $m^3/h.m^2$ again at 4 Pa Recommended limit 1 $m^3/h.m^2$
United Kingdom	According to CIBSE TM23 2000 Not in Building regs yet) **Air Leakage index** **Dwellings** 15.0 $m^3.h.m^2$ at 50Pa (Good practice) 8 $m^3.h.m^2$ at 50Pa (best practice) **Dwellings (with whole house balanced mech. Vent)** 8.0 (GP) – 4.0 (BP) $m^3.h.m^2$ at 50Pa **Nat Vent. Offices** 10.0 (GP)- 5.0(BP) $m^3.h.m^2$ at 50Pa **Offices with Mech. Vent.** 5.0(GP)-2.5 (BP) $m^3.h.m^2$ at 50Pa **Superstores** 5.0(GP)-2.0 (BP) $m^3.h.m^2$ at 50Pa **Industrial** 15.0(GP)-2.0 (BP) $m^3.h.m^2$ at 50Pa
United States of America	Normalised leakage range taken from measurements at 4Pa ELA for whole of USA. From <0.1 -1.60 (from ASHRAE 119-1988 (RA)Apped.B ACH≈LN. therefore <0.1-1.6ach) Note: Standard requires no part of the US to be tighter than 0.28 (only a small part of upp er Midwest) Mostly the tightness requirement is 0.4.

The optimum performance of a ventilation system as well as energy control and comfort conditions are dependent on the airtightness of the building envelope. This is defined as the volumetric flow rate or air change rate for a building artificially pressured to, for example, 50Pa, with all purpose provided openings sealed. Excessively leaky buildings will interfere with the performance of modern mechanical systems and will greatly reduce the net efficiency of heat recovery devices. On the other hand, naturally ventilated buildings may require higher levels of permeability preferably through purpose provided openings in order that sufficient ventilation air is provided.

Airtightness is frequently expressed in terms of an artificially induced pressure (usually 50Pa). The basis of this pressure is that it is sufficiently large to prevent naturally occurring pressures from influencing the result, but not so large that cracks and gaps and not distorted by the applied pressure.

From the data outlined in Table 2.2, five countries (Belgium, Italy, Netherlands, Norway and the United States of America) express criteria of whole building airtightness in terms of air changes per hour (ACH) at a specific reference pressure. These are compared in Figure 2.1 below.

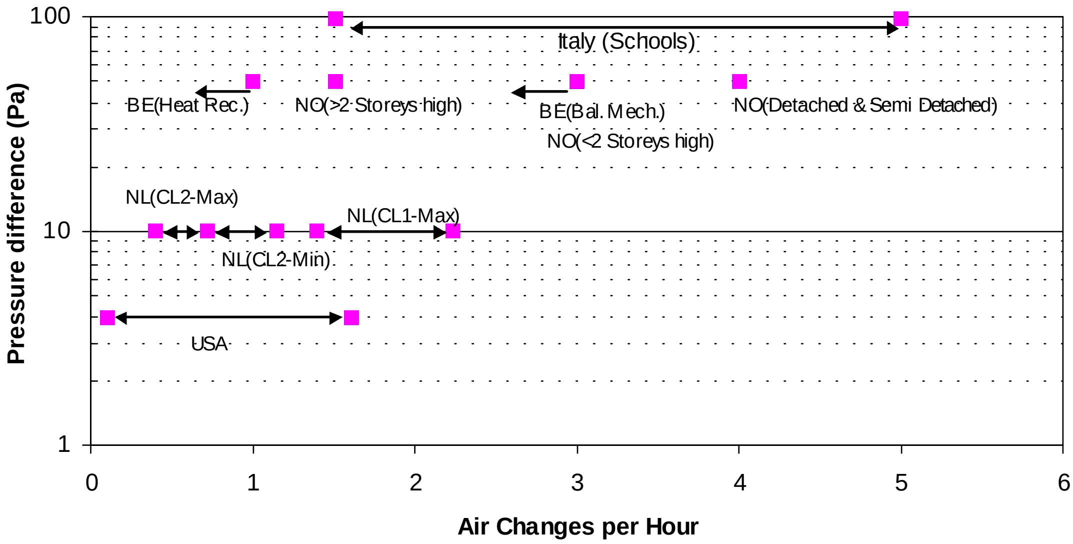

Figure 2.1 Whole building airtightness comparison in air changes per hour at the specified pressure difference.

To enable a comparison between whole building values in air changes per hour (ach) the given requirements should be expressed at the same reference pressure. Normally taken as 50 Pa, Belgium and Norway already express their values to this pressure. However, Italy, Netherlands and the United States express their data at other pressures (98, `10 and 4 Pa respectively). To normalise these criteria to the same 50Pa reference pressure it is first necessary to determine the flow coefficient at the given pressure and then apply it to the normalised 50 Pa reference pressure. This has been undertaken in tables 2.3 and 2.4.

Table 2.3 A comparison of flow coefficients and air change rates from maximum airtightness standards for whole buildings (In certain cases only applicable to certain ventilation systems)

Country	ACH (max) at specified pressure difference (Pa)	Calculated flow coefficient k, (m^3/s) at specified air change rate and pressure difference (Pa)	Normalised air change rate to 50Pa
Italy (schools)	1.5 ach at 98Pa	0.073	1.0 ach at 50Pa
Netherlands (NL)(Cl1-Max)	0.4 ach at 10Pa	0.088	1.2 ach at 50Pa
United States of America	0.1 ach at 4Pa	0.04	0.53 ach at 50Pa

Table 2.4 A comparison of flow coefficients and air change rates from minimum airtightness standards for whole buildings (In certain cases only applicable to certain ventilation syste ms)

Country	ACH (max) at specified pressure difference (Pa)	Calculated flow coefficient k, (m^3/s) at specified air change rate and Pressure Difference (Pa)	Normalised air change rate to 50Pa
Italy (schools)	5.0 ach at 98Pa	0.243	3.2 ach at 50Pa
Netherlands (NL)(Cl1-Min)	2.24 ach at 10Pa	0.49	6.5 ach at 50Pa
Netherlands (NL)(Cl2 Min)	1.15 ach at 10Pa	0.252	3.3 ach at 50Pa
United States of America	1.6 ach at 4Pa	0.64	8.5 ach at 50Pa

Figure 2.2 below compares the normalised criteria with that already quoted at 50 Pa from Belgium, and Norway. The figure below indicates that typical airtightness criteria lie between 1 and 4 ach at 50 Pa. In the United States the minimum whole building air leakage standard requires no part of the US to be tighter than 0. 28 ach at 4 Pa (1.5 ach at 50Pa) (only a small part of the mid west) mostly the tightness requirement is 0.4 ach at 4Pa (equivalent to 2.1 ach at 50Pa).

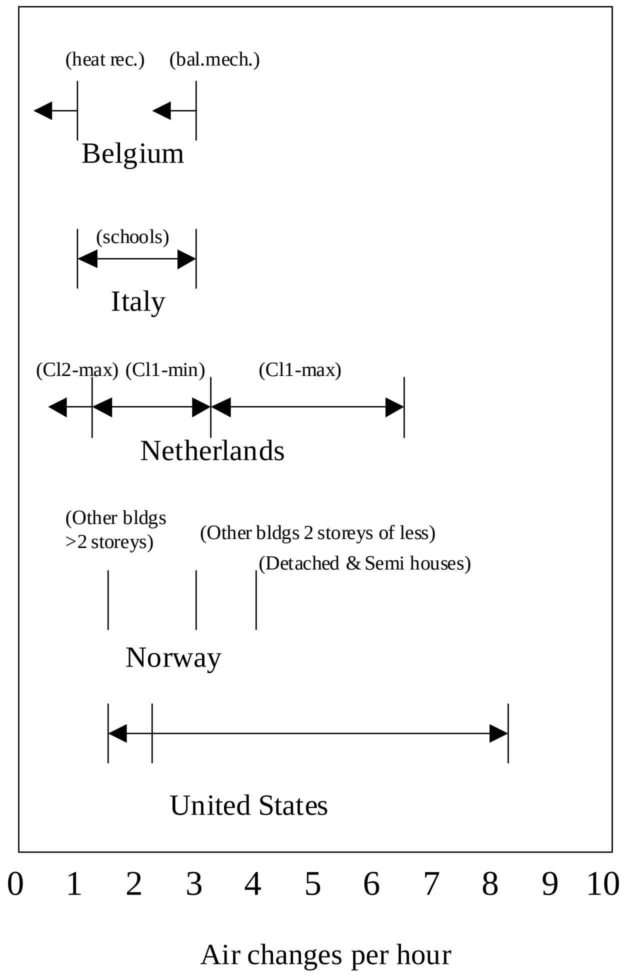

Figure 2.2 Whole building airtightness comparison in Air Changes per Hour at a normalised pressure difference of 50Pa.

France, Switzerland and the United Kingdom express whole building air tightness criteria in terms of $m^3/h.m^2$ at a given pressure differential. In Sweden the criteria is expressed in terms of $l/s\ m^2$, which can easily be converted to $m^3/h\ m^2$. Comparisons appear in figure 2.3 below.

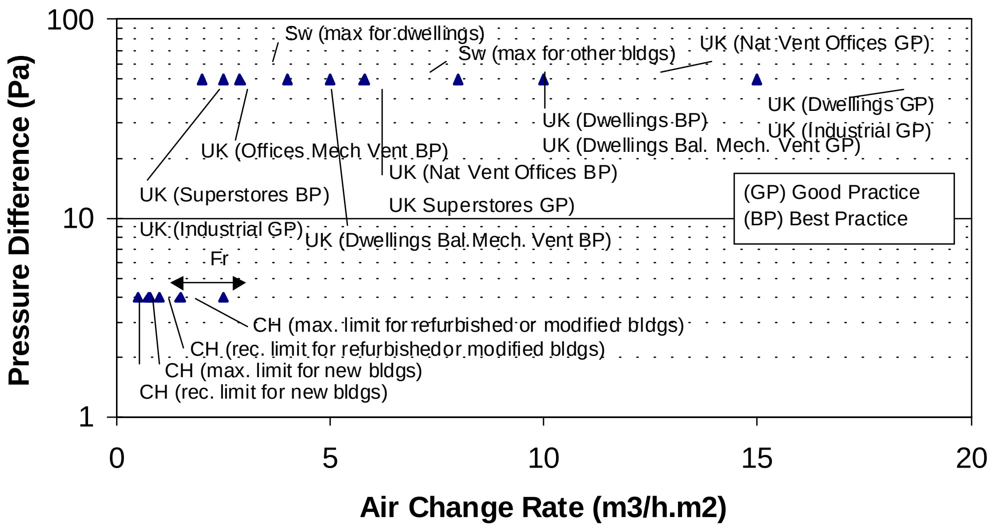

Figure 2.3 Whole building airtightness comparison in $m^3/h.m^2$ at the specified pressure difference.

In order to compare these criteria with the air change per hour (ACH) criteria expressed by other countries, a typical building volume and surface area has been assumed. For example assuming a typical building volume of $300m^3$ and a surface area of $250m^2$ air leakage rates can now be compared, if very crudely. This type of analysis is however limited, since the air changes rates outlined below, cover a wide range of building types, from dwellings to superstores. Naturally the size and nature of these buildings govern the permitted air change recommendations. However, the normalised figures do compare quite well with those outlined above. Naturally ventilated buildings have a less stringent air tightness requirement, to ensure adequate ventilation provision is provided and not reduced too much. Mechanically ventilated buildings are more stringently controlled, to save energy in terms of infiltration losses and to enable better control of ventilation air.

Table 2.5 Airtightness criteria expressed in terms of leakage area ($m^3/h.m^2$) converted to an air change rate (ACH) and then normalised to a standard 50Pa pressure differential.

Country	Recommendation	Convert to ach	***Normalise to 50 Pa***
France	0.8 to 2.5 $m^3/h.m^2$	(0.8x250)/300=0.67ach at 4 Pa (2.5x250)/300=2.10 ach at 4 Pa	***3.54 ach at 50 Pa*** ***11 ach at 50 Pa***
Switzerland (4 Pa)	New Build. 0.5 $m^3/h.m^2$ (rec) New Build 0.75 $m^3/h.m^2$ (max) Refurb 1 $m^3/h.m^2$ (rec) Refurb. 1.5 $m^3/h.m^2$ (max)	(0.5x250)/300=0.42 ach at 4 Pa (0.75x250)/300=0.63 ach at 4 Pa (1x250)/300=0.8ach at 4 Pa (1.5x250)/300=1.25 ach at 4 Pa	***2.2 ach at 50 Pa*** ***3.3ach at 50 Pa*** ***4.2ach at 50 Pa*** ***6.61ach at 50 Pa***
United Kingdom (50Pa)	Dwellings 15.0 $m^3.h.m^2$ at 50Pa (Good practice) 8 $m^3.h.m^2$ at 50Pa (best practice) Dwellings (with whole house balanced mech. Vent) 8.0 (GP) – 4.0 (BP) $m^3.h.m^2$ at 50Pa Nat Vent. Offices 10.0 (GP)- 5.0(BP) $m^3.h.m^2$ at 50Pa Offices with Mech. Vent. 5.0(GP)-2.5 (BP) $m^3.h.m^2$ at 50Pa Superstores 5.0(GP)-2.0 (BP) $m^3.h.m^2$ at 50Pa Industrial 15.0(GP)-2.0 (BP) $m^3.h.m^2$ at 50Pa	(15x250)/300=12.5ach at 50 Pa (8x250)/300=6.7 ach at 50Pa (8x250)/300=6.7ach at 50Pa (4x250)/300=3.3ach at 50 Pa (10X250)/300= 8.3ach at 50 Pa (5x250)/300=4.1ach at 50 Pa (5x250)/300=4.1ach at 50 Pa (2.5x250)/300=2ach at 50 Pa (5x250)/300=4.1ach at 50 Pa (2x250)/300=1.7ach at 50Pa (15x250)/300=18ach at 50 Pa (2x250)/300=1.7ach at 50Pa	***12.5ach at 50Pa*** ***6.7ach at 50 Pa*** ***6.7 ach at 50 Pa*** ***3.3ach at 50Pa*** ***8.3ach at 50 Pa*** ***4.1ach at 50Pa*** ***4.1 ach at 50 Pa*** ***2ach at 50 Pa*** ***4.1 ach at 50Pa*** ***1.7 ach at 50 Pa*** ***12.5 ach at 50 Pa*** ***1.7 ach at 50 Pa***

To attempt a more thorough comparison, information regarding typical building volumes would be required, and then only buildings of a similar sector could be compared. Such comparisons would naturally need to take account of local weather, terrain and shelter and thus would be hard to compare.

2.4 Building Components

Component pressurisation standards are designed to test the manufacture and quality of materials of these elements. The various techniques used to measured their integrity have been briefly highlighted in section 2.2 above. The two main types of components which have criteria applying to them are windows and doors, although floors and walls are also considered in some countries. Table 2.6 outlines the criteria specified by various countries, which are more fully detailed in Appendix A1.

Table 2.6 Building component airtightness requirements

Country	**Components**	
	Windows	**Doors**
Belgium		
Denmark		0.50 dm^3.s/m at 50Pa
Finland	Class 1 <0.5 $m^3/h.m^2$ at 50 Pa Class 2 0.5-2.5 $m^3/h.m^2$ at 50 Pa Class 3 >2.5 $m^3/h.m^2$ at 50 Pa	
France	Class A1 20-60 $m^3/h.m^2$ at 100Pa ClassA2 7-20 $m^3/h.m^2$ at 100Pa Class A3 <7 $m^3/h.m^2$ at 100Pa	Class A1 20-60 $m^3/h.m^2$ at 100Pa ClassA2 7-20 $m^3/h.m^2$ at 100Pa Class A3 <7 $m^3/h.m^2$ at 100Pa
Germany	The standard classifies windows by exposure level and gives acceptable air permeability values for each group under pressure over the range 10 to 1000Pa pressure Difference 1-20 m^3/h.m length of crack over pressure diff 10 to 1000 Pa	
Italy	1.4 – 4.0 m^3/h.m at 50 Pa air flow rate per unit length of opening. 4.8 – 31 $m^3/h.m^2$ at 50 Pa air flow rate per unit area of window.	
Netherlands	2.5 dm^3/s per m length of crack at 75Pa 0.5 dm^3/s per 100 mm of frame section **. (NEN 2636)**	
New Zealand	0.6-4.0 dm^3/s per m length of joint at 150 Pa 2.0-17 $dm^3/s.m^2$ windows area at 150Pa.	
Switzerland	0.2 m^3/h at 1 Pa (when n=0.66) (a) 5.65 m^3/h.m at 150 Pa (b) 8.95 m^3/h.m at 300 Pa (c) 14.25 m^3/h.m at 600 Pa	
United Kingdom	1.22-6.2 m^3/h.m of joint opening at 50Pa	
United States of America	Windows are .3 cfm per m^2 of window area, when tested by ASTM E28 **ASHRAE Standard 90.1-99** gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400.. Air leakage shall not exceed 5 l/s.m ^{2} for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products. ***ASHRAE 90.2-1999.*** (a) aluminium windows shall be 0.37cfm/ft of sash crack (b) PVC windows shall be either 0.37cfm/ft of sash crack, or 0.375 cfm/ft of area sash crack. (c) wood windows shall be 0.34 cfm/ft of sash crack, as specified in ANSI/WWDA I.S 2 87 (d) The requirement for manufactured housing windows shall be 0.50 cfm/ft^2 of window area. The air infiltration rate requirement for windows not covered by any of the listed references shall be 0.34 cfm/ft of sash crack. The requirement for fixed windows shall be0.34 cfm/ft^2 of window area.	**ASHRAE Standard 90.1-99** gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400.. Air leakage shall not exceed 5 l/s.m ^{2} for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products. **Sliding Doors** (a) Aluminium sliding doors 0.37 cfm/ft^2 of door area (b) PVC sliding doors either 0.37 cfm/ft^2 of door crack, 0.375 cfm/ft^2 of door area. (c) wooden sliding doors shall be 0.34 cfm/ft^2 of door area, (d) manufactured housing sliding doors shall be 0.50 cfm/ft^2 of door area, **Swinging Doors** The infiltration rate shall not exceed 0.5 cfm/m ^{2} of door area except for manufactured housing swinging doors. The requirement for these shall be 1.0 cfm/ft^2 of door area.

2.4.1 Windows

Finland, France, Germany, Italy, Netherlands, New Zealand, Switzerland, United Kingdom and the United States of America have airtightness criteri a for windows.

However, the criteria are expressed in two formats, Germany, Netherlands, New Zealand, Switzerland, and the United Kingdom express window air leakage criteria in terms of unit length of crack (m^3/h.m) while Finland, France, New Zealand, and United States of America express criteria in terms of unit area of window (m^3/h.m^2). These have been outlined in figures 2.5 and 2.6 below. However, due to the slightly different ways of expressing airtightness criteria for windows, i.e. per unit length of crack and per m^2 or window area, a direct comparison is not possible between the two formats.

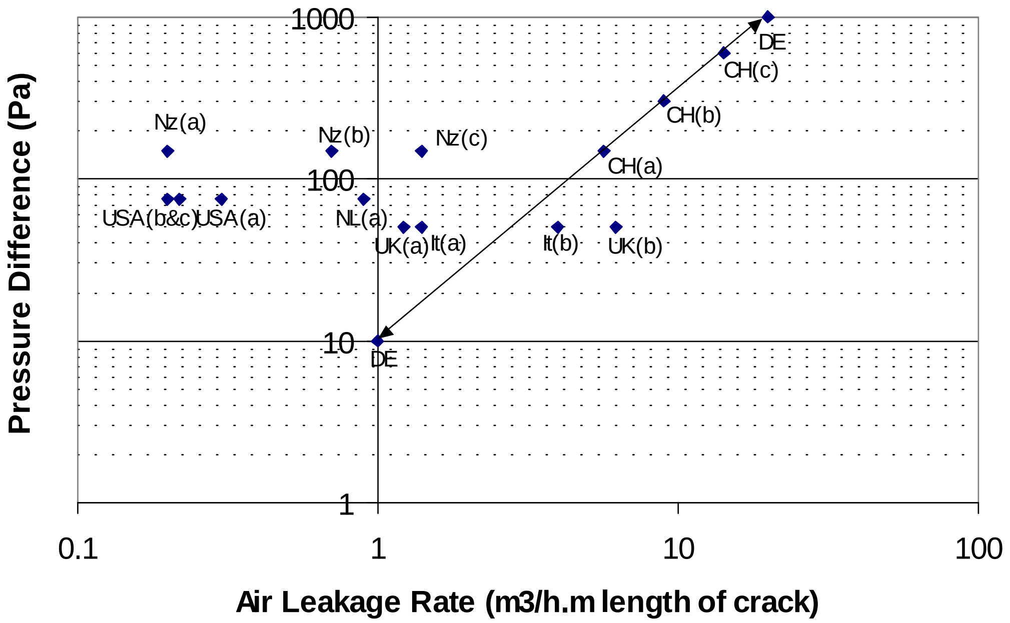

Figure 2.5 Window air leakage rates (per metre length of joint)

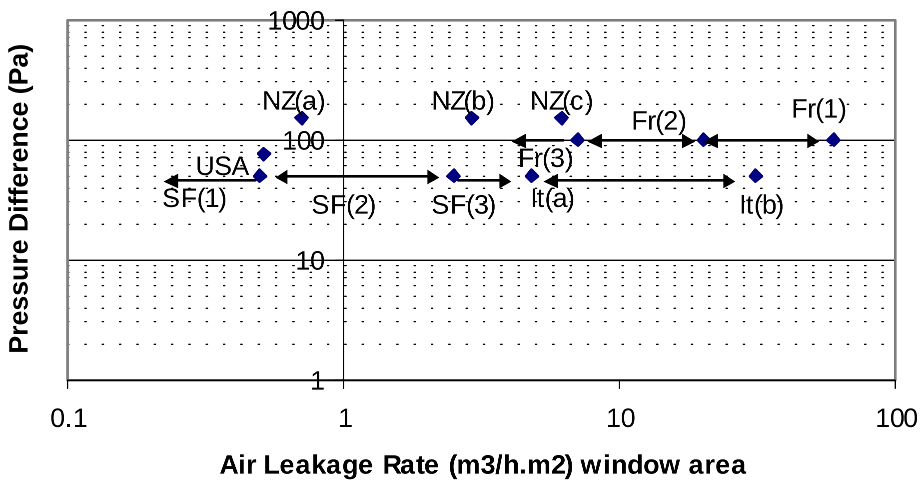

Figure 2.6 Window air leakage rates (per m^2 of window area)

Countries express window leakage criteria in terms of grades of window, most having three grades or categories of window leakage which cover airtight, moderate and low air resistance without specific applications for each particular grade. The Netherlands and Switzerland specify criteria relating to building height, and the Netherlands further considers building location (coastal, inland etc). Figures 2.5 and 2.6 summarize the air leakage criteria for windows. It can be seen that the criteria are expressed over a range of pressure differentials. Some countries specify grades of windows at a single pressure (for example Italy, New Zealand and the USA), while others specify window leakage criteria over a range of pressures (for example, Germany and the United Kingdom).

Criteria for countries in colder climates and/or for buildings designed to incorporate mechanical ventilation systems tend to have more stringent air leakage criteria. In countries where the climate is more moderate and/or natural ventilation is common, less importance is placed on the levels of specified air leakage for components. However, air leakage represents a significant potential energy loss, and as such is attracting more importance. It is no longer acceptable to provide poorly fitting building components as an alternative to providing well designed natural ventilation strategies. If natural ventilation is chosen as a ventilation strategy, then it should be well designed and implemented, and not supplemented by poor leaky building components.

2.4.2 Doors

Only Denmark, France, and the United States have airtightness standards for doors. Denmark expresses criteria in terms of $dm^3/s.m$ at 50Pa, France in terms of $m^3/h.m^2$ at 100 Pa and are the same as those used for windows, and the United States in cfm/ft^2 and l/s m^2. The French and USA criteria are expressed in terms of door area and can be normalised to the same units, but the Belgian criteria is expressed in terms of length of door crack and cannot adequately be compared.

Table 2.7 Normalised door leakage criteria

Country	Specified criteria	Normalised to the same units
France	A1 20 – 60 $m^3/h.m^2$ at 100 Pa A2 7 – 20 $m^3/h.m^2$ at 100 Pa A3 <7 $m^3/h.m^2$ at 100 Pa	A1 20 – 60 $m^3/h.m^2$ at 100 Pa (13–38 $m^3/h.m^2$ at 50 Pa) A2 7 – 20 $m^3/h.m^2$ at 100 Pa (5-13 $m^3/h.m^2$ at 50 Pa A3 <7 $m^3/h.m^2$ at 100 Pa (<5 $m^3/h.m^2$ at 50 Pa)
Denmark	0.5 dm^3/s at 50 Pa length of crack	0.18 $m^3/h.m$ at 50 Pa length of crack
United States	ASHRAE Standard 90.1-99 gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400.At a reference pressure of 75Pa. Air leakage shall not exceed 5 $l/s.m^2$ for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products. Sliding Doors (a) Aluminum sliding doors 0.37cfm/ft^2 of door area (b) PVC sliding doors either 0.37cfm/ft^2 of door crack, 0.375 cfm/ft^2 of door area. (c) wooden sliding doors shall be 0.34 cfm/ft^2 of door area, (d) manufactured housing sliding doors shall be 0.50 cfm/ft^2 of door area, Swinging Doors The infiltration rate shall not exceed 0.5 cfm/m^2 of door area except for manufactured housing swinging doors. The requirement for these shall be 1.0 cfm/ft^2 of door area.	ASHRAE Standard 90.1-99 gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400. At a reference pressure of 75Pa. Air leakage shall not exceed 18 $m^3/h.m^2$ (14 $m^3/h.m^2$ at 50 Pa) for glazed swinging entrance doors and for revolving doors 7.2 $m^3/h.m^2$ (5.5 $m^3/h.m^2$ at 50 Pa) for all other products. Sliding Doors (a) Aluminum sliding doors 0.63 $m^3/h.m^2$ (0.48 $m^3/h.m^2$ at 50 Pa) of door area (b) PVC sliding doors either 0.63 $m^3/h.m^2$ (0.48 $m^3/h.m^2$ at 50 Pa) of door crack, 0.64 $m^3/h.m^2$ (0.49 $m^3/h.m^2$ at 50 Pa) of door area. (c) wooden sliding doors shall be 0.58 $m^3/h.m^2$ (0.45 $m^3/h.m^2$ at 50 Pa) of door area, (d) manufactured housing sliding doors shall be 0.85 $m^3/h.m^2$ (0.66 $m^3/h.m^2$ at 50 Pa) of door area, Swinging Doors The infiltration rate shall not exceed 0.85 $m^3/h.m^2$ (0.66 $m^3/h.m^2$ at 50 Pa) of door area except for manufactured housing swinging doors. The requirement for these shall be 1.7 $m^3/h.m^2$ (1.3 $m^3/h.m^2$ at 50 Pa) of door area.

From the above table it can be seen that when normalised to 50 Pa pressure difference, the criteria from the United States compares with those from France. In addition the United States appears to have more stringent criteria for sliding and swinging doors requiring greater levels of air tightness.

2.4.2 Other Components

The Netherlands also specify air leakage criteria for floor space directly above a crawl space, and France specifies air leakage rate of opaque external walls of dwellings, both specified in $m^3/h.m^2$ at 1 Pa pressure difference.

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3.0 Minimum Ventilation Rate Requirements

3.1 Ventilation in Dwellings

Minimum ventilation rate standards for dwellings are essential to provide occupant health and comfort and to remove and dilute the dominant pollutants. In dwellings these are pollutants generated by cooking (moisture, NO_x) and washing (moisture), as well as in some cases tobacco smoke.

Whilst it is best to design dwellings which minimise the generation and spread of moisture, the relatively small size of most dwellings means that some moisture generation is inevitable. Therefore guidelines are given for pollutants such as NO_2 (released when using gas appliances) or environmental tobacco smoke. Cooking and other combustion appliances can be modified to pollute less. Moisture whilst in its pure form is not really of concern, can indirectly result in structural problems, caused by excessive condensation, and the formation of mould. Moulds can be harmful to occupant health if spores are released into the indoor environment. To minimise the ill effects of these pollutants, and to ensure the energy saving measures do not restrict ventilation to unacceptable levels, minimum ventilation rate standards have been set by most countries.

These are based primarily on bioeffluents as the main polluter, ensuring design and education will minimise the pollutant problems associated with dwellings. In most countries the additional requirement of mechanical extract devices in bathrooms and kitchens attempts to deal locally with excessive moisture and pollutants associated with cooking. All criteria have been summarised in table 3.1 and appear in more detail in Appendix C.

Table 3.1 Minimum ventilation rate criteria for dwellings

Country and Reference	Minimum ventilation rate criteria for dwellings					
	Whole Building (Dwelling) ventilation Rates	Living Room	Bedrooms	Kitchen	Bathroom +WC	WC only
Belgium (NBN D 50-001 1991)	1 l/s per m^2 of floor area with some specific values for kitchens, toilet and bathrooms.	Supply 1 l/s per m^2 Min 75 m^3/h (21 l/s) May be limited to 150 m^3/h (42 l/s)	Supply 1 l/s per m^2 Min 25 m^3/h (7 l/s) May be limited to 36 m^3/h per (10 l/s) person	Exhaust 1 l/s per m^2 Min 50 m^3/h 14 l/s) May be limited to 75 m^3/h (21 l/s)	Exhaust 1 l/s per m^2 Min 50 m^3/h (14 l/s) May be limited to 75 m^3/h (21 l/s)	Exhaust 25m^3/h (7 l/s)
Canada (F326.1-M1989)	>0.3 ach 5.0 l/s person			Exhaust 50 l/s (Inter.) 30 l/s (cont.)	Exhaust 25 l/s (Inter.) 15 l/s (cont.)	
Denmark	0.5ach	Supply of fresh air: Hinged window, hatch or door, together with one or more fresh air valves with a total clear opening of at least 30cm^2 per 25m^2 floor area.		Supply: Hinged window, hatch or door or fresh air valve. Extraction: Volume flow 20l/s. The air shall be extracted through an extractor hood.	Supply: Hinged window, hatch or door or fresh air valve. And or opening to the access. Extraction: Volume flow 15l/s.	Supply: Hinged window, hatch or door or fresh air valve. And or opening to the access. Extraction: Volume flow 10l/s.
Finland	Exhaust figures air flows can be reduced when the spaces are not in use provided that	0.5 l/s m^2	Min. 4.0 dm^3/s.person 4.0 l/s person or (0.7 $dm^3/s/m^2$ of	Exhaust air flow 20 l/s	Exhaust 15 l/s	

	the air change rate in the whole building is greater than 0.4 ach and minimum air flow rates in bedrooms and living rooms are fulfilled.		floor area) 0.7 l/s m^2 floor area			
France				**Continuous:** 20-45 m^3/h (5.6-13 l/s) **Intermittent:** 75-135 m^3/h 21-38 l/s)	15-30 m^3/h (4.2-8.4 l/s)	15-30 m^3/h (4.2-8.4 l/s)
Germany	<50m^2 up to 2 occupants Min 60 m^3/h (17 l/s). Total 60 m^3/h (17 l/s) <80m^2 up to 4 occupants Min 90 m^3/h (25 l/s) Total 120 m^3/h (34 l/s) >80m^2 up to 2 occupants Min 120 m^3/h (34 l/s) Total 180 m^3/h (50 l/s)	1,0-1.5 ach		**Normal** 40 m^3/h (>12 hr occupation /day) (11l/s) 60m^3/h (overall air flow) (17l/s) **Purge** 200 m^3/h (>12 hr occupation /day) (56l/s) 200m^3/h (overall air flow) (56l/s) **Kitchen et** 40 m^3/h (>12 hr occupation /day) (11l/s) 60m^3/h (overall air flow) (17l/s)	40 m^3/h (>12 hr occupation /day) (11 l/s) 60m^3/h (overall air flow) (17 l/s)	20 m^3/h (>12 hr occupation /day) (5.6 l/s) 30m^3/h (overall air flow) (8l/s)
Greece	Dwellings Est 5 persons per 100m^2 of floor area Flats Est 7 persons per 100m^2 of floor area	Dwellings and Min 8.5 m^3/h person (2.4 l/s) Max 12-17 5 m^3/h (3 – 5l/s)		Dwellings and flats Min 8.5 m^3/h person (2.4 l/s) Max 50-85 m^3/h (14-24 l/s)	Dwellings and flats Min 34 m^3/h person (10 l/s) Max 50-85 m^3/h (14-24 l/s)	
Italy (Ministerial Decree 05.07.75) (Standard UNI 10339)	Naturally ventilated dwelling 0.35 to 5.0 ach	15m^3/h per person (4 l/s) 40 m^3/h person (11 l/s)	40 m^3/h person (11 l/s)	1.0 ach 4 vol/h exhaust ventilation	2.0 ach 4 vol/h exhaust ventilation	1.0 ach
Netherlands Building Decree		0.9 dm^3/s.m^2 of floor area (0.3m^3/h.m^2) (0.08 l/s.m^2)	0.9 dm^3/s.m^2 of floor area (0.3m^3/h.m^2) (0.08 l/s.m^2)	21 dm^3/s (7.6 m^3/h) (2 l/s)	14 dm^3/s (5 m^3/h) (1.4 l/s)	7 dm^3/s (2.5 m^3/h) (0.7 l/s)
New Zealand (ASHRAE 62-1999)	0.35ach but no less than 7.5 l/s person Natural vent. Min area of openable window as 5% of floor area in each room.			50 l/s Inter. Or 12 l/s cont. Or Operatable windows	25 l/s Inter. Or 10 l/s cont. Or Operatable windows	
Norway (Norwegian Bldg Code)	Not less than 0.5 ach	Supply : Openable windows or inlet larger than 100cm^2 in external wall.	Supply : Openable windows or inlet larger than 100cm^2 in external wall.	Extract Mech extract of 60 m^3/h 17l/s or Natural extract : at least 150 cm^2 duct above roof.	Extract Mech extract of 60 m^3/h 17l/s or Natural extract : at least 150 cm^2 duct above roof.	Extract:Mechanical 40 m^3/h (11 l/s) or Natural 100cm^2/duct above roof.
Sweden (BFS 1998:38)	Requirements : Rooms shall have continual air change when they		Recommendations: The rate of flow of outside air to rooms or	Recommendations Mech.10 l/s high speed extraction rate	10 l/s - with openable window:	10 l/s

	are in use. The rate of flow of outside air shall be not less than 0.35 l/s per m^2 of floor area.		parts of rooms for sleep and rest should be not less than 4 l/s per bed place.	with not less than 75% extraction capacity for airborne contaminants	10 l/s with high speed extraction rate up to 30 l/s or 15 l/s without without openable windows	
Switzerland (SIA 180 :00)	15 m^3/h person (Non smoking) (4.2 l/s.person)					
United Kingdom	Average Dwelling: Rec: 12 l/s.person Min: 8.0 l/s person Luxury Dwelling Rec: 18 l/s person Min: 12 l/s person Background vent ≈ 6000mm^2 per room with min ≈ 4000mm^2	Rapid vent:1/20th of floor area Background Vent: 8000mm^2	Rapid vent:1/20th of floor area Background Vent: 8000mm^2	Rapid vent:Opening window (no minimum size) Background Vent: 4000mm^2 Extract vent rates of passive stack: 30 l/s adjacent to hob or 60 l/s elsewhere or PSV	Rapid vent:Opening window (no minimum size) Background Vent: 4000mm^2 Extract vent rates of passive stack: 15 l/s or PSV	Rapid vent:Openin g window (no minimum size) Background Vent: 4000mm^2 Extract vent rates of passive stack: 30 l/s adjacent to hob or 60 l/s elsewhere or PSV
United States of America (ASHRAE 62-99)	0.35ach but no less than 7.5 l/s person Natural vent. Min area of openable window as 5% of floor area in each room.			50 l/s Inter. Or 12 l/s cont. Or Operatable windows	25 l/s Inter. Or 10 l/s cont. Or Operatable windows	

Table 3.1 shows that minimum ventilation rate criteria for dwellings are given as whole building ventilation rates, in air changes per hour (ACH), m^3/h or l/s per person or per m^2 floor area. Criteria are also given for individual dwelling rooms based on either occupation (m^3/h or l/s per person) or floor area (m^3/h or l/s m^2). All criteria where expressed in m^3/h have been converted to l/s for comparative purposes.

Whole building minimum ventilation rate criteria are difficult to compare, principally because the overall size and nature of typical dwellings and typical population densities vary from country to country. In some countries, multistorey multifamily homes are normal, while in others, single storey single family homes are more common. Generally such variations vary regionally as well.

Where mechanical ventilation is common, minimum ventilation criteria are given as an extract or supply rate in, for example l/s per person. Where natural ventilation is used criteria are specified as an openable area. In natural ventilated buildings mechanical extraction can also be utilised, in terms of bathroom or kitchen extract fans which are operated intermittently.

From the criteria outlined in table 3.1 minimum ventilation rates for ***Living Rooms***, are quoted in m^3/h by Belgium, in m^3/h per person by Greece and Italy, l/s per m^2 or dm^3/m^2 of floor area by Finland and the Netherlands, in air changes per hour (ach) by Germany and by openable area by Denmark, Norway and the United Kingdom. Belgium also quotes ventilation rates as a supply rate of 1 l/s per m^2.

For Bedrooms ventilation rates are quoted in m^3/h by Belgium, Italy, l/s per person by Finland, Sweden, l/s per m^2 or $dm^3.s/m^2$ of floor area by Netherlands and by openable area by Norway and the United Kingdom. Belgium also quotes ventilation rates as a supply rate of 1 l/s per m^2.

The criteria for Kitchens, Bathrooms and WC's are quoted extraction rates in most cases, assuming mechanical continuous or intermittent ventilation. Supply can either be via mechanical means or more frequently by the provision of an openablable window. Extraction rates are quoted in m^3/h, by Belgium, France, Germany, Greece, and Norway; l/s per m^2 or dm^3/m^2 of floor area, by Belgium, The Netherlands, New Zealand, Sweden and the United Kingdom; l/s Canada, Denmark and the United States of America; air changes per hour (ach) by Italy and by openable area by United Kingdom. Belgium also quotes ventilation rates as a exhaust rate of 1 l/s per m^2.

Where criteria are expressed in terms of m^3/h they can be easily converted to l/s. The difficultly arises where criteria are quoted in terms of either per person or per m^2 of floor area. Typical levels of occupation vary from country and also typical room sizes also vary greatly. What can be inferred from the criteria is that in kitchens, bathrooms and toilets, where pollution can be extreme, but only for a short period of time, ventilation provision is more of a purging nature, mainly extracting high rates of polluted air over a short period. Supply is generally provided via background ventilation through adventitious infiltration (either from outside or adjacent rooms), openable windows or a much lower rate mechanical supply system. In living rooms and bedrooms occupants gather and can pollute the air via CO_2 and other bioeffluents and tobacco smoke (mainly in living rooms). The criteria suggest ventilation rates are more continuous and provided on a per person or room area basis. Background ventilation rates are therefore higher, but there is less need to purge to air on a frequent basis. However, the mechanical extraction systems in place in the bathrooms, kitchens and WC's will gradually draw out this polluted air, which will be replaced over time by outside air.

3.2 Ventilation in Offices

The dominant pollutants in offices are ozone (O_3) and odour. Carbon dioxide is often used as a tracer or indicator of deteriorating indoor air quality. Other specific pollutants may be present, depending upon the nature of activities undertaken within the office or adjacent rooms such as tobacco smoke (although this is becoming less important with legislative restrictions becoming even greater). Heat is another dominant pollutant generated from lighting, personal computers, photocopiers, printers and solar gains.

The outside air may also contribute to the pollutant load within office spaces, for example traffic pollution.

Table 3.2 Minimum ventilation rate criteria for offices

Country	Minimum ventilation rate criteria for offices
Belgium (Walloon Region)	Single Office - 2.9 m³/h per m² of floor area (0.8 l/s.m^2) Landscaped office - 2.5 m³/h per m² of floor area (0.7 l/s m^2) Conference room - 8.6 m³/h per m² of floor area (2.4 l/s m^2) Cafeteria restaurant – 115 m^3/h per m^2 of floor area(32 l/s m^2) WC – 30m^3/h (8.4 l/s) per bowl of toilet (if continuous) 60 m^3/h (17 l/s) per bowl of toilet (if not continuous)
Canada	Measures for energy conservation in new buildings sets out the requirements for mechanical ventilation - where the outdoor air supply will be in line with those stated in ASHRAE 62-1989: 8 to 30 l/s per person for commercial and factory buildings.
Denmark	In offices the ventilation rate is subject to approval by the local authority having regard to the size and use of the room. (Guidance: Attention is drawn to the fact that, in some cases, the need for ventilation can be covered by natural ventilation, while in others, mechanical ventilation should be stipulated in order to achieve a healthy indoor climate. Examples of room in which natural ventilation will suffice are offices for one person or a few people, hotel rooms and certain types of commercial premises. Examples of rooms in which mechanical ventilation may be needed are offices for a large number of people, assembly rooms, canteens, restaurants and rooms at hospitals. The size of the ventilation can be determined on the basis of section 2.2 of DS447: Code of prac tice for ventilation installations).
Finland	Indoor Climate and Ventilation in Buildings. Regulations and Guidelines. Guidelines 1985. National Building Code of Finland. (In Finnish). This standards also specifies 4 - 10 l/s per person. The values are based on removal of pollutants, where smoking is allowed recommend high ventilation rate of 10l/s per person, independent on room size. Where smoking is not allowed, the ventilation rate per person decreases as the room volume increases.
France	Practical guidance to Meeting the requirements of the Thermal and Ventilation Regulations for Un residential Buildings - Cahiers du CSTB No. 2286 - October 1988. (Exemples de solutions pour facliter l'application du reglement relatif aux equipments et aux caracteristiques thermiques dans le batiments autres que l'habitation. VENTILATION). Requirements: The minimum ventilation rates are function of the types of premises and are indicated in the charts here enclosed. For current teaching rooms the required value of fresh air is 15 m^3/h per person. For current offices it is 25 m^3/h per person (7 l/s.person) and for meeting rooms 18 m^3/h person (5l/s.person) (non -smoking) or 30 m^3/h per person (8. l/s) (Smoking). The maximum ventilation rate is 1.2 (for cold climatic zones) or 1.3 (For temperate climatic zone) times the minimum ventilation rate.
Germany	DIN 1946 gives a general air flow rate for indoor air quality of 20 to 30 m^3/h person (6–8 l/s .person) to maintain acceptable air quality.
Greece	Office space (based on 10 people per 100m^2 floor area) Min 25.5 m^3/h per person (7l/s person) (Max 25.5 – 42.5 (7-12 l/s person) Meeting rooms (based on 65 people per 100m^2 floor area) Min 42.5 m^3/h (12 l/s person) per person Max 51 -68 (14-19 l/s person) Designing rooms (based on 22 people per 100m^2 floor area) Min 12 m^3/h per person (3.4 l/s person) Max 17-25.5 (5 – 7 l/s per person)

	Waiting rooms (based on 32 people per 100m² floor area) Min 12 m³/h per person (3.4 l/s person) Max 25.5-34 (7-10 l/s person) Computer rooms (based on 22 people per 100m² floor area) Min 8.5m³/h per person (2 l/s person) Max 12-17 (3-5 l/s person)
Italy	Standard UNI 10339 "Air-conditioning systems for thermal comfort in buildings" Single offices and open space offices: 40 m³/h per person (11 l/s person) Meeting rooms and computers: 35 m³/h per person (10 l/s person) toilets: exhaust ventilation 8 ach Ministerial Decree 04.02.76 Ventilation requirements for schools. 1.5 to 5 ach for School buildings.
Netherlands	1.3 dm³/s per m² of floor area (Building Decree) (0.5m ³/h.m²) 0.1 l/s per m²)
Norway **Norway cont/…**	Requirements for office and school buildings are formulated in the regulation guidance book (thus not being formal part of the regulations). Air supply is calculated depending on ventilation load from persons, building materials, inventory and processes. Normal ventilation requirements from person load are 7 litres pr. sec. And person (Area pr. person depend on building use and can be taken from tables). In rooms where smokers are allowed, ventilation requirements from person load are 20 litres pr. sec. and person. In schools and kindergartens 8 litres pr. sec. and person is often used. Ventilation requirements from materials ranges from: 0.7 litres pr. sec. and m²(gross floor area) for documented low emitting building materials 1.0 litres pr. sec. and m² for normal low emitting materials 2.0 litres pr. sec. and m² for undocumented materials There are specific requirements for air extraction from sanitary rooms and other special rooms (lift, basements). NS3031 Energy and power demands for heating of buildings. Calculation rules. For other than domestic buildings the ventilation requirements are given as air flow rate per unit floor area. NS3031 gives an assumed air change rate of 0.5 ach for a building when calculating ventilation heat loss. Work rooms 5 m³/h. m² or 16.5 m³/h per person (1.4 -5 l/s.person) Offices 7 l/s plus 0.7 l/s.m² floor area
Sweden	Requirements: Rooms shall have continual air change when they are in use. The rate of flow of outside air shall be not less than 0,35 l/s per m² of floor area. When rooms are not in use the air flow rate may be reduced but not to such an extent that health risks arise or so that there is a risk of damage to the building or its services. Such reduction may be effected continuously, in several stages or in the form of intermittent operation. Recommendations: Outside air Other premises: The rate of flow of outside air to rooms or parts of rooms for places of assembly, shops, offices, schools etc where persons are present other than occasionally, should be not less than 7 l/s for each person who may be expected to be there at the same time.
Switzerland	Non smoking (0.15% CO_2) v=12-15 m³/h.person (3-4 l/s.person) (0.10% CO_2) V = 25-30 m³/h.person (7-8 l/s.person) Smoking v=30-70m³/h.person (8-20 l/s.person) (There is no distinction between Schools and Offices)
United Kingdom	BS5925 : Offices (open plan) Smoking some Recommended 8 l/s.person Minimum 5 l.s.person. Offices (private) Smoking Heavy Recommended 12l/s.person Minimum 8 l/s .person.
United States of America	Office 10 l/s person Reception spaces 8 l/s person Telecommunications centres 10 l/s person Conferences rooms 10 l/s person

From the above table it can be seen that most countries express their criteria in terms of l/s or m³/h per person. Belgium, Netherlands and Norway express minimum ventilation rates criteria for offices in terms of m³/h per m² of office area. Most countries make a distinction between ventilation for occupant comfort and ventilation for indoor air quality control (in for smoking). Typical ventilation rates of between 3 to 10 l/s per person are outlined above for normal office areas. Where smoking is allowed rates are generally higher, in the region of 8 to 20 l/s per person.

3.3 Ventilation in Schools

Occupant emitted human bioeffluents are the dominant pollutant in classrooms and lecture theatres. Schools are dominated by high occupant loads, very transient occupation and higher levels of metabolic activity. In the absence of high heat loads, the dominant pollutants are derived from metabolism. In some countries CO_2 demand controlled ventilation systems and passive infra-red detectors have been used to regulate the rate of ventilation.

Table 3.3 Minimum ventilation rate criteria for schools

Country	Minimum ventilation rate criteria for schools
Belgium (Walloon Region)	Auditorium – 23 m³/h per m² of floor area (6 l/s m^2) Cafeteria restaurant - 11.5 m³/h per m² of floor area (3 l/s m^2) Classroom - 8.6 m³/h per m² of floor area (2 l/s m^2) Kindergarten - 10.1 m³/h per m² of floor area (3 l/s m^2) WC - 30 m³/h per bowl of toilet (if continuous) (8 l/s m^2) 60 m³/h per bowl of toilet (if not continuous) (17 l/s m^2)
Canada	Classrooms 8 l/s per person. Laboratories 10 l/s person Auditoriums 8 l/s person Libraries 8 l/s person
Denmark	Classrooms in schools and similar shall be ventilated with a mechanical ventilation system comprising both injection and extr action of at least 5 l/s per person, and 0,4 l/s per m^2 floor area.
Finland	D2 - National Building Code of Finland:Indoor climate and ventilation in buildings. Regs and guidelines - 1987. Classroom: Outdoor air supply rate of 6 dm^3/s persons. (2 m^3/h ≈ 0.56 l/s person) Lecture room: Outdoor air supply rate of 8 dm^3/s persons. (3 m^3/h ≈ 0.84 l/s person)
France	Practical guidance to Meeting the requirements of the Thermal and Ventilation Regulations for Un residential Buildings - Cahiers du CSTB No. 2286 - October 1988. (Exemples de solutions pour facliter l'application du reglement relatif aux equipments et aux caracteristiques thermiques dans le batiments autres que l'habitation. VENTILATION). Requirements: The minimum ventilation rates are function of the types of premises and are indicated in the charts here enclosed. For current teaching rooms the required value of fresh air is 15 m^3/h per person.(4l/s person) For current offices it is 25m ^{3}/h per person (7 l/s person) and for meeting rooms 18 m^3/h person (5l/s person) (non -smoking) or 30 m^3/h per person (8 l/s person) (Smoking).
Germany	DIN 1946 gives a general air flow rate for indoor air quality of 20 to 30 m^3/h person (6-8 l/s person) to maintain acceptable air quality. The standard gives minimum ventilation rates for schools as 30 m^3/h per person.(8 l/s person)
Greece	Teaching rooms (based on 55 people per 100m^2 floor area) Min 17 m^3/h per person (5 l/s person) Max 17-26 (5-7 l/s person) Laboratories (based on 32 people per 100m^2 floor area) Min 17 m^3/h per person (5 l/s person) Max 17-26 (5 – 7 l/s person) Libraries (based on 22 people per 100m^2 floor area) Min 12 m^3/h per person (3 l/s person) Max 17-21 (5 – 6 l/s person) Amphitheatres (based on 110 people per 100m^2 floor area) Min 17 m^3/h per person (5 l/s person) Max 26-34 (7-10 l/s person) Gymnasiums (based on 75 people per 100m^2 floor area) Min 34.5m^3/h per person (10 l/s person) Max 42-51 (12 –14 l/s person) -
Italy	Classrooms: 2.5 ach for nursery school and primary schools 3.5 ach for secondary schools 5 ach for high schools Toilets, gymnasium, refectories: 2.5 ach Other rooms: 1.5 ach Standard UNI 10339 “Air-conditioning systems for thermal comfort in buildings” Nursery school 15 m^3/h per person (4 l/s person)

<table>
<tr><td></td><td>Classrooms

primary schools: 18 m^3/h per person (4 l/s person)
secondary schools: 21 m^3/h per person (6 l/s person)
high schools: 24 m^3/h per person (7 l/s person)
universities: 24 m^3/h per person (7 l/s person)
transit areas: exhausts
toilets: exhaust ventilation 8 ach
libraries, teachers rooms: 21 m^3/h per person (6 l/s person)
music classrooms, laboratories: 24 m^3/h per person (7 l/s person)</td></tr>
<tr><td>Netherlands</td><td>Buildings Decree

8.8 dm^3/s at a person density of lower than 1.3 m^2 per person (3m3/h ≈ 0.84 l/s person)
3.5 dm^3/s at a person density of 1.3 to 3.3 m^2 per person (1.26m3/h ≈ 0.35 l/s person)
1.4dm^3/s at a person density of 3.3 to 8 m^2 per person (0.5m3/h ≈ 0.14 l/s person)</td></tr>
<tr><td>New Zealand</td><td>New Zealand ASHRAE 62-1990 – NZ4303 – Ventilation for Acceptable Air Quality and AS1668 Pt 2 1991 – Mechanical Ventilation for Acceptable Indoor Air Quality.

In schools: 8 l/s.person</td></tr>
<tr><td>Norway</td><td>Norwegian National Building Code: Ventilation and Installation.

Minimum ventilation rates for classrooms: 5.5 l/s per person plus 0.7 l/s. m^2.</td></tr>
<tr><td>Sweden</td><td><u>Requirements</u>: Rooms shall have continual air change when they are in use. The rate of flow of outside air shall be not less than 0.35 l/s per m² of floor area. When rooms are not in use the air flow rate may be reduce d but not to such an extent that health risks arise or so that there is a risk of damage to the building or its services. Such reduction may be effected continuously, in several stages or in the form of intermittent operation.

<u>Recommendations: Outside air</u>

Other premises: The rate of flow of outside air to rooms or parts of rooms for places of assembly, shops, offices, schools etc where persons are present other than occasionally, should be not less than 7 l/s for each person who may be expected to be ther at the same time.</td></tr>
<tr><td>Switzerland</td><td>Non smoking (0.15% CO_2) v=12-15 m^3/h.person (3-4 l/s person)
(0.10% $C0_2$) v=25-30 m^3/h.person (7-8 l/s person)

Smoking v=30-70 m^3/h.person (8-20 l/s person)

There is no distinction between schools and offices.</td></tr>
<tr><td>United Kingdom</td><td>The Chartered Institution of Building Services Engineers (CIBSE) Guide A4 - 14 Air Infiltration.

Empirical values for air infiltration and ventilation allowance for buildings on normal sites in winter:

Classrooms 2 ach
Lecture rooms 1 ach

The Chartered Institution of Building Services Engineers (CIBSE) Guide B2 - 7 Ventilation and Air Conditioning (Requirements) From table: B2.3 Ventilation requirements.

Schools recommended fresh air supply rate: that working areas sho uld be capable of being ventilated at least up to 8.3 l/s per person.

DFEE Regulations
(1) All occupied areas in a school building shall have controllable ventilation at a minimum rate of 3 litres of fresh air per second for each of the maximum number of persons the area will accommodate.
(2) All teaching accommodation, medical examination or treatment rooms, sick rooms, isolation rooms, sleeping and living accommodation shall also be capable of being ventilated at a minimum rate of 8 litres of fresh air per second for each of the usual number of people in those areas when such areas are occupied.
(3) All washrooms shall also be capable of being ventilated at a rate of at least six air changes an hour.
(4) Adequate measures shall be taken to prevent condensation in, and remove</td></tr>
</table>

	noxious fumes from, every kitchen and other room in which there may be steam or fumes. The Health and Safety Executive guidance given in the Advisory Code of Practice to the Workplace (Health, Safety and Welfare) Regulations 1992 states "The fresh air supply rate should not normally fall below 5 to 8 litres per second, per occupant. Factors to be considered include the floor area per person, the processes and equipment involved, and whether the work is strenuous".
United States of America	Classrooms 8 l/s per person. Laboratories 10 l/s person Auditoriums 8 l/s person Libraries 8 l/s person

Minimum ventilation rate criteria outlined in table 3.3 above show that most countries express these in terms of l/s per person and in m^3/h per person. Typical rates for classrooms outlined are within the range 4-10 l/s per person. These are similar to those criteria outlined above for offices. Some countries express their criteria in terms of $m^3/h\ .m^2$ and whole room air changes per hour (ach), for any comparison of these criteria or comparisons against those expressed per person, typical occupant densities and room volumes are necessary.

4.0 Indoor Air Quality Requirements

Indoor air quality criteria is expressed in terms of concentrations of pollutant in air in parts per million (ppm) or as a measure of concentration by volume, in milligrams per cubic metre of air (mg/m^3), a measure of concentration by mass. Criteria are also expressed in terms of long and short term exposure and in terms of Maximum allowable concentrations (MAC) and Acceptable indoor concentrations (AIC) concentration.

4.1 Carbon dioxide (CO_2)

Carbon dioxide is a by-product of metabolism. It is also a product of combustion, and as a consequence can be found in large quantities in cooking areas and in areas of unvented heating appliances. It is generally regarded as non toxic, in itself and unlikely to cause injury, even at relatively high concentrations. However is does represent an indicator of deteriorating indoor air quality. High levels can demonstrate the need to increase ventilation and as such CO_2 is a common tracer used to control demand control ventilation systems.

Table 4.1 An overview of carbon dioxide (CO_2) criteria by country

Country	CO_2 Standard
Belgium	MAC 5000ppm Peak limit (15min) 30000ppm
France	1000 ppm in building office (1300 ppm in no smoking area)
Germany	MAC 5000ppm 9000 mg/m^3
Greece	Instantaneous death 360-550mg/1 Dangerous for inhalation from 1/2 hr to 1 hr 90 -120mg/1 Dangerous for many hours inhalation 20-30 mg/1 Concentration perceivable by smell odourless MAC for working spaces 9.0mg/1 (5000 cm^3/m^3)
Italy	1500ppm
Netherlands	Schools 1500 ppm Dwellings 1200 ppm Offices 1000 ppm
Norway	<1800 mg/m^3 1000ppm
Sweden	MAC 5000 ppm Peak limit 10000ppm AIC 1000 ppm (Concentration CO_2 in supply air <1/10 of MAC)
United States of America	5000ppm **OSHA** 5000ppm 30000 ppm [15min] **NIOSH**
United Kingdom	Long tem exposure limit 8 hour TWA ref. period) 5000ppm (9000mg/m^3) Short term exposure limit (15 minute ref. period) 15000 ppm (27000 mg/m^3)

The above table indicates that CO_2 concentrations of 5000 ppm represent the most common Maximum Allowable Concentration limits, with Allowable Indoor Concentrations (AIC) varying slightly around 1000ppm. Extremely high concentrations are required before occupants feel any thing more worrying that increased perspiration, as identified by Greece where MAC levels represent the equivalent of 5000ppm, (0.9mg/1) but for instantaneous death 360-550 mg/1are required. These levels are not experienced in virtually all but the most extreme cases.

4.2 Carbon monoxide (CO)

Carbon monoxide is a highly toxic, odourless and colourless gas that is product of incomplete combustion. It can occur from gas, oil coal or wood burning appliances, especially if the oxygen supply or flue venting is restricted. Very sensitive and inexpensive detectors are now widely available. Concentrations above 50 ppm are poisonous because CO blocks oxygen respiration.

Table 4.2 An overview of carbon monoxide (CO) criteria by country

Country	CO Standard
Belgium	MAC 50ppm Peak limit (15min) 400ppm
Germany	MAC 30ppm 33 mg/m^3
Greece	Instantaneous death 6-12mg/1 Dangerous for inhalation from 1/2 hr to 1 hr 2 -3mg/1 Dangerous for many hours inhalation 0.2 mg/1 Concentration perceivable by smell odourless MAC for working spaces 0.055mg/1 (50 cm^3/m^3)
New Zealand	Concentrations of limited or no concern 2% COHb (Carboxyhaemoglobin) Concentration of concern 3% COHb 99.9% According to the Environmental Health Criteria No4 Geneva World Health Organisation 1977.
Norway	25 mg/m3 (1 hr average) 10 mg/m3 (8 hour average)
Sweden	MAC 35 ppm Peak limit 100ppm AIC 5 (8 hour) 52 (24hour) ppm (Concentration CO in supply air <1/10 of MAC)
United Kingdom	Long tem exposure limit 8 hour TWA ref. period) 50ppm (55mg/m^3) Short term exposure limit (15 minute ref. period) 300 ppm (330 mg/m^3)
United States of America	**ASHRAE 62-1999** Concentrations of limited or no concern 12% COHb Concentration of concern 3% COHb 99.9% According to the Environmental Health Criteria No4 Geneva World Health Organisation 1977. **Outdoor Standards** National Ambient Air Quality Primary Standard 10 mg/m^3 (9 ppm) 8hr avg. 40 mg/m^3 (35 ppm) 1 hr avg. (EPA, 40 CFR 50.8) (C9) State air quality limits: CT 1000 µg/m^3 8hr NV 1.2100 mg/m^3 8hr NATICH Data Base, 1986) (C-8) **Industrial Workplace** 55 mg/m^3 (50ppm) 8hr (OSHA, 29 CFR 1910.1000, Table Z-1)(C-12) (C30 CFR 57.5001 (a)) (C-13)
General/International	**WHO Guidelines (1987)** 15 min: 87 ppm (109 mg/m^3) 30 min 50 ppm (62.5 mg/m^3) 1 hr 25 ppm (31.25 mg/m^3) 8 hr 10ppm (12.5 mg/m^3) The WHO guidelines are calculated such that a normal subject engaging in relatively heavy work will not exceed a COHb level of 2.5 %.

The table above indicates that the maximum allowable concentration required by most countries is 50ppm or equivalent. Germany and Sweden specify 35 ppm MAC. Other countries outline CO limits in terms of mg/m^3 for 1 hour and 8 hour time weighted averages. All stated limits are below 50ppm or equivalent (with 1 hour averages approximately 25-30 mg/m^3 and 8 hour averages approximately 10 mg/m^3).

4.3 Formaldehyde (HCHO)

Formaldehyde is used in the manufacture of fibreboards and foam insulation. Controls on emissions of such products have been introduced in some countries. Formaldehyde is an irritant and has been linked to an increased risk of cancer. Urea formaldehyde foam insulation (UFFI) was extensively used in construction in the 1980's but is now rarely used, but formaldehyde based resins are components of finishes, plywood, panelling, fibreboard and particleboard, all widely used. Airborne formaldehyde acts as an irritant to the conjunctiva and upper and lower respiratory tract. Symptoms are temporary and depend upon the level of exposure. These may range from burning or tingling sensations in eyes, nose and throat to chest tightness and wheezing. Acute severe reactions to formaldehyde vapour can be associated with hypersensitivity.

Table 4.3 An overview of formaldehyde (HCHO) criteria by country

Country	HCHO Standard
Belgium	MAC 1ppm Peak limit (15min) 2ppm
Denmark	Chipboard, wood-fibre and plywood panels and similar containing synthetic resin binder that emits formaldehyde may only be used provided they are subject to a control scheme approved by the Ministry of Housing. (Guidance: The general aim of this provision is to ensure that the concentration of formaldehyde in air, corresponding to room air with realistic use of the building materials in question and prescribed ventilation, temperature and relative humidity, does not exceed 0,15 mg/m^3.) An approved inspection and testing scheme has been established under the Danish Control Organization for Wood-based Panels. Methods and test conditions are prescribed in the organizations approval and inspection rules. Thermal insulation materials, which are made by foaming urea and formaldehyde may only be used provided they are subject to a control scheme approved by the Ministry of Housing. The mater ials may only be used for insulating external wall structures. (Guidance: The general aim of this provision is to ensure that the concentration of fomaldehyde in air, corresponding to room air with realistic use of the building materials in question and prescribed ventilation, temperature and relative humidity, does not exceed 0,15 mg/m^3).
Germany	MAC 1ppm 1.2 mg/m^3
Greece	Dangerous for inhalation from 1/2 hr to 1 hr 0.8mg/1 MAC for working spaces 0.006mg/1 (5 cm^3/m^3)
New Zealand	ASHRAE 62 - 1999 Concentration reported 0.05-2 mg/m^3 Concentrations of limited or no concern <0.06 mg/m^3 Concentration of concern >0.12 mg/m^3 Long and short term
Netherlands	1.2 mg/m^3 Building Decree
Norway	<100 mg/m^3 (30 min average)
Sweden	MAC 0.5 ppm Peak limit 1 (15 min) AIC 0.01-0.04 (Concentration HCHO in supply air <1/20 of MAC)
United Kingdom	Long tem exposure limit 8 hour TWA ref. period) 2 ppm (MEL) (2.5mg/m3 (MEL)) Short term exposure limit (15 minute ref. period) 2 ppm MEL (2.5 mg/m^3) MEL HCHO is maximum exposure limit
United States of America	**Indoor Standards** Federal : 0.4 ppm target ambient level, HUD standard for manufactured homes, achieved through product emissions standards of .2 and .3ppm (HUD, 24 CFR 3280.308, 1984) State: 0.4ppm standard for indoor exposure (MN statute 144.495, 1985) (C -15)

	Outdoor Standards No federal standard State air quality limits :CT 12.00 µg/m^3 8hr IL 0.0150 µg/m^3 1 yr IN 18.00 µg/m^3 8hr MA 0.2000µg/m^3 24hr NC 300.00 µg/m^3 15min NV 0.0710 µg/m^3 8hr NY 2.000 µg/m^3 1hr VA 12.000 µg/m^3 24hr (NATICH Database, 1986) (C-8) **Industrial Workplace** 1ppm 8hr TWA-PEL 2ppm 15 min STEL OSHA, 29 CFR 1910.1lth 000 Table Z -2 OSHA issued a final rule Dec 4 1987 (52 FR 46168) lowering a previous standard to the above level, which was effective on Feb 1988) Mine Safety and Health Admin uses ACGIH TLVs (30 CFR 57.5001 (a) (C -13)

Maximum allowable concentrations specified in the above table vary between 0.5-1ppm. Short term peak levels (15 min) are specified between 1.2 -2ppm.

4.4 Ozone (O_3)

Indoor to outdoor ratios of O_3 have been found to be in the range 0.1-0.3 ppm but may be as high as 0.7 ppm. Although indoor levels of O_3 are significantly less than those reported for the ambient environment, the latter is the primary source of O_3 indoors. Indoor sources may include electric dust cleaners, ion generators, and office equipment such as copiers etc. Ozone can represent a long term health threat and causes respiratory complaints. It is released from photocopiers, laser printers and other office equipment. Carbon filters are commonly fitted to these devices, to minimise emissions, but without regular maintenance ozone levels can become unacceptable.

Table 4.4 An overview of ozone (O_3) criteria by country

Country	O_3 Standard
Germany	MAC 0.1 ppm 0.2 mg/m^3
Greece	Dangerous for inhalation from 1/2 hr to 1 hr 0.0 ^{3}mg/1 Dangerous for many hours inhalation 0.001 mg/1 Concentration perceivable by smell 0.00002 mg/1 MAC for working spaces 0.0002 mg/1 (0.1 cm^3/m^3)
United Kingdom	50ppb measured as running 8 hour mean *Objective by 2005 50ppb 97th %tile*
United States of America	**Indoor Standards** FDA prohibits devices (e.g. germicides, deodorisers) that result in more than 0.05 ppm in occupied enclosed spaces such as homes, offices or hospitals, or that result in any releases in places occupied by the ill or infirm. (21 CFR 801.415) (C-16) **Outdoor Standards** National Ambient Air Qualtity Primary and Secondary standards: 235 µg/m^3 (0.12 ppm)max hourly avg. (EPA, 40 CFR 50.9) (C9) State air quality limits: CT 235.0 µg/m^3 1 hr NV 0.005 mg/m^3 8hr (NATICH Database, 1986) (C-8) **Industrial Workplace** 0.2 mg/m^3 (0.1 ppm) 8hr TWA (OSHA, 29 CFR 1910.1000, Table Z-1)(C-12) Mine and Safety and Health Admin. uses ACGIH TLV (30 CFR 57.5001(a) (C-13)
Internation Organisations	WHO Air Quality Guidelines (1987) 1hr : 76 – 100 ppb (152-200 µg/m^3) 8hr: 50-60 ppb (100-120 µg/m^3) **Revision of WHO AQS: 1996 Expert GROUP recommendations:** 8 hr: 60 ppb (120 µg/m^3) (1 hr guideline abandoned) + tables of exposure response for 1 hr and 8 hr because there was little evidence of a threshold for effects. **EC Directive** Health protection threshold 8hr: 55ppb (110 µg/m^3) Population information threshold 1hr: 90 ppb (180 µg/m^3) Population warning value 1hr : 180 ppb (360 µg/m^3)

Criteria is given in parts per billion (ppb), part per million (ppm), and µg/m^3 . Criteria ranges from maximum allowable concentrations of around 0.1 ppm or less to 1 and 8 hour averages between 180ppb and 55 ppb respectively.

4.5 Nitrogen dioxide (NO_2)

Nitrogen dioxide is a gas, which is light yellowish orange to reddish brown at relatively low and high concentrations respectively. It is pungent, with an irritating odour. It is also relatively toxic and because of its high oxidation rate it is also extremely corrosive. The relatively low water solubility of NO_2 means that it causes minimal mucous membrane irritation of the upper airway. Instead the main site of toxicity is the lower respiratory tract. Low level NO_2 exposure may cause increased bronchial reactivity in some asthmatics, decreased lung function in patients with chronic obstructive pulmonary disease and an increased risk of respiratory infections, especially in young children. Nitrogen dioxide is a relatively reactive gas, and in the absence of indoor sources indoor/outdoor ratios are usually less than 1.0. For example, in residences with electric stoves an indoor/outdoor ratio of 0.38 has been reported. However residences with gas cooking appliances or unvented gas or kerosene heaters commonly have indoor NO_2 levels that exceed the outdoors. With indoor sources, NO_2 exposures may exceed ambient exposures by a factor of 2.

Table 4.5 An overview of nitrogen dioxide (NO_2) criteria by country

Country	NO_2 Standard
Belgium	MAC 3ppm Peak limit (15min) 5ppm
Denmark	Nitrogen oxides emitted to the indoor climate from combustion in stoves, central heating boilers and similar shall be limited by removal of the flue gases. (Guidance: For kitchens, this requirement may be deemed to be met by extraction through a hood, see section 2.2.)
Germany	MAC 5ppm 9 mg/m^3
Greece	NO_X Instantaneous death 0.45mg/1 Dangerous for inhalation from 1/2 hr to 1 hr 0.05-0.1mg/1 Dangerous for many hours inhalation - Concentration perceivable by smell 0.010 1mg/1 MAC for working spaces 0.009mg/1 (5.0 cm ^{3}/m^3)
New Zealand	Concentration reported 0.05-1 mg/m^3 Concentrations of limited or no concern <0.19 mg/m^3 Concentration of concern >0.32 mg/m^3
Norway	100 mg/m3 (1 hour average)
Sweden	MAC 2 ppm Peak limit 5ppm (15min) AIC 0.004-0.06 ppm (Concentration NO_2 in supply air <1/20 of MAC)
United Kingdom	EH 40/94Occupational Exposure limits Long tem exposure limit 8 hour TWA ref. period) 3ppm (5mg/m^3) Short term exposure limit (15 minute ref. period) 5 ppm (9 mg/m^3) NAQS Concentration 150ppb (1 hour mean) 21 ppb (annual mean)
United States of America	**Industrial workplace standards** 6 mg/m^3 (3ppm) 8hr TLV-TWA 10 mg/m^3 (5ppm) 15 min STEL (ACGIH 1986-87)(C-1) NAS recommended for manned spacecraft: C-18 4mg/m^3 (2.0ppm) 60min 1.0 mg/m^3 (0.5ppm) 90days 1.0 mg/m^3 90.5ppm) 6 months.
General/International	**WHO Air Quality Guidelines (1987)** 1 hr 210 ppb (385 µg/m^3)

	24hr 80 ppb (150µg/m^3) Revision of WHO AQGS 1996 - Expert Group recommendations (24 hr guideline abandoned) 1 hr 110 ppb (207 µg/m^3) Annual : 21 ppb (40 µg/m^3) The change in the 1 hour guideline reflects the increasing concern that NO_2 may play some adjuvant role in asthma both in terms of the provocation of attacks by allergens and, though less likely, in terms of the initiation of the disease. The introduction of an annual guideline reflects the results of epidemiological studies which show a negative association between long term average concentrations on NO_2 and indices of lung function. There is some room for doubt in the interpretation of the results of these studies as regards which pollutant or combination of pollutants is responsible fo r the described effect and the annual guideline is less firmly founded than some other WHO Air Quality Guidelines. **EC Directive Limit Values** Limit value: 98%ile hourly mean: 104.6 ppb (197 µg/m^3) Guide values: 98%ile hourly mean: 70.6 ppb (133 µg/m^3) 50%ile hourly mean : 26.2 ppb (49 µg/m^3)

The criteria outlined above indicate that maximum allowable concentrations range from 2-5 ppm. Acceptable indoor concentrations are much lower in the region of 0.004-0.6ppm. Time weighted average criteria also varies from 5ppm for 15 min, 110 -210ppb for 1 hour and 3ppm for 8 hour exposures. The increased risk of NO_2 playing a more important contributory role in the spread and aggravation of asthma has lead to the introduction of standards limiting the exposure of NO_2 concentration over a year period by the World Health Organisation (WHO). They recommend limiting concentrations of NO_2 to 21 ppb (40 µg/m^3) for the year.

4.6 Sulphur dioxide (SO_2)

Sulphur dioxide is a ubiquitious air pollutant produced by combustion and processing of sulphur containing fossil fuels. A major source of SO_2 is the combustion of coal in electric power plants. Local sources of SO_2 in the ambient air can be copper smelters, oil refineries and domestic and industrial oil heating systems. Since SO_2 is denser than air, most settles to the ground within a few miles of its sources when it enters the natural sulphur cycle. Indoor levels are usually lower than outdoor levels because SO_2 can be absorbed by many building materials, and can also react with formaldehyde. The high water solubility of SO_2 causes it to be extremely irritating to the eyes and upper respiratory tract. Concentrations above 6ppm produce mucous membrane irritation. Epidemiologic studies indicate that chronic exposure to SO_2 is associated with increased respiratory symptoms and decrements in pulmonary function. Some asthmatics have been shown to respond with bronchoconstriction to even brief exposure to SO_2 levels as low as 0.4ppm.

Table 4.6 An overview of sulphur dioxide (SO_2) criteria by country

Country	SO_2 Standard
Germany	MAC 2ppm 5 mg/m^3
Greece	Instantaneous death 5.5 mg/1 Dangerous for inhalation from 1/2 hr to 1 hr 1.0 -1.7mg/1 Dangerous for many hours inhalation 0.02-0.03 mg/1 Concentration perceivable by smell 0.008-0.013mg/1 MAC for working spaces 0.0130mg/1 (5.0 $cm3/m^3$)
United Kingdom	NAQS Concentration 100ppb (15 minute mean)
United States of America	**Outdoor Standards** National Ambient Air Quality Primary Standard: 80 $\mu g/m^3$ (0.03 ppm) annual arithmetic mean 365 $\mu g/m^3$ (0.14 ppm) 24 hr Secondary Standard: 1300 $\mu g/m^3$ (0.5 ppm) 24 hr (EPA, 40 CFR 50.4, 50.5) (C-9) State air quality limits: CT 860.0 $\mu g/m^3$ 8hr NV 0.119 mg/m^3 8hr TN 1.200 $\mu g/m^3$ 1 yr (NATICH Database 1986) (C-8) **Industrial workplace standards** 13 mg/m^3 (5ppm) 8 hr TWA (OSHA, 29 CFR 1910.1000, Table Z-1) (C12) Mine Safety and Health Admin . uses ACGIH TLV (30 CFR 57.5001 (a)) (C-13) **Table C2 Guidelines for common indoor pollutants** 5 mg/m^3 (2ppm) 8hr/ TLV-TWA 10 mg/m^3 (5ppm) 15 min. STEL (ACGIH, 1986-87)(C-1) NAS recommendation for manned spacecraft (C-18) 13 mg/m^3 (5.0ppm) 60min 3mg/m^3 (1.0 ppm) 90 days 3 mg/m^3 (1.0 ppm) 6 months.
General/International	**WHO Air quality Guidelines (1987)** 10 min 175 ppb (501$\mu g/m^3$) 1 hr 122 ppb (349 $\mu g/m^3$) **Revision of WHO AQGS: 1996 Expert Group recommendations** (1 hour guideline and link with smoke abandoned) 10 min 175 ppb (500.5 $\mu g/m^3$) 24 hr: 45 ppb (128.7 $\mu g/m^3$) Annual 17 ppb (47 $\mu g/m^3$) **EC Directive : limit values** *Annual median of daily means* 30 ppb (UK equiv 34μg/m3) if smoke > 40$\mu g/m^3$ 45 ppb if smoke < 40 $\mu g/m^3$ *Winter median of daily means:* 48.8 ppb (UK equiv 51$\mu g/m^3$) if smoke > 60 $\mu g/m^3$ 67.5 ppb if smoke < 60 $\mu g/m^3$ *98%ile of daily means:* 93.8 ppb (UK equiv 1281 $\mu g/m^3$) if smoke >150$\mu g/m^3$ 131.3 ppb if smoke <150 $\mu g/m^3$

	Guide values: Annual Average: 15-22.9 ppb (43-65 µg/m^3) Daily average: 37.5 - 56.4 ppb (107-161 µg/m^3)

Criteria is mainly given as a time weighted average for 1 and 8 hours, although concentrations for other time scales are also given, for example, 10 and 15 minutes and 24 hours, annual and winter periods. Concentrations of 100ppb to 5ppm for 15 minutes criteria are given, and 122ppb for a 1 hour time interval. Criteria for 8 hour averages range from 2 to 5ppm. EC guide values for annual averages range from 15-22.9 ppb and a daily average 37.5-56.4 ppb.

4.7 Other relevant pollutants

Bioeffluents

Humans release a large variety of volatile substances from body surfaces and openings. These include among others pyruvic acid, lactic acid, CH_4, NH_3, acetaldehyde, butyric acid, diethyl ketone, ethyl alcohol, methanol, CO_2, CO and H_2S. Historically the major bioeffulent of concern has been that of body odour. However this has been an issue of comfort and has not been associated with untoward health effects. Ventilation standards in large buildings (auditoria etc) have been based on providing sufficient ventilation air to reduce human odour to acceptable levels. Metabolically generated CO_2 has received considerable attention, because of all of the bioeffulents, it is produced in the highest concentrations. Metabolically augmented CO_2 levels in the air of an office building may be often be 2-6 times as high as ambient levels.

Odour

Odour is generated as part of metabolism and is also emitted from furnishings and fabrics. Odour causes discomfort to occupants and can sometimes be the main reason for ventilation.

Moisture

Moisture is mainly generated by occupant activities such as cooking washing and clothes dying. It is also major constituent of combustion and therefore may be present in large amounts where gas cooking and unvented space heating takes place. Moisture vapour condenses on cold surfaces where it can cause considerable damage through mould growth and fabric decay.

Tobacco Smoke

Several thousand gaseous and particulate phase compounds have been identified in tobacco smoke. Some of the more significant by-products of tobacco smoke include respirable particles, nicotine, nitrosamines, PAH, CO, CO_2, NO_X, acrolein, HCHO and hydrogen cyanide.

5.0 Thermal Insulation Requirements

Some countries provide recommended U-values, whilst others provide standard equations to determine the overall energy consumption of the building. There are several methods to express requirements with respect to the thermal performances of the building envelope:

- Requirements at component level: U value requirement
- Requirements concerning the average insulation level of the building envelope
- Requirements concerning the normalised total energy use of the building

The first requires the minimum amount of calculation. The requirements are met if the thermal performances of the construction elements conform to those specified by the relevant code. The total U-value for a particular element is specified and the total composite wall must equal or better the requirement. For example if the specified U-value for a masonry wall is 0.45 $W/m^2 K$, then the designer can met the requirement if the wall's U-value, which consists of the combined U values for the outer brick layer, air gap, insulation inner block layer, and plaster finish, is less than or equal to the requirement. Countries that have adopted this approach include United Kingdom, and Norway *(allows all three methods).*

The second method sets average U-values for buildings, and is met provided the total U-values for the design do not exceed those stated. Within certain limits this method allows more flexibility than the first method outlined above, in selecting areas of windows, personnel doors and roof-lights and/or the insulation levels of individual elements in the building envelope. Calculations should show that the rate of heat loss through the envelope of the proposed building (which could have different U-values or areas of openings from those given in the elemental method) is not greater than the rate of heat loss from a notional building of the same size and shape designed to comply with the elemental method. Countries that have adopted this approach include: Belgium, Greece, Norway *(allows all three methods)*, Sweden and the United States of America.

The third method takes account of ventilation rate, fabric losses, water heating requirements, internal fabric gains and solar gains. The requirement is met provided the building achieves or betters the values stated in the standard assessment procedure energy rating for a particular building. Countries that have adopted this approach include: Belgium (level BE 450 in the Walloon Region), Denmark, France, Netherlands, New Zealand and Norway*(allows all three methods).*

The table below by EURIMA shows changing insulation levels in walls and Roofs in 16 countries since 1982 to 1999 has been compared. It can be seen that nearly all levels have steadily increased from, for example, 130mm to 240mm in walls, while in others the change has been more moderate (for example, in Spain roof insulation has increased from 60mm to 100mm and for walls from 50mm to 60mm). Changes in insulation levels is predominately climate driven, in that the temperature difference between inside and outside has a more pronounced effect in colder countries compared to milder Mediterranean countries. The potential energy saving and effectiveness of insulation reaches an optimum in milder countries at lower levels compared to colder climates. Insulation levels in Sweden, Finland and Norway etc are therefore higher than in Spain, Italy and Greece. Insulation has to be coupled with good design and construction techniques and practices, good heating and ventilation systems and an understanding and need to achieve a comfortable and safe indoor environment, if real savings are to be made.

Table 5.1 :Insulation thickness in mm in different European countries

Country	Roofs				Walls			
	1982	**1990**	**1995**	**1999**	**1982**	**1990**	**1995**	**1999**
Sweden	200	300	450	450	130	220	240	240
Finland	300	320	320	320	180	180	200	200
Norway	175	225	225	300	130	150	150	175
Denmark	200	230	250	250	130	150	175	175
France	175	200	200	220	80	100	100	100
Austria	120	150	200	200	70	80	120	120
England	100	150	200	200	50	50	60	60
Germany	100	120	150	180	50	60	80	80
Ireland	100	100	150	150	50	50	60	60
Switzerland	100	100	120	140	80	100	100	120
Netherlands	60	80	90	110	55	65	70	85
Belgium	50	50	70	100	50	50	50	50
Turkey		60	60	100		30	30	50
Spain	60	70	70	100	50	50	60	60
Italy	60	60	60	60	50	55	55	55
Greece	50	50	50	50			50	50

Source: Insulation Thickness (mm) in various European Countries (1999) EURIMA.

6.0 Conclusions

The present review of ventilation, airtightness, air quality and thermal insulation criteria brings together information from Belgium, Denmark, Finland, France, Germany, Greece, Netherlands, New Zealand, Norway, Sweden, United Kingdom and the United States of America. One fundamental observation is that comparisons of this type are extremely difficult to achieve with any realistic conclusions. Hindered by some of the facts presented in the introduction, most importantly, the differences in the way criteria is expressed (i.e. units) and the use and meaning of associated jargon (i.e., the use of the words standards, decree etc).

The former case is possibly the most important, countries express criteria in a variety of different ways, however no reasons are given for their preferred way of expression compared to another country, for example, whole building airtightness is expressed in terms of air changes per hour and in terms of $m^3/h.m^2$ and $l/s.m^2$ at a given pressure differential, which in turn can also vary (4, 10 and 50 Pa) are all used. However, comparisons are possible, but estimates have to be made regarding typical building volumes etc, which are not outlined in the countries' criteria, and which can lead to errors if wrongly assumed. Therefore, examinations can only be undertaken where units are comparable. Normalised values have only limited usefulness, they do however, enable a basic comparison to be made, associated errors can be significant. Another example is minimum ventilation rates, expressed in terms of air changes per hour (ACH), (m^3/h or l/s) per person and per m^2 floor area. Criteria is also given for individual dwelling rooms based on either occupation (m^3/h or l/s per person) or floor area (m^3/h or l/s m^2). Such examples make real comparisons difficult and the formulation of accurate conclusions impossible.

However, what could be determined from this review is that five countries (Belgium, Italy, Netherlands, Norway and the United States of America) express airtightness criteria of whole buildings. Such criteria are important to enable the optimum performance of a ventilation system as well as energy control and comfort conditions. Excessively leaky buildings will interfere with the performance of modern mechanical systems and will greatly reduce the net efficiency of heat recovery devices. Naturally ventilated buildings may require higher levels of permeability preferably through controllable purpose provided openings in order that sufficient ventilation air is provided. Examining the criteria shows that naturally ventilated buildings have a less stringent air tightness requirement, to ensure adequate ventilation provision is provided. Mechanically ventilated buildings are more stringently controlled, to save energy in terms of infiltration losses and enable better control of ventilation air.

For Building Components, nine countries specify airtightness criteria for Windows (Finland, France, Germany, Italy, Netherlands, New Zealand, Switzerland, United Kingdom and the United States of America). Criteria are expressed in two formates, Germany, Netherlands, New Zealand, Switzerland, and the United Kingdom express window air leakage criteria in terms of unit length of crack ($m^3/h.m$) while Finland, France, New Zealand, and United States of America express criteria in terms of unit area of window ($m^3/h.m^2$). This precludes a direct comparison. What is common throughout is that countries express window leakage criteria in terms of grades of window at a single pressure, most have three grades or categories of window leakage which cover airtight, moderate and low air resistance without specific applications for each particular grade. The Netherlands and Switzerland specify criteria relating to building height, and the Netherlands further considers building location (coastal, inland etc).

Again, criteria for countries in colder climates and/or for buildings designed to incorporate mechanical ventilation systems tend to have more stringent air leakage criteria. In countries where the climate is more moderate and/or natural ventilation is common, less importance is placed on the levels of specified air leakage for components. However, air leakage represents a significant potential energy loss, and as such is attracting more importance. It is no longer acceptable to provide poorly fitting building components as an alternative to providing well designed natural ventilation strategies. If natural ventilation is chosen as a ventilation strategy, then it should be well designed and implemented, and not supplemented by poor leaky building components.

Only Denmark, France, and the United States specify airtightness criteria standards for doors, all using different units and pressure differentials. It can be seen that when normalised to 50 Pa pressure difference, the criteria from the United States comparable with those from France, for revolving and swinging doors. In addition the United States appears to have more stringent criteria for sliding and swinging doors requiring greater levels of air tightness.

Regarding *minimum ventilation rate criteria in Dwellings*, these are expressed as whole building ventilation rates, in air changes per hour (ACH), m^3/h or l/s per person or per m^2 floor area. Criteria are also given for individual dwelling rooms based on either occupation (m^3/h or l/s per person) or floor area (m^3/h or l/s m^2). Whole building minimum ventilation rate criteria is difficult to compare, principally because the overall size and nature of typical dwellings and typical population densities vary from country to country. In some countries multistorey, multifamily homes are normal, while in other single storey single family homes are more common. Generally such variations vary regionally as well. Where mechanical ventilation is common, minimum ventilation criteria are given as an extract or supply rate in for example l/s per person. Where natural ventilation is used criteria are specified as an openable area. In natural ventilated buildings mechanical extraction can also be utilised, in terms of bathroom or kitchen extract fans which are operated intermittently. What can be inferred from the criteria is that in, kitchens, bathrooms and toilets where pollution can be extreme, but only for a short period of time, ventilation provision is more of a purge, mainly extracting high rates of polluted air over a short period. Supply is generally provided via background ventilation through adventitious infiltration (either from outside or adjacent rooms), openable windows or a much lower rate mechanical supply system. In living rooms and bedrooms occupants gather and can pollute the air via CO_2 and tobacco smoke (mainly living rooms). Criteria suggests ventilation rates are more continuous and provided on a per person or room area basis. Background ventilation rates are therefore higher, but there is less need to purge to air on a frequent basis. However, the mechanical extraction systems in place in the bathrooms, kitchens and WC's will gradually draw out this polluted air, which will be replaced over time by outside air.

Minimum ventilation rates in offices is expressed in terms of l/s or m^3/h per person. Belgium, Netherlands and Norway express minimum ventilation rates criteria for offices in terms of m^3/h per m^2 of office area. Most countries make a distinction between ventilation for occupant comfort and ventilation for indoor air quality control (in for smoking). Typical ventilation rates of between 3 to 10 l/s per person are outlined above for normal office areas. Where smoking is allowed rates are generally higher, in the re gion of 8 to 20 l/s per person.

In schools, minimum ventilation rate criteria is expressed by most countries in terms of l/s per person and in m^3/h per person. Typical rates for classrooms outlined are within the range 4-10 l/s per person. These are similar to those criteria outlined above for offices. Some countries express their criteria in terms of m^3/h .m^2 and whole room air changes per hour (ach), for any comparison of these criteria or comparisons against those expressed per person, typical occupant densities and room volumes are necessary

Indoor air quality criteria is expressed in terms of concentrations of pollutant in air in parts per million (ppm) or as a measure of concentration by volume, in milligrams per cubic metre of air (mg/m^3), a measure of concentration by mass. Criteria is also expressed in terms of long and short term exposure and in terms of Maximum allowable concentrations (MAC) and Acceptable indoor concentrations (AIC) concentration. Pollutants compared in this review include carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), ozone (O_3), sulphur dioxide (SO_2), and nitrogen dioxide (NO_2). Not all countries specify criteria for indoor pollutant levels.

Carbon dioxide (CO_2) concentrations of 5000 ppm represent the most common Maximum Allowable Concentration limits, with Allowable Indoor Concentrations (AIC) varying slightly around 1000ppm. Carbon monoxide maximum allowable concentration levels required by most countries is 50ppm or equivalent. Germany and Sweden specify 35 ppm MAC. Maximum allowable concentrations of Formaldehyde specified varies between 0.5-1ppm. Short term peak levels (15 min) are specified between 1.2-2ppm. Criteria for ozone (O_3) is given in parts per billion (ppb), part per million (ppm), and $\mu g/m^3$. Criteria ranges from maximum allowable concentrations of around 0.1 ppm or less to 1 and 8 hour averages between 180ppb and 55 ppb respectively. Nitrogen dioxide (NO_2) maximum allowable concentrations range from 2-5 ppm. Acceptable indoor concentrations are much lower in the region of 0.004-0.6ppm. Time weighted average criteria also varies from 5ppm for 15 min, 110 -210ppb for 1 hour and 3ppm for 8 hour exposures. Sulphur dioxide (SO_2) is mainly given as a time weighted average for 1 and 8 hours, although concentrations for other time scales are also given, for example, 10 and 15 minutes and 24 hours, annual and winter periods. Concentrations of 100ppb to 5ppm for 15 minutes criteria are given, and 122ppb for a 1 hour time interval. Criteria for 8 hour averages range from 2 to 5ppm. EC guide values for annual averages range from 15-22.9 ppb and a daily average 37.5-56.4 ppb.

Regarding Thermal Insulation Requirements some countries provide recommended U values, whilst others provide standard equations to determine the overall energy consumption of the building. There are several methods to express requirements with respect to the thermal performances of the building envelope: Requirements at component level: U value requirement United Kingdom, and Norway *(allows all three methods);* Requirements concerning the average insulation level of the building shell; Belgium (level BE 450 in the Walloon region), Greece, Norway *(allows all three methods)*, Sweden and the United States of America; Requirements concerning the normalised total energy use of the building (*Denmark, France, Netherlands, New Zealand and Norway(allows all three methods)).* Further changes in insulation levels is predominately climate driven, in that the temperature difference between inside and outside has a more pronounced effect in colder countries compared to milder Mediterranean countries. The potential energy saving and effectiveness of insulation reaches an optimum in milder countries at lower levels compared to colder climates. Insulation levels in Sweden, Finland and Norway etc are therefore higher than in Spain, Italy and Greece. Insulation has to be coupled with good design and construction techniques and practices, good heating and ventilation systems and an understanding and need to achieve a comfortable and safe indoor environment, if real savings are to be made.

While the aim of this document was to thoroughly compare international criteria, it has proved very difficult to conclusively achieve. While a true and thorough comparison has not been possible, due to the many differences outlined in this section, this document provides a valuable up-to-date compendium of current criteria, which can be used as a source of information and reference. The next step is to provide a greater understanding of the methodology behind the criteria, which will ultimately lead to a clearer understanding of these criteria themselves. More uniformity is needed it the way criteria is expressed, and if a variety of ways are used, it is essential to understand why they have been expressed in that way and how they can be compared. Useful information for example, would be relating to specific typical room and /building sizes, occupant densities and the typical building types given for a particular country or region (for example, dwellings, are they typically, multi storey, single story detached, terraced, two bedroom, three bedroom etc).

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8.0 Bibliography of Additional Reading Material

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Appendix A Airtightness Requirements

A1 Whole building leakages

Currently Belgium, France, Italy, Netherlands, Norway, Sweden, Switzerland and the United States of America have criteria for the airtightness of whole buildings. These are briefly outlined below.

A1.1 Belgium

Belgian Standard NBN D 50-001 Ventilation systems for housings. October 1991

This Belgian standard recommends an air leakage rate at 50 Pa of less than 3 ach for dwellings equipped with balanced mechanical ventilation and less than 1 ach when heat recovery devices are used

A1.2 France

Ventilation in the RT 2000 new French thermal regulation

A new Regulation has been approved in end of November 2000 (réglementation thermique 2000, so called RT2000). Its aim is to reduce the energy consumption of new buildings. It will be applicable to all new buildings from June 2001.

The regulation stipulates that the conventional primary energy consumption of a given building (C coefficient), must be less than or equal to a reference value Cref. A calculation method (called Th C) has been defined according to CEN standards in order to calculate the C coefficient. The Cref value is calculated by the same method and by replacing the actual characteristics of the building by reference ones, defined in the regulation.

The ventilation impact on energy needs in taken into account more precisely and widely than in the previous regulation. Its basis of is to calculate the different airflows by using an implicit calculation method on the basis of the prEN 13465 (TC 156WG2). The calculation method takes into account mechanical ventilation (extract only and balanced systems), passive duct systems and window airing.

The different building and system characteristics are as follows :

Building airtightness
The reference value is the air flow at 4 Pa, divided by the area of the envelope (and so expressed in $m^3/(h.m^2)$). The reference value varies from 0.8 to 2.5 depending on the type of construction. If the actual value is unknown, a default value can be applied by adding 0,5 to the reference one.

Ducts airtightness
The reference value is the class A. If the actual value is unknown, a reference value equal 2.5 times the reference one can be applied

A1.3 Italy

Ministerial Decree 18.12.75 "Technical standards for educational buildings…"

Ministerial Decree 05-07-75 Ventilation requirements for residential buildings.

Ministerial Decree 18.12.75 "Technical standards for educational buildings…" specifies a recommendation for an envelope air leakage value for schools; the infiltration rate across one square metre of exterior envelope should not exceed 10m3/h at a pressure difference of 10mm of water (98Pa). It also gives prescribed air changes rates of between 1.5 - 5.0 ACH for rooms in school buildings.

Ministerial Decree 05-07-75 "Ventilation requirements for residential buildings" states that all dwellings, bedrooms, living rooms and kitchen must be provided with an openable window of area not less than 1/8th of the floor area. No actual values are given.

A1.4 Netherlands

NEN2687. Air leakage of dwellings - requirements. (Luchtdoorlatendheid van Woningen) - Eisen

This standard only applies to dwellings, but work is currently underway for commercial buildings (NEN 2689). The envelope air leakage rate at 10 Pa, is defined according to the type of ventilation system. The systems fall into 2 classes as laid down in standard NEN1087.

Class 1
System A - Natural Supply and Extract.
System C - Natural Ventilation Supply with Mechanical Extract.
Class 2
System B - Mechanical Supply and Natural Extract.
System D - Mechanical Supply and Extract.

The first table below, outlines the permitted mechanical air leakage at an applied pressure of 10 Pa while the second table lists the minimum permitted leakage.

Maximum Recommended Air Leakage							
	Building Volume (m^3)		**Flow rate at 10 Pa (dm^3/s)**	**Equivalent to ACH at 10Pa**		**Equivalent to ACH at 50Pa**	
	Greater than	**Less than**					
Class 1	-	250	100	-	1.4	-	4.16
	250	500	150	2.24	1.12	6.25	3.21
	500	-	200	1.44	-	4.16	-
Class 2	-	250	50	-	0.72	-	2.08
	250	-	80	1.15	-	3.3	-
Minimum Recommended Air Leakage							
Class 1	-	250	30	-	0.43	-	1.24
	250	500	50	0.72	0.36	2.0	1.0
	500	-	50	0.36	-	1.0	-

NOTE: No minimum value given for Class two because there needs to be some residual air leakage.

A1.5 Norway

The new Norwegian regulations try to formulate its code as performance based (functional requirements). Thus requirements for air tightness are formulated in general terms (as opposed to insulation requirements):

Technical Regulations under the Planning and Building Act 1997 (22 January 1997 No. 33) Regulations concerning requirements for construction works and products for construction works. Chapter VIII Environment and health. § 8-22 Air tightness: Buildings shall be so impervious that the effect of thermal insulation is not reduced by unintentional flow of air through them. Moisture shall not be allowed to penetrate and reduce the effect of thermal insulating or worsen the design life of the building. Buildings shall be so impervious that the indoor climate is not negatively affected and in such manner that unpleasant draught does not occur**.** (See also http://www.be.no/beweb/english/englishtop.html)

The previous table of air change rates has now been moved down to the regulation guidance book (thus not being formal part of the regulations). The values of the table are unchanged.

Building Type	**Air Change Rate pr hour at 50 Pa**
Detached and undetached houses	4
Other buildings two storeys high or less	3
Other buildings more than two storeys high	1.5

A1.6 Sweden

Source: BFS 1998:38 Chapter 9:212 Airtightness. National Board of Housing, Building and Planning.

Requirements: The building envelope shall be so airtight that the average air leakage rate at a pressure difference of 50 Pa does not exceed 0.8 l/s per m² for dwellings and 1.6 l/s m² for other spaces. Consideration shall be given to the Area A_{om}. A_{om} is the aggregated area (m²) of the surfaces, in contact with the heated indoor air, of enclosing elements of structure. The term enclosing element of structure refers to elements, which separate the heated parts of dwellings or non-residential premises from the external air, the ground or partly heated or unheated spaces.

A1.7 Switzerland

SIA 180 Thermal protection of buildings. Warmeschutz im Hochbau.

The new version of SIA 180, in force since 1st January 2000, clearly states in chapter 3 dedicated to ventilation and airing, that the envelope should be sufficiently airtight (with closed ventilation openings), and that airing or ventilation should be ensured by ad -hoc means.

The air permeability of the envelope is no longer defined by the air change rate at 50 Pa, but by the airflow rate at 4 Pa, $\dot{V}_4$ related to the envelope area, A_e:

$$v_{a,4} = \frac{\dot{V}_4}{A_e} \quad \text{in } m^3/(h\ m^2)$$

The airflow rate at 4 Pa is extrapolated from pressurisation measurements performed according to ISO 9972.

The envelope area includes all envelope elements separating the indoor environment from outdoor or unheated spaces, but does not include areas directly connected to the ground. However, it is especially stated that special caution should be taken in areas exposed to radon emission from the ground.
Requirements are as follows:

	$v_{a,4,max}$ in $m^3/(h\cdot m^2)$	
Category	Upper limit	Recommended limit
New buildings	0.75	0.5
Refurbished or modified buildings	1.5	1

In addition, no zone (such as occupied attics) can be higher than 2 $m^3/(h\cdot m^2)$.

A1.8 United Kingdom

There is a proposal in the New UK Building regulations for a Air Leakage standard

Reference: Building Regulations June 2000 – Proposals for Amending the Energy Efficiency Provisions

2.16 Buildings should be reasonably airtight to avoid unnecessary space heating and cooling demand and to facilitate the effective performance of ventilation systems. The requirement will be met if the air leakage index is not greater than 10 cubic metres per hour per square metre of external surface area ($m^3/h/m^2$) at an applied pressure difference of 50Pa, for non domestic buildings.

2.17 In order to achieve satisfactory air leakage performance the following measures can be adopted:

a) a reasonably continuous air barrier in contact with the insulation layer should be provided over the whole thermal envelope (including separating walls). Special care must be taken at junction between elements and around door/window openings. A selection of satisfactory design details and installation practice is described in the report on robust standards details. (CIBSE Daylight and Window design LG10, 1999)

b) sealing of gaps around service penetrations

c) external doors and opening windows should be fitted with draughtstrips.

In the longer term a more specific requirement based on emerging weather tightness European Standards may be included.

CIBSE TM23:2000 – Testing buildings for Air Leakage

Building Type	Air Leakage Index (Pa m^3 h^{-1} m^{-2} at 50 Pa)		Air Permeability (m^3 h^{-1} m^{-2} at 50 Pa)	
	Good practice	*Best practice*	*Good practice*	*Best practice*
Dwellings	15.0	8.0	10.0	5.0
Dwellings (with balanced whole house mechanical ventilation)	8.0	4.0	5.0	3.0
Offices (naturally ventilated)	10.0	5.0	7.0	3.5
Offices (with balanced mechanical ventilation	5.0	2.5	3.5	2.0
Superstores	5.0	2.0	3.0	1.5
Industrial	15.0	2.0	10.0	3.5

Air leakage index –Q_{50}/S is the air leakage rate at a pressure difference of 50Pa Q_{50} divided by the building envelope area S (m^2). The air leakage index of the building envelope area S (m^2) is defined as the internal surface area of the external façade, and is calculated from the dimensions bordering the internal volume of the building under test. The area is given by the total of the walls, top floor ceiling (or underside of roof) depending on where the air barrier is with no deductions for partitions and division walls with adjacent buildings or attached garages.

The airtightness of dwellings has in the past been expressed as a leakage rate in air changes per hour i.e., volume flow rate (m^3 h^{-1}) at 50 Pa reference pressure difference per cubic metre (m^3) of building volume (Q_{50}/V). Expressing air leakage rates allows its air infiltration rate to be predicted using the 1/20th rule.

prEN 13829 Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurisation method ISO 9972: 1996 modified)

Air permeability – is the air leakage parameter used in the provisional European Standard prEN 13829. It has been found advantageous to use it for reasons of simplicity in air leakage standard for both non domestic and domestic buildings under regulatory specification in Building Regulations Approved Document Part L. In this parameter the ground floor area is included in the building envelope area S_T (m^2) for all building types.

A1.9 United States of America

Window and door infiltration rates are defined in the US and Canada combined International Building Code Council:

ASHRAE 136 1993 "a Method for Determining Air Changes Rates in Detached Dwellings" incorporates a weather factor for different regions within the US. Formula given to achieve the effective air change rate due to infiltration is $A_I = L_n \times W$

Where A_I is the air change rate per hour,
L_n is the Normailised air leakage rate (determined by blower door test as per ASTM E779).
and
W is a factor accounting for the effect of local weather.

ASHRAE 119-1988 (RA)- Air Leakage Performance for Detached Single-Family Residential Buildings. (Reaffirmation of ANSI/ASHRAE 119-1988) with minor editorial changes.

This applies to single family dwellings based on the climate region in which the dwelling is constructed. Airtightness is specified in the form of normalised leakage; Ln, taking into account building height, floor area and leakage area at a reference pressure of 4Pa. This standard has not yet been adopted by any state of the United States and is therefore not currently a legal requirement.

Classification of leakage is given for a range of normalised leakage based on the following equation:

$$Ln = 1000\,(L/A)(H/Ho)^{0.3}$$

Where

Ln = the normalised leakage (ELA/Floor area)
Ho = the height of the single storey (8ft)[2.5m]
H = the height of the building (ft) [m]
L = the leakage area of the space (ft^2) [m^2]
A = the floor area of the space (ft^2) [m^2]

Classification of leakage	
Normalised leakage range	**Leakage Class**
Ln<0.1	A
0.10 ≤Ln<0.14	B
0.140 ≤Ln<0.20	C
0.20 ≤Ln<0.28	D
0.28 ≤Ln<0.40	E
0.40 ≤Ln<0.57	F
0.57 ≤Ln<0.80	G
0.80 ≤Ln<1.13	H
1.13 ≤Ln<1.60	I
1.60 ≤Ln	J

Maps and tables show the regions and cities which have been given a leakage class based on the normalised leakage range.

NOTE: The standard requires no part of the US to be tighter than 0.28 ach at 4 Pa (equivalent to 1.5 ach at 50 Pa) and that is only required for a tiny part of the upper Mid west; mostly the tightness requirement is 0.4 ach at 4 Pa (equivalent to 2.2 ach at 50 Pa).

A2 Component leakages

A2.1WINDOWS

France and the United States have recommendations for doors and windows, while the remaining countries have recommendations for windows only.

A2.1.1 Finland

SFS 3304 Window, functional requirements, clarification and testing, 1978. (in Finnish).

The Finnish classification for window airtightness (SFS 3304) is voluntary, but is widely used among window manufactures and builders. The values are given in $m^3/h.m^2$ at a pressure differential of 50 Pa, and are outlined below:

	Airtightness at 50 Pa pressure difference
Window Class 1	<0.5 $m^3/h.m^2$
Window Class 2	0.5 - 2.5 $m^3/h.m^2$
Window Class 3	>2.5 $m^3/h.m^2$

A2.1.2 France

French Standard NF P20-302 Windows Characteristics 1980.

Window Classification	**Quoted values ($m^3/h.m^2$) at 100 Pa pressure difference**
A1	20 to 60
A2	7 to 20
A3	Less than 7

Leakage flow rates are divided by window area. Exponent of the flow rate pressure drop relationship is taken as 2/3 (0.66). The above classification is defined in NF P 20-302 with reference to windows, but this standard is also used for doors.

A2.1.3 Germany

DIN 180 55. Windows. Air permeability of joints, water tightness and mechanical strain, requirements and testing. (Fenster. Fugendurchlassigkeit, Schlargegendichtheit und mechanische Beanspruchung Anforderungen und Prufung). October 1981.

This standard classifies windows by exposure level and gives acceptable air permeability values for each group under pressure, over the range 10 to 1000 Pa pressure difference.

Exposure Level		Range of Pressure difference 10 to 1000Pa v=in m^3/h.m length of crack					
		10	50	100	150	300	1000
A	V=	2	6	9.5	15.0	-	-
B-D	V=	1	3	4.8	6.0	10.0	20.0

A2.1.4 Italy

UNI 7979 Classification of window performance.

The Italian standard UNI 7979 classifies external vertical windows according to air permeability, water tightness and resistance to wind action. As regards air permeability windows are classified into three categories A1, A2 and A3 in ascending order of air tightness. They are given in two formats (Airflow rate per unit length of opening(m^3/h.m); and Air flow rate per unit area of window (m^3/h. m^2))

	Air flow rate per unit length of opening, (m^3/h.m at 50Pa)		Airflow rate per unit area of window (m^3/h.m^2 at 50 Pa)	
A1	4.0	8.0	13.0 - 31.0	
A2	1.3	4.0	4.8	13.0
A3	0.0	1.4	0.0	4.8

A2.1.5 Netherlands

NEN 3661 Window frames, air permeability, water tightness, rigidity and strength. (Gevelvullingen Luchtdoorlatendheid, Waterdichtheid stijfheid en sterkte) Eisen NNI 1988.

The Dutch standard NEN 3661 gives air leakage through cracks in windows, given at two exposure levels, four classes of test pressures and three heights of window. The average leakage rate must not exceed 2.5 dm^3/s per metre length of crack.

Height of building in which the window is located (m)	Exposure	Pressure difference (Pa)	Air Leakage (dm^3/ m.s)
15	Normal	100	3.5
40	Normal	200	3.0
100	Normal	300	2.5
15	Coastal	300	2.5
40	Coastal	300	2.5
100	Coastal	450	2.5

A further requirement to the above is that the local air leakage along any 100 mm section of frame, should not exceed 0.5 dm^3/s at the prescribed test pressures.

A2.1.6 New Zealand

There is still no airtightness requirement in buildings although windows as elements in a building must meet air leakage criteria.

NZS 4211:1987. Specification for performance of windows. Standards Association of New Zealand.

New Zealand has few airtightness and ventilation rate standards. Windows for domestic buildings must pass an air leakage test set out in NZS N4211:1987. This standard classifies windows into three categories according to air leakage performance, and gives maximum rates of leakage at 150 Pa for each level. These are given below:

	Rate of air leakage (dm^3/s)		
	1	2	3
Per m of opening joint length	0.6	2.0	4.0
Per m^2 of total window area	2.0	8.0	17.0
Notes: *1 Airtight.* *2 Moderate air leakage.* *3 Low air leakage resistance.* *1 Tested for both inwards and outward leakage.* *2 and 3 Tested for inward air leakage only.*			

A2.1.7 Switzerland

SIA 331 Windows, Fenster

In this standard upper limits for the leakage of windows are given. In additions to this standard only one value for Q – value (termed a-value in standard) is used (0.2 m^3/h where n=0.66).

Window Group	**A**	**B**	**C**
Pressure in test (Pa)	150	300	600
Building height (m)	0..8	>8..20	>20..100
Requirements:			
Allowable volume flow rate at given pressures ($m^3/h.m$)	5.65	8.95	14.25
To work backwards to obtain volume flow rate assume Q to equal ($m^3/h.m$ Pa n=0.66)	0.2	0.2	0.2

New windows can easily be 10 times tighter than this prescribed value (0.2 m^3/h.m at Pa 2/3^{rds}) and thus in many cases this prohibits basic ventilation.

A 2.1.8 United Kingdom

BSI 6375:1983 Performance of windows. PT 1, Classification of weathertightness.

The British Standard: BSI 6375:1989 classifies airtightness according to exposure, and is applicable to all window types in which any frame member is not longer than 3 m, including adjustable louvers and sliding windows.

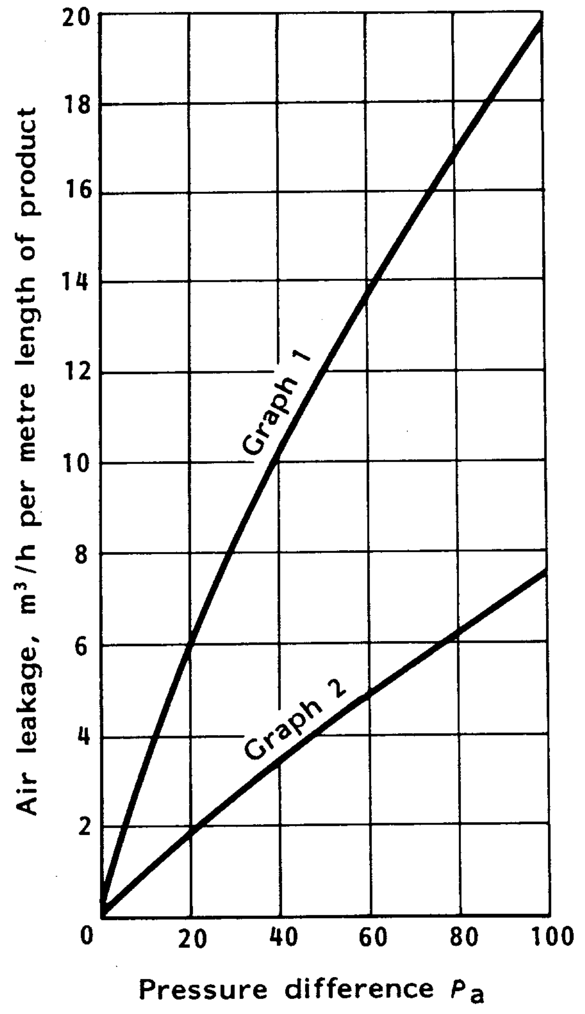
The standard gives air permeability limits for windows, between the limits of window category A & B, where respective K values are; KA = 0.4678 & KB = 0.357, and where n=0.66. Values for a third category of window are also stated, for air conditioned Buildings, type C, in this case KC = 0.0928. The air leakage values are outlined below:

Therefore allowable air leakage at test pressure of 50Pa (m^3/h.m)	Allowable air leakage last test pressure (m^3/h.m)
A=6.3	200Pa A=15.40
B=4.8	300Pa B=15.40
C=1.22	600Pa C=6.6

BS7396:1990 Specification for: Draughtstrips for the draught control of existing doors and windows in housing (including test methods).

This standard specifies air the maximum air leakage through a product as follows:

When tested by the methods described in A.7 and when installed in the maximum gap size specified, and compressed/deflected in accordance with the product information, products designed to fit a maximum gap size of 10mm shall comply with line (a); those designed to fit a maximum gap size greater than 10mm shall comply with line (b).



NOTE: Graph 1: products designed to fit maximum gap size of 10 mm or less. Graph 2: products designed to fit maximum gap size greater than 10mm.

A2.1.9 United States of America

Window and door infiltration rates are defined in the US and Canada combined International Building Code Council:

Windows are 0.3 cfm per m^2 of window area, when tested by ASTM E28
AAMA 101.S.2
ASTM 4009

ASHRAE 90.1-1999. Energy Standard for Buildings Except Low Rise Residential Buildings

(Now under Continuous maintenance)
ASHRAE 90.2-1999. Energy Efficient Design of New Low Rise Residential Buildings
(Now under Continuous maintenance)

The **American ASHRAE Standard 90.1-99** gives recommendations for the leakage rate of windows and doors in accordance with NFRC 400. Air leakage shall be determined by a laboratory accredited by a national recognised accreditation organization such as the National Fenestration Rating Council and shall be labeled and certified by the manufacturer. Air leakage shall not exceed 5 l/s.m^2 for glazed swinging entrance doors and for revolving doors 2.0 l/s m^2 for all other products.

ASHRAE 90.2-1999. Energy Efficient Design of New Low Rise Residential Buildings
(Now under Continuous maintenance)

According to section 5.6.2 Air leakage Requirements

5.6.2.1 Windows – Windows shall be designed to limit air leakage.
(a) The requirement for aluminum windows shall be 0.37cfm/ft of sash crack as specified in ANSI/AAMA 101-88

(b) The requirement for PVC windows shall be either 0.37cfm/ft of sash crack, as specified in AAMA 101V86 or 0.375 cfm/ft of sash crack, as specified in ASTM D 4099-89

(c) The requirement for wood windows shall be 0.34 cfm/ft of sash crack, as specified in ANSI/WWDA I.S 2 87

(d) The requirement for manufactured housing windows shall be 0.50 cfm/ft^2 of window area, as specified in AAMA 1701.2 1985.

The air infiltration rate requirement for windows not covered by any of the listed references shall be 0.34 cfm/ft of sash crack. The requirement for fixed windows shall be 0.34 cfm/ft^2 of window area.

A2.2 Doors

Denmark, France and the United States of America are the only countries to have specific airtightness standards for doors.

A2.2.1 Denmark

DK-418 Beregning af bygningers varmetab. 1977.

0.50 dm^3/s.m at 50 Pa length of crack.

A2.2.2 France

French Standard NF P 20-302 applies to windows, but is also used for doors. (See Windows section A.1.2.1).

A2.2.3 United States of America

ASHRAE 136 1993 "a Method for Determining Air Changes Rates in Detached Dwellings" incorporates a weather factor for different regions within the US. Formula given to achieve the effective air change rate due to infiltration is $A_I = L_n \times W$

Where A_I is the air change rate per hour,
L_n is the Normailised air leakage rate (determined by blower door test as per ASTM E779).
and
W is a factor accounting for the effect of local weather.

ASHRAE 90.1-1999. Energy Standard for Buildings Except Low Rise Residential Buildings
(Now under Continuous maintenance)
ASHRAE 90.2-1999. Energy Efficient Design of New Low Rise Residential Buildings
(Now under Continuous maintenance)

ASHRAE 90.2-1999. Energy Efficient Design of New Low Rise Residential Buildings
(Now under Continuous maintenance)

Sliding Doors

Sliding doors used for entry or exit from residential living units shall be designed to limit air leakage.

(a) The requirement for aluminium sliding doors shall be 0.37cfm/ft^2 of door area as specified in ANSI/AAMA 101-88

(b) The requirement for PVC sliding doors shall be either 0.37cfm/ft^2 of door area, as specified in AAMA 101V86 or 0.375 cfm/ft^2 of door area, as specified in ASTM D 4099-89

(c) The requirement for wood sliding doors shall be 0.34 cfm/ft^2 of door area, as specified in ANSI/WWDA I.S 3-88

(d) The requirement for manufactured housing sliding doors shall be 0.50 cfm/ft^2 of door area, as specified in AAMA 1701.2 1985.

Swinging Doors

The air infiltration rate shall not exceed 0.5 cfm/ft^2 of door area except for manufactured housing swinging doors. The requirement for these shall be 1.0 cfm/ft^2 of door area as specified in AAMA 1702.2 1985.

A2.3 Other Components.

A2.3.1 Netherlands

Ref: Mentioned in Building Decree 16th Dec. 1991, p20: (NEN 2690).

Dutch legal requirement for floor directly above crawl space is $20x10^{-6}$ $m^3/m^2.s$ at 1 Pa.

A2.3.2 France

In order to calculate ventilation heat losses, French Building Regulations, according to *DTU Regles ThG April 1991*, stipulate that the air leakage rate of opaque external walls of dwellings is:

Single family dwellings:	0.5 $m^3/h.m^2$ for ΔP - 1 Pa.
Multifamily dwellings:	0.25 $m^3/h.m^2$ for ΔP 1 Pa.

The values are given for $1m^2$ of dwelling surface area.

APPENDIX B Techniques for measuring Air Leakage

B1 Whole buildings

B1.1 Canada

Determination of Airtightness of Buildings by the Fan Depressurisation Method.CAN2-149.10-M86

B1.2 France

Test method for determining airtightness of residential buildings.

(Guide methodologique pour la mesure de la permeabilite a l'air des enveloppes de batiments) Cahiers du CSTB No. 2493. 1991.

B1.3 Netherlands

NEN 2686 Air leakage of buildings - Method of measurement. (Luchtdoorlatendheid van gebouwen Meetmethode) NNI 1988.

B1.4 Norway

A 1.2.4.1 Techniques for measuring air leakage of whole buildings

NS-INSTA 130 Airtightness of buildings. Test method. (Bygningers lufttetthet. Provingsmetode) NSF 1981

B1.5 Sweden

SS02 15 51 Buildings - Determination of airtightness. 1987. (ver 2).
A method for determination of the air leakage rate is given in Swedish Standard SS 02 15 51,

NT VVS 019 Method of determining the local mean age of ventilation air in buildings. 1986.

B1.5 United Kingdom

Determining air tightness of buildings by the fan pressurisation method: BRE recommended procedure.

B1.6 United States of America

ASTM E779-99 Standard test method for determining air leakage rate by fan pressurisation.

B1.7 ISO

DP 9972 Measurement of building airtightness using fan pressurisation. Draft Proposal.

Appendix B2 Components

B2.1 Belgium

STS 52.0 Menuiseries Exterieures - Generalities.

NBN B25-204 (EN42): Methods of testing windows. Part 1 : Air Permeability tests, 1981.

NBN B25-205 (EN77): Methods of testing windows. Part 2 : Wind resistance tests, 1981.

NBN B25-206 (EN78) : Methods of testing windows. Part 3: Form of test report, 1981.

NBN B25-209 (EN86): Methods of testing windows. Part 4 : Water tightness test under static pressure, 1981.

NBN B25-210 (EN107): Methods of testing windows. Part 5 : Mechanical tests, 1982 .

B2.2 Denmark

DS/EN42 Methods of testing windows. Air permeability test (Vinduesprovning Luftaehed). 1976.

B2.3 France

Methods of testing windows. (Methodes d'essais des fenetres) French Standard NF P 20 501 July 1974.

B2.4 Germany

DIN 180 55. Windows. Air permeability of joints, water tightness and mechanical strain, requirements and testing. (Fenster. Fugendurchlassigkeit, Schlargegendichtheit und mechanische Beanspruchung Anforderungen und Prufung). October 1981.

DIN (EN42) Methods of testing windows. Part 1: Air permeability tests, 1981.

DIN (EN77) Methods of testing windows. Part 2: Wind resistance tests, 1981.

DIN (EN78) Methods of testing windows. Part 3: Form of test report, 1981.

DIN (EN86) Methods of testing windows. Part 4: Water tightness test under static pressure. 1981.

DIN (EN107) Methods of testing windows. Part 1: Mechanical tests, 1982.

B2.5 Italy

UNI 7357 Calculation of heat requirements for building heating.

Ministrial Decree 05.07.75 Ventilation requirements for residential buildings.

Ministerial Decree 02.02.76 Ventilation requirements for schools.

B2.6 Netherlands

NEN 3660 Window frames - Air permeability, rigidity and strength. Methods of test. NNI 1988

B2.7 New Zealand

NZS 4211:1987 Specification for performance of windows. Standards Association of New Zealand.

B2.8 Norway

NS3206 Methods of testing windows. Airtightness. NSF 1974.

The Norwegian standard NS3206 is still used for measuring air tightness for windows and doors, but prEN 1026 soon will change into an official NS-EN-standard.

B2.9 Sweden

SS02 I5 51 Buildings - Determination of airtightness. 1987.

B2.10 Switzerland

EN ISO 12114 Sept 2000 Thermal Performance of Buildings - Air Permeability of Building components and Building Elements - Lab test method.

B2.11 United Kingdom

BS 5368 PT 1:1976 Methods of testing windows. Part 1. Air permeability test.

B2.12 United States of America

ASTM E783-93 Standard Test Method for Field Measurement of air leakage through installed exterior windows and doors.

ASTM E283-91(1999) Standard Test Method for determining the rate of air leakage through exterior windows curtain walls and doors under specified pressure differences across the specimen.

B2.13 International Standards Organisation (ISO)

ISO 6613-1980(E) Windows and door height windows - Air permeability. 1980.

ISO 6589-1981 Joints in building - Method of test for air permeability of joints. 1981.

European Standard EN42 Method of testing Windows; Air permeability

EN ISO 12114 - Thermal Performance of Buildings - Air Permeability of buildings - Air permeability of building components and building elements - Laboratory test method. September 2000

Draft European Standard. This document and test method has been organised by CEN members Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

This standard describes the general laboratory test method for determing the air permeability of building components or building elements, when subjected to positive or negative qair pressure differences.

Appendix C Minimum Ventilation Rates

C1 Minimum ventilation rates standards for dwellings

C1.1 Belgium

Belgian Standard NBN D 50-001 Ventilation systems for housings. October 1991

The basic principle is 1 l/s per m² of floor area with some specific values for kitchen, toilet and bathroom.

Living rooms	Supply	1 l/s per m²	Min 75 m³/h	May be limited to 150 m³/h
Bedrooms	Supply	1 l/s per m²	Min 25 m³/h	May be limited to 36 m³/h per person
Kitchens	Exhaust	1 l/s per m²	Min 50 m³/h	May be limited to 75 m³/h
Bathrooms	Exhaust	1 l/s per m²	Min 50 m³/h	May be limited to 75 m³/h
WC	Exhaust	25 m³/h		

In the Walloon Region (Decree of Walloon Government of 15 February 1996) the application of this standard is obligatory for new dwellings and, to a certain extent, for retrofitted dwellings.

C1.2 Canada

CSA Preliminary Standard F326.1-M1989 Residential Mechanical Ventilation Requirements.

0.3 ach or 5.0 l/s per person (for mechanical system to each inhabitable room)

Kitchen exhaust - intermittent	50 l/s
Kitchen exhaust - continuous	30 l/s
Bathroom exhaust - intermittent	25 l/s
Bathroom exhaust - continuous	15 l/s

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 62-1999 Ventilation for acceptable indoor air quality.

Outdoor air requirements for ventilation of residential facilities.

Whole buildings 0.35 ACH but no less than 7.5 l/s per person.

Kitchen: 50 l/s intermittent OR 12 l/s continuous OR operatable windows.
Bathroom: 25 l/s intermittent OR 10 l/s continuous OR operatable windows.

Intermittent and Continuous refer to installed mechanical capacity.

C1.3 Denmark

General

Ventilation systems shall be so operated and maintained that their performance is at least as specified in 2.2 and 2.3, while they are in use. Fresh air shall be supplied through direct openings to the outside air or by means of a mechanical ventilation system. In connection with the supply of fresh air and removal of stale air, it must be ensured that draughts do not occur in the heating season in the living zone of rooms, which are occupied for a prolonged period of time (Guidance: air velocities in the occupied zone should not exceed 0,15 m/s). Air transfer, including recirculation between rooms, may only take place from rooms with fresher air to rooms with staler air. In commercial and industrial buildings, recirculation will only be permitted provided there are no contaminants. Mechanical ventilation systems and ventilation openings shall be so constructed and installed that they do not supply the ventilated rooms with substances, including microorganisms, which make the indoor climate unsatisfactory with respect to health.

Residential buildings (multifamily buildings)

In each habitable room and in the dwelling as a whole there shall be a total air change of at least 0.5 times per hour. Dwellings shall be ventilated with a ventilation system, which may be either a mechanical extraction system combined with fresh air valves or a mechanical injection and extraction system. The system shall be so designed that the fresh air supply at least corresponds to the larger of the following two values:

the extraction volume flow prescribed later in the paragraph, or

an air change of 0,5 times per hour for the dwelling as a whole, distributed proportionally between extraction from kitchen and sanitary accommodation on the basis of the volume flows prescribed below

The requirements concerning ventilation in rooms with normal ceiling height will be deemed to be met if the supply of fresh air and the extraction of stale air are effected as prescribed below. The extraction is given and volume flow in l/s. (Guidance: A fresh air valve should filter the incoming air sufficiently and be so placed that the air supplied is as little contaminated as possible. The fresh air valve should be adjustable and capable of being operated by a person standing on the floor)

Habitable rooms
Supply of fresh air: Hinged window, hatch or door, together with one or more fresh air valves with a total clear opening of at least 30 cm^2 per 25 m^2 floor area. Alternatively, the area for the fresh air valve may be based on a calculation.

Kitchens
Supply of fresh air: Hinged window, hatch or door or fresh air valve.
Extraction: Volume flow 20 l/s. The air shall be extracted through an extractor hood.

Sanitary accommodation

Supply of air: Hinged window, hatch or fresh air valve, and/or opening to the access room.
Extraction: Volume flow 15 l/s

Separate lavatories
Supply of air: Hinged window, hatch or fresh air valve, and/or opening to the access room.
Extraction: Volume flow 10 l/s

Utility rooms or storerooms in dwellings
Supply of air: Hinged window, hatch or fresh air valve, and/or opening to the access room.

Extraction: Volume flow 10 l/s if the air is supplied through the access room; otherwise, no separate mechanical extraction.

Stairway enclosures or common lobbies with direct access to dwellings
Supply of air: Hinged window, fresh air valve or air-lock. The opening shall be at the bottom of the stairway enclosure or lobby.

For other rooms than those mentioned above, the dimensioning of the ventilation system is subject to approval by the local authority having regard to the size and the use of the room.

C1.4 Finland

D2 - Indoor climate and ventilation in buildings.Regulations and Guidelines. National Building code of Finland. The Ministry of the Environment.

Bedrooms minimum air flow rate of (4.0 dm^3/s.person) 4.0 l/s per person or (0.7 $dm^3/s/m^2$ of floor area) 0.7 l/s m^2 floor area

Living rooms:	0.5 l/s.m^2
Kitchen Exhaust air flow	20 l/s
Bathroom exhaust air flow:	15 l/s

These exhaust air flows can be reduced when the spaces are not in use provided that the air change rate in the whole building is greater than 0.4 ach and minimum air flow rates in bedrooms and living rooms are fulfilled.

C1.5 France

French regulations for ventilation of dwellings.
Flow values in wet rooms are dependant on dwelling size (number of dry rooms)

Kitchens	continuous:	20 - 45 m^3/h
	intermittent:	75-135 m^3/h
Bathrooms with (or without) WC :		15-30 m^3/h
WC only:		15-30 m^3/h

C1.6 Germany

DIN 18017 Ventilation in bathrooms and WC's witho ut outside windows by fans, amendment 1. April 1988.

Part 1. Ventilation of bathrooms and WC's without outside windows; single shaft systems with out ventilators. Feb. 1987

Part 3. Ventilation of bathrooms and WC's without outside windows; with ventila tors.

Part 4. Ventilation of bathrooms and wash-down closets without outside windows with ventilators; rules for the calculation of the airflow requirements.

DIN 1946 Pt. 6. Ventilation and air conditioning ventilation for residential buildings;

Requirements, performance and testing. (VDI ventilation rules)(draft November 1989)

Dwelling group	Dwelling space m^2	Number of Occupants	Ventilation rate (m^3/h)	
			Min	Total
1	*<50*	*upto 2*	*60*	*60*
2	*<80*	*upto 4*	*90*	*120*
3	*>80*	*upto 6*	*120*	*180*

The above table gives ventilation rates in rooms with windows.

Dwelling Rooms	Airflow when occupied for more than 12 hours per day (m^3/h)	Overall Airflow (m^3/h)
Kitchen (Normal)	*40*	*60*
Kitchen (purge)	*200*	*200*
Kitchen -et	*40*	*60*
Bathroom (with WC)	*40*	*60*
WC	*20*	*30*

The above table gives recommended ventilation rates for rooms in dwellings which not have windows.

VDI 2088 - Ventilating of dwellings - 1976

Living rooms :	1.0 to 1.5 ach
Bathrooms and toilets:	6.0 ach
Kitchens (exhaust ventilation):	120 m^3/h
Internal bathrooms (exhaust ventilation):	60 m^3/h
Internal toilet (exhaust ventilation):	30m^3/h

232.2 Outdoor air change rate for dwellings (l/h)

Old single glazed (mostly unsealed)	0.5….1.0
Sealed windows and outside doors	0.05…0.2
Necessary value (room contents no occupants and smoking permitted)	0.5…1.0 …1.5
Following DIN 4701 (minimum ventilation requirements)	0.5
Following DIN 18017/88 (for dwellings)	≤0.8
DIN 4701 (internal bath, WC)	4.0
Following VDI 2088 (1970)	0.4….0.8

232.3 Recommended outdoor air volume flow for groups of dwellings (DIN 1946/6)

Group		I	II	III	IV	V
Floorspace **No of persons**	m^2 P	72 2	95 3	104 4	116 6	82 2-3
Basic ventilation **Additional ventilation**	m^3/h m^3/h	50 10	70 20	90 30	100 80	70 20
Total volume flow	m^3/h	60	90	120	180	90

C1.7 Greece

Reference: Greek Legislative Framework Document

Space	Estimated persons per 100m² of floor area	Demanded Ventilation (m^3/h per person)	
		Minimum	Recommended
Detached houses			
Sitting rooms – Bedrooms	5	8.5	12-17
Bathrooms – Kitchens	-	34	50-85
Block of Flats			
Sitting rooms – Bedrooms	7	8.5	12-17
Bathrooms - Kitchens	-	34	50-85

C1.8 Italy

Standard UNI 10339 "Air-conditioning systems for thermal comfort in buildings"

Living rooms and bedrooms: 40 m^3/h per person
Kitchen and bathrooms: 4 vol/h exhaust ventilation

Presidential Decree 28/6/77 n. 1052 "Regulations for the application of Law 373/76, relative to energy consumption for thermal use in buildings"

For the design of the heating system, the number of air changes per hour is conventionally assumed equal to 0.5 h^{-1}, referred to the gross volume.

Ministerial Decree 05.07.75 Ventilation requirements for residential buildings.

Naturally ventilated Dwellings: 0.35 ach to 0.5 ach
Kitchens: 1.0 ach
Bathrooms: 2.0 ach
Ante-bathrooms: 1.0 ach
Normal living spaces (living rooms etc.,):15 m^3/h per person

C1.9 Netherlands

Ref: Mentioned in Building Decree

Occupational rooms:	0.9 $dm^3/s.m^2$ of floor area
Kitchen :	21 dm^3/s
Bathroom with WC:	14 dm^3/s
WC only:	7 dm^3/s

Tested : According to NEN 1087 Ventilation of Buildings, Determination methods for new estate. May 1997.

C1.10 New Zealand

Ventilation specifications are usually by the ASHRAE 62:1990 standard.

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 62-1999 Ventilation for acceptable indoor air quality.

Outdoor air requirements for ventilation of residential facilities.

Whole buildings 0.35 ACH but no less than 7.5 l/s per person.

Kitchen :	50 l/s intermittent	or	12 l/s continuous or operatable windows.
Bathroom :	25 l/s intermittent	or	10 l/s continuous or operatable windows.

Intermittent and Continuous refer to installed mechanical capacity.

New Zealand have adopted the ASHRAE 62 -1999 standard.

Ventilation requirements for domestic buildings are mentioned in chapter 4 of NZS 1900, no ventilation rates are specified directly but gives a minimum area of openable window as 5 % of the floor area in each room.

C1.11 Norway

Requirements for dwellings are formulated in the regulation guidance book (thus not being a formal part of the regulations).

Total air change should not be less than 0.5 air exchanges per hour.

Kitchen, washing rooms, bathrooms, toilets etc. should have extract air of at least 10 litres per second and possibility of extra ventilation for shorter periods.

Mechanical ventilation and heat exchanging is not compulsory in dwellings in Norway.

Norwegian Building Code Chapter 47, Ventilation and installation. 1987.

The Norwegian Building Code gives requirements for minimum ventilation rates expressed in either minimum sectional area of ventilation ducts from different room when using natural ventilation

Room in Dwelling	Exhaust air Cross section of duct (cm^2)
Living rooms (Including bedrooms)	Supply Air: Openable windows or inlet bigger than 100 cm^2 in external wall
Kitchen and Bathrooms	Extract Air : Mechanical Extract of $60m^3/h$ 17 l/s or Natural Extract: At least $150cm^2$ duct above roof.
WC Only	Extract Air: Mechanical 40 m^3/h (11 l/s) or Natural $100cm^2$/duct above roof

C1.12 Sweden

BFS 1998:38 Chapter 6:232 Air Exchange.

National Board of Housing, Building and Planning.

Requirements: Rooms shall have continual air change when they are in use. The rate of flow of outside air shall be not less than 0,35 l/s per m^2 of floor area. When rooms are not in use the air flow rate may be reduced but not to such an extent that health risks arise or so that there is a risk of damage to the building or its services. Such reduction may be effected continuously, in several stages or in the form of intermittent operation.

Outside air to dwellings shall be primarily supplied in rooms or parts of rooms for everyday social contact and for sleep and rest.

Recommendations: Outside air

Dwellings: The rate of flow of outside air to rooms or parts of rooms for sleep and rest should be not less than 4 l/s per bed place.

Other premises: The rate of flow of outside air to rooms or parts of rooms for places of assembly, shops, offices, schools etc where persons are present other than occasionally, should be not less than 7 l/s for each person who may be expected to be there at the same time.

Recommendations: Mechanical ventilation

Mechanical ventilation should be designed so that it has the capacity to provide rates of flow of extract air not less than:

Space	Least rate of flow of extract air
Dwellings	
Kitchen	10 l/s, high speed extraction rate with not less than 75% extraction capacity for airborne contaminants.
Bathroom or shower room with openable window	10 l/s
Bathroom or shower room without openable window	10 l/s with high speed extraction rate up to 30 l/s, or 15 l/s
Lavatory	10 l/s
Recreational premises	10 l/s
Places of assembly, shop premises and similar	
Rooms specially designated for smoking	20 l/s per person
Sanitary accommodation for the public	20 l/s per lavatory pan
Service spaces	
Cleaner's room	3 l/s per m² floor area, but not less than 15 l/s.
Laundry room, drying room	10 l/s
Refuse storage room	5 l/s per m² floor area
Refuse storage room for dry refuse only	0,35 l/s per m² floor area
Refuse chute	50 l/s
Lift well	8 l/s per m² well area
Garage, (number of parking movements/space < 1 pr 8h)	0,9 l/s per m² floor area
Garage, (number of parking movements/space >1 pr 8h)	1,8 l/s per m² floor area

Source: AFS 1993:5 §3

National Board of Occupational Safety and Health, Sweden.

Recommendation: In premises for office work, education or similar, where indoor air pollution is primarily caused by emissions from persons, the concentration of carbon dioxide can be used as indicator of the indoor air quality. In such premises the aim should be a carbon dioxide concentration of less than 1000 ppm.

C1.13 Switzerland

The new version of SIA 180, in force since 1st January 2000, clearly states in chapter 3 dedicated to ventilation and airing, that the ventilation rate should in principle be adjusted to limit the indoor air contaminants below an acceptable concentration.

It indicates that 15 m³/h is necessary to ventilate a non smoking person, which corresponds to 0.15% CO_2 concentration.

A special clause addresses air moisture, which is the prevalent contaminant in dwellings. Table 3 indicates source strengths of various water vapour sources:

Source	**Emission *G* in g/h**
Person, light work	30 - 60
Person, household work	60 - 90
Person, heavy work	100 - 200
Cooking	400 - 800
Dishwasher	200 - 400
Shower	1500 - 3000
Bath	600 - 1200
Open water surface (per m²)	30 - 50
Plants	7 - 15

Table 4 gives reference values for average water vapour production, G, per net internal floor area, A_{PN}::

Moisture production	Production G/A_{PN} g/(h·m^2)	Type of occupancy
Small	2	Dwellings, low occupancy, few plants, offices, storage
Average	4	Dwellings, high occupancy, many plants, schools, meeting rooms, assembly halls.
High	6	Restaurants, kitchens, sporting halls, hospitals
Very high	> 10	Washrooms, wet industrial production.

In the future, the existing standards SIA 382/1 "Ventilation and AC plants", and SIA 384/2 Heating load calculation should be revised to comply to these requirements.

The indoor air moisture should be adjusted mainly to avoid mould growth on external walls. Since a minimum insulation level is required for the whole external envelope, including thermal bridges, the maximum daily average indoor air moisture is give as follows in Table 5:

External average temperature θ_e, °C	+20	+15	+10	+5	0	-5	-10	-15	-20
Air vapour content $v_{i,max}$ in g/m^3	13.5	11.9	10.5	9.3	8.2	7.3	6.5	5.8	5.2
Internal maximum partial water vapour pressure $p_{i,max}$ in Pa [1)]	1823	1605	1418	1255	1114	988	880	786	703
Internal maximum relative humidity at 20°C: $\varphi_{i,max}$, in percent[2)]	78	69	61	54	48	42	38	34	30
Dew point $\theta_{i,D}$, en °C	16.0	14.1	12.2	10.3	8.6	6.8	5.1	3.5	1.9

[1)] approximation: $p_{i,max} = 0.3744 \cdot \theta_e^2 + 27.607 \cdot \theta_e + 1112.2$ Pa

2) when the internal temperature differs from 20°C, $\ddot{o}_{i,\max} = \frac{100 \cdot p_{i,\max}}{p_{sat}(\grave{e}_i)}$

In the near future, the existing standards SIA 382/1 “Ventilation and AC plants”, and SIA 384/2 Heating load calculation should be revised to comply to these requirements.

SIA 384/2 Heating load calculations.1980.

This recommendation deals with heat loss calculations and gives some procedures how to determine the ventilation losses. The air flows mentioned cannot directly be interpreted as minimum ventilation requirements, but are commonly cited due to lack of other Swiss standards.

SIA 382/1. Ventilation and AC Plants, technical requirements. 1992.

The airflows to be assumed are :

The natural in/exfiltration flows through windows and other component leakages, according to the procedure given in recommendation. The lower limit (minimum ventilation rates) is either:

0.3 ACH or
13.0 m^3/h (non-smokers)
20.0 m^3/h (smokers)

For rooms with mechanical extract 1 hour peak and 24 hour mean air flow are given from SIA 382/1 1992

C1.14 United Kingdom

British Standard BS5720 - 1979 - Code of Practice for Mechanical ventilation and air conditioning in buildings.

British Standard BS5925: 1991 - Code of Practice for Ventilation principles and designing for natural ventilation.

CIBSE - Guide A - Design Data.CH 1 - Environmental Criteria for design. The Chartered Institute of Building Services Engineers. Delta House, Balham High Road, London.

Both of these standards and the CIBSE guide give the following recommended and minimum ventilation rates for residences.

	Ventilation Rate (l/s.person)	
	Recommended	**Minimum**
Average Dwelling	12.0	8.0
Luxury Dwelling	18.0	12.0

United Kingdom Building Regulations Part F 1991. Revised 1995. Ventilation. F1 Means of ventilation. Pub. The Department of the Environment

The requirement of this building code is that there shall be adequate means of ventilation provided for people in the building. Applying to dwellings, spaces in any building containing two or more dwellings which are used solely or principally with those dwellings, bathrooms and rooms containing sanitary conveniences.

A) Ventilation of habitable rooms.

- Rapid ventilation: one or more ventilation openings with a total area or at least 1/20th of the floor area of the room, and with some part of the ventilation opening at least 1.75m above the floor level, eg. an opening window, and
- Background Ventilation: a ventilation opening(s) e.g. trickle ventilators air bricks with a "hit and miss" ventilator or where appropriate suitably designed opening windows. The ventilation openings should be, reasonably secure, adjustable and located (typically 1.75 m above the ground level) so as to prevent rain ingress,
- Extract ventilation either by mechanical extract ventilation operated manually and/or automatically by sensor or controller, or
- Passive stack ventilation operated manually and or automatically by sensor or controller

- An appropriate open flued heating appliance.

For kitchens utility rooms, bathroom and sanitary accommodation not containing openable windows

A – mechanical extract ventilation rated as in table 1 and the fan has a 15 minute overrun and is either controlled automatically or manually.
B - Passive stack ventilation or
C - An open flue heating appliance.

All should have an air inlet provided by, for example a 10mm gap under a door.

Two habitable rooms may be treated as a single room for ventilation purposes if there is an area of permanent opening between them equal to at least 1/20th of the combined floor areas.

A habitable room may be ventilated through an adjoining space if:

1. the adjoining space is a conservatory or similar space and- there is an opening (which may be closable) between the room and the space with an area not less than 1/20th of the combined floor areas of the room and space and- there are one or more ventilation openings with a total of at least 1/20th of the combined floor area of the room and space and with some part of the ventilation opening at least 1.75m above the floor level and- for background ventilation there are ventilation openings to the space and openings between room and space, each having a total area not less than 4000 square millimetres. The openings should be located so as to avoid undue draughts.

Table 1 Ventilation in rooms containing openable windows (ie located on an external wall)

Room	Rapid ventilation (eg opening windows)	Background ventilation	Extract ventilation fan rates or passive stack (PSV)
Habitable room	1/20th of floor area	8000 mm^2	-
Kitchen	Opening window (no minimum size)	4000 mm^2	30 litres/second adjacent to a hob or 60 litres /second elsewhere or PSV
Utiliy room	Opening window (no minimum size)	4000mm^2	30 litres/second or PSV
Bathroom (with or without WC)	Opening window (no minimum size)	4000 mm^2	15 litres/second or PSV
Sanitary accommodation (separate from bathroom)	1/20th of floor area or mechanical extract at 6 litres/second	4000 mm^2	-

As an alternative to the provisions listed in table 1 the overall provision for background ventilation for a dwelling should be equivalent to an average or 6000mm^2 per room for the rooms listed in table 1, with minimum provision of 4000mm^2 in each room.

B) Ventilation of Kitchens

The requirement shall be satisfied if there is both:

- mechanical extract ventilation for rapid ventilation, rated as capable of extracting at a rate not less than 60 l/s (or incorporated within a cooker hood and capable of extracting at a rate of 30 l/s) which may be operated intermittently, for instance during cooking, and

- background ventilation either:
a) by controllable and secure ventilation opening(s) having a total area not less than 4000 square millimetres, located so as to avoid draughts, e.g., a trickle ventilator,

b) by the mechanical ventilation being in addition capable of operating continuously at nominally 1 ach.

C) Ventilation of common spaces containing two or more dwellings.

The requirement shall be satisfied if there is provision for ventilation by ventilation opening(s) with a total area of at least 1/50th of the floor area of the common space or communicating common spaces.

Where the space is wholly internal and is used for access only the requirement can also be satisfied by the provision of mechanical extract ventilation capable of 1 ach.

D) Ventilation of bathrooms.

The requirement shall be satisfied by the provision of mechanical extract ventilation at a rate not less than 10 l/s which may be operated intermittently.

E) Ventilation of Sanitary accommodation. either - rapid ventilation by one or more ventilation openings with a total area of at least 1/20th of the floor area of the room, and with some part of the ventilation opening at least 1.74 metres above the floor level;

or

mechanical extract ventilation capable of extracting air at a rate not less than 3 ach, which may be operated intermittently with 15 minutes overrun.

C1.15 United States of America

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 62-1999 Ventilation for acceptable indoor air quality.

ASHRAE 62 has been revised and published as 62-1999. The new version of 62 sets values in non smoking areas only, and makes it clear that the rates outlined do not account for any smoking. Another clarification is that is does not consider CO_2 as a contaminant, but an indicator of bioeffluents and only as an increment over outdoors, not as an absolute. Because the rates in 62 only partially depend on bioeffluents, it does not make sense to talk about a target level of CO_2.

Outdoor air requirements for ventilation of residential facilities.

Whole buildings 0.35 ACH but no less than 7.5 l/s per person.

Kitchen:	50 l/s intermittent or 12 l/s continuous or operatable windows.
Bathroom:	25 l/s intermittent or 10 l/s continuous or operatable windows.

Intermittent and continuous refer to installed mechanical capacity.

C2 Minimum ventilation requirements for office and school buildings

C2.1 Belgium

In the Walloon Region (Decree of Walloon Government of 15 February 1996) new and retrofitted office and school buildings have to comply with the following requirements:

Single office	2.9 m^3/h per m^2 of floor area
Landscaped office	2.5 m^3/h per m^2 of floor area
Conference room	8.6 m^3/h per m^2 of floor area
Auditorium	23 m^3/h per m^2 of floor area
Cafeteria or restaurant	11.5 m^3/h per m^2 of floor area
Classroom	8.6 m^3/h per m^2 of floor area
Kindergarten	10.1 m^3/h per m^2 of floor area
WC	30 m^3/h per bowl of toilet (if continuous) 60 m^3/h per bowl of toilet (if not continuous)

There is also a general requirement (Regulation for Labour Protection - valid in whole Belgium) for the ventilation of office- and working places. A ventilation rate of 30 m^3/h per person is required.

C2.2 Canada

NRCC No. 22432. Measures for energy conservation in New Buildings. Associate Committee on the National Building Code. National Research Council of Canada. No. 22432 Ottawa. 1983.

“Measures for energy conservation in new buildings” sets out the requirements for mechanical ventilation - where the outdoor air supply will be in line with those stated in ASHRAE 62 -1999:
Office 10 l/s person
Reception spaces 8 l/s person
Telecommunications centres 10 l/s person
Conferences rooms 10 l/s person

The are no provisions in the Canadian or provincial building codes on ventilation for schools. Most schools are owned and operated by local boards. Many of these boards follow the ASHRAE 62-1999 standard, but this is not consistent or universal.

Classrooms 8 l/s per person
Laboratories 10 l/s person
Auditoriums 8 l/s person
Libraries 8 l/s person

C2.3 Denmark

Buildings other than dwellings

Habitable rooms in day-care and residential institutions shall be ventilated with a mechanical ventilation system comprising both injection and extraction of at least 3 l/s per child and at least 5 l/s per adult, and 0.4 l/s per m^2 floor area. (Guidance: This applies, for example, to child -care institutions, such as créches, kindergartens, after-school care facilities, recreation centres, day centre and other institutions for similar purposes. The prescribed ventilation rate for the building is based on the use of building materials with low emission of contaminants.)

Classrooms in schools and similar shall be ventilated with a mechanical ventilation system comprising both injection and extraction of at least 5 l/s per person, and 0.4 l/s per m^2 floor area. If special building measures are used, e.g. larger room volumes per person and provision of several possibilities for airing rooms, including possibilities for cross ventilation, the requirement of mechanical ventilation may be waived provided a healthy indoor climate can be maintained. (Guidance: The prescribed ventilation rate for the building is based on the use of building materials with low emission of contaminants.)

For other rooms than those mentioned above, the ventilation rate is subject to approval by the local authority having regard to the size and use of the room. (Guidance: Attention is drawn to the fact that, in some cases, the need for ventilation can be covered by natural ventilation, while in others, mechanical ventilation should be stipulated in order to achieve a healthy indoor climate. Examples of room in which natural ventilation will suffice are offices for one person or a few people, hotel rooms and certain types of commercial premises. Examples of rooms in which mechanical ventilation may be needed are offices for a large number of people, assembly rooms, canteens, restaurants and rooms at hospitals. The size of the ventilation can be determined on the basis of section 2.2 of DS447: “Code of practice for ventilation installations”.)

C2.4 Finland

Indoor Climate and Ventilation in Buildings. Regulations and Guidelines. Guidelines 1985. National Building Code of Finland. (In Finnish).

This standard specifies 4 - 10 l/s per person. The values are based on removal of pollutants, where smoking is allowed it recommends a high ventilation rate of 10 l/s per person, independent of room size. Where smoking is not allowed, the ventilation rate per person decreases as the room volume increases.

D2 - National Building Code of Finland:Indoor climate and ventilation in buildings. Regs and guidelines - 1987.

Classroom:	Outdoor air supply rate of 6 l/s persons.
Lecture room:	Outdoor air supply rate of 8 l/s persons.

C2.5 France

Practical guidance to Meeting the requirements of the Thermal and Ventilation Regulations for Residential Buildings - Cahiers du CSTB No. 2286 - October 1988. *(Exemples de solutions pour facliter l'application du reglement relatif aux equipments et aux caracteristiques* *thermiques dans le batiments autres que l'habitation. VENTILATION).*

This document indicates minimum and maximum ventilation rates for different kinds of non residential premises, particularly for schools and buildings designed for teaching and for office buildings.

Requirements: The minimum ventilation rates are functions of the types of premises and are indicated in the charts included. For current teaching rooms the required value of fresh air is 15 m^3/h per person. For current offices it is 25 m^3/h per person and for meeting rooms 18 m^3/h person (non-smoking) or 30 m^3/h per person (smoking).

The maximum ventilation rate is 1.2 (for cold climatic zones) or 1.3 (for temperate climatic zones) times the minimum ventilation rate.

C2.6 Germany

DIN 1946 Part 2. Room ventilation technique; Technical health principles (VDI ventilation rules). (1983)

DIN 1946 gives a general air flow rate for indoor air quality of 20 to 30 m^3/h person to maintain acceptable air quality.

The standard gives minimum ventilation rates for schools as 30 m^3/h per person.

232.1 Outdoor air flow in m^3/h every m^2 effective area following VDI 2803

Administrative buildings	Internal corridors	meeting rooms	canteens	kitchens	toilets	warehouses
8 to 15	4 to 6	18 to 26	20 to 24	60 to 90	14 to 18	8 to 12

232.6 Air rate for commercial kitchens in $m^3/(h.m^2)$ (VDI 2052)

Type of cooking	Boil	Roast/grill/ bake	Washing area	neigbouring rooms	all kitchen areas
Snack bar/hotel kitchen	-	120	-	-	80
Cafeterias	105	120	120	45	60
Canteens, students refactory	105	120	120	45	90
Main kitchen/hospi tal	105	120	120	45	90
Homes	105	120	120	45	60

C2.7 Greece

REF: Greek Legislative Framework Document

Minimum and recommended ventilation requirements per person for different spaces

Space	Estimated persons per 100m^2 of floor area	Demanded Ventilation (m^3/h per person)	
		Minimum	**Recommended**
Educational Buildings			
Teaching rooms	55	17	17-26
Laboratories	32	17	17-26
Amphitheatres	110	17	26-34
Libraries	22	12	17-21
Offices	10	12	17-26
Gymnasiums	75	34	42-51
Restaurants	110	17	26-34
Auxiliary spaces	3	8.5	12-17
Offices			
Office space	10	25.5	25.5-42.5
Meeting rooms	65	42.5	51-68
Designing rooms	22	12	17-25.5
Waiting rooms	32	12	25.5-34
Computer rooms	22	8.5	12-17
Industrial Spaces		42.5-68	

C2.8 Italy

Educational buildings

Ministerial Decree 18.12.75 "Technical standards for educational buildings…"

Classrooms: 2.5 ach for nursery school and primary schools
3.5 ach for secondary schools
5 ach for high schools
Toilets, gymnasium, refectories: 2.5 ach

Other rooms: 1.5 ach

Standard UNI 10339 "Air-conditioning systems for thermal comfort in buildings"

Nursery school 15 m^3/h per person

Classrooms

primary schools: 18 m^3/h per person

secondary schools: 21 m^3/h per person
high schools: 24 m^3/h per person
universities: 24 m^3/h per person
transit areas: exhausts
toilets: exhaust ventilation 8 ach
libraries, teachers rooms: 21 m^3/h per person
music classrooms, laboratories: 24 m^3/h per person

Office buildings

Standard UNI 10339 "Air-conditioning systems for thermal comfort in buildings"

Single offices and open space offices: 40 m^3/h per person
Meeting rooms and computers: 35 m^3/h per person
toilets: exhaust ventilation 8 ach

Ministerial Decree 04.02.76 Ventilation requirements for schools.

1.5 to 5 ach for School buildings.

C2.9 Netherlands

Ref: Mentioned in Building Decree

8.8 dm^3/s at a person density of lower than 1.3 m^2 per person.
3.5 dm^3/s at a person density of 1.3 to 3.3 m^2 per person.
1.4 dm^3/s at a person density of 3.3 m^2 per person.

Cox C W J (1990), Standards and guidelines for indoor air quality. Normen en richtlijnen voor het binnenmilieu. Netherlands, Klimaatbeheersing, Vol 19, No 6, June 1990, pp 172-177, 9 in Dutch *(#NO 4573)*

Office:

35 m^3/h outside air per person if there is no smoking allowed.

55 to 60 m^3/h per person if smoking is allowed.
ASHRAE 62-1999 General office Space: 35 m^3/h per person
Smoking 100 m^3/h per person.

C2.10 New Zealand

New Zealand ASHRAE 62-1990 – NZ4303 – Ventilation for Acceptable Air Quality and AS1668 Pt 2 1991 – Mechanical Ventilation for Acceptable Indoor Air Quality.

Schools:	8 l/s.person
Offices:	minimum 10 l/s.person, whether smoking is permitted or not. (Note design occupancy)

In Smoking lounges: 30 l/s.person.

C2.11 Norway

Requirements for office and school buildings are formulated in the regulation guidance book (thus not being formal part of the regulations). Air supply is calculated depending on ventilation load from persons, building materials, inventory and processes. Normal ventilation requirements from person load are 7 litres per second and person (area per person depending on building use and can be taken from tables). In rooms where smokers are allowed, ventilation requirements from person load are 20 litres per second and person. In schools and kindergartens 8 litres pr. sec. and person is often used. Ventilation requirements from materials ranges from:

0.7 litres per second and m²(gross floor area) for documented low emitting building materials
1.0 litres per second and m² for normal low emitting materials
2.0 litres per second and m² for undocumented materials

There are specific requirements for air extraction from sanitary rooms and other special rooms (lift, basements).

NS3031 Energy and power demands for heating of buildings. Calculation rules.

For other than domestic buildings the ventilation requirements are given as air flow rate per unit floor area.

NS3031 gives an assumed air change rate of 0.5 ach for a building when calculating ventilation heat loss.

Work rooms 5 m^3/h. m^2 or 16.5 m^3/h per person
Offices 7 l/s plus 0.7 l/s.m^2 floor area

Schools

Norwegian National Building Code: Ventilation and Installation.

Minimum ventilation rates for classrooms: 5.5 l/s per person plus 0.7 l/s. m^2.

C2.12 Sweden

Source: *BFS 1998:38 Chapter 6:232 Air Exchange.*

National Board of Housing, Building and Planning.

Requirements: Rooms shall have continual air change when they are in use. The rate of flow of outside air shall be not less than 0,35 l/s per m² of floor area. When rooms are not in use the air flow rate may be reduced but not to such an extent that health risks arise or so that there is a risk of damage to the building or its services. Such reduction may be effected continuously, in several stages or in the form of intermittent operation.

Recommendations: Outside air

Other premises: The rate of flow of outside air to rooms or parts of rooms for places of assembly, shops, offices, schools, etc where persons are present other than occasionally, should be not less than 7 l/s for each person who may be expected to be there at the same time.

Recommendations: Mechanical ventilation

Mechanical ventilation should be designed so that it has the capacity to provide rates of flow of extract air not less than:

Space	Least rate of flow of extract air
Places of assembly, shop premises and similar	
Rooms specially designated for smoking	20 l/s per person
Sanitary accommodation for the public	20 l/s per lavatory pan
Service spaces	
Cleaner's room	3 l/s per m² floor area, but not less than 15 l/s.
Laundry room, drying room	10 l/s
Refuse storage room	5 l/s per m² floor area
Refuse storage room for dry refuse only	0,35 l/s per m² floor area
Refuse chute	50 l/s
Lift well	8 l/s per m² well area
Garage, (number of parking movements/space < 1 pr 8h)	0,9 l/s per m² floor area
Garage, (number of parking movements/space >1 pr 8h)	1,8 l/s per m² floor area

Source: AFS 1993:5 §3

National Board of Occupational Safety and Health, Sweden.

Recommendation: In premises for office work, education or similar, where indoor air pollution is primarily caused by emissions from persons, the concentration of carbon dioxide can be used an indicator of the indoor air quality. In such premises the aim should be a carbon dioxide concentration of less than 1000 ppm.

B2.13 Switzerland

SIA 382/1. Ventilation and AC Plants, technical requirements. 1992.

This standards recommends outside air rates per p erson [m^3/h. person]

Zone type	Air Quality Level	Air Flow Rate (m^3/h)
Non smoking	0.15% CO_2	V=12-15 m^3/h.person
	0.10% CO_2	V=25-30 m^3/h.person
Smoking		V=30-70 m^3/h.person

Note there is no special distinction between schools and offices.

For non-occupied rooms: 0.3 ach or pre-ventilation is recommended.

C2.14 United Kingdom

Workplaces

British Standard BS5720 - 1979 - Code of Practice for Mechanical ventilation and air conditioning in buildings.

British Standard BS5925: 1991 - Code of Practice for Ventilation principles and designing for natural ventilation.

Work Place	Smoking	Recommended (l/s.person)	Minimum (l/s.person)
Factories	None	8	5
Offices (open plan)	Some	8	5
Offices (private)	Heavy	12	8
Laboratories	Some	12	8
Conference rooms	Some	18	12
Board Rooms, executive offices and conference rooms	Very Heavy	25	18

Recommended levels: 8 - 25 l/s person
Minimum Levels: 5 - 18 l/s per person

Guidance Note EH 22 from the Health and Safety Executive. Ventilation of the workplace. (Revise may 1988)

Respiration: A person’s need for fresh air depends on his metabolism, or rate of activity. On average 0.5 l/s per person of fresh air will be required to provide sufficient oxygen for respiration but this can range from 0.15 to 1.0 l/s for heavy work. Approximately 2 l/s per person will be required to dilute exhaled carbon dioxide to the occupational exposure limit 0.5%.

Odour: Requirements depend largely on space available per person, personal cleanliness and personal sensitivity. Odour is unlikely to be a problem at ventilation rates of 9.0 l/s per person.

Tobacco Smoke: The Chartered Institution of Building Services Engineers (CIBSE) recommends air supply rates ranging from 16 l/s person where there is some smoking to 32 l/s person for very heavy smoking.

The fresh air supply rate to a workplace should not fall below 5 l/s person. Higher rates are recommended especially is some or all of the occupants smoke.

According to this publication the rates specified in the above table (taken from BS5925; BS5720 and the CIBSE Guide A1) may be used as a general guide to requirements for non-air conditioned spaces.

Smoking in Public Places: Guidance for owners and managers of places visited by the public. Code of Practice. Pub. Dept. of the Environment.p7

A ventilation rate of 8 l/s per person (30m^3/h) of outdoor air is usually adequate for non smoking rooms. But where smoking is allowed this rate must be three to four times greater to avoid acute irritating effects even in health of people.

Air contaminated with tobacco smoke should not be recirculated, and separate smoking rooms set up in air conditioned buildings for example should be separately vented to the outside.

Workplace health, safety and welfare. Approved code of practice. Health and safety commission. 1992.

Regulation 6. Ventilation.
This regulation covers general workplace ventilation, but not exhaust ventilation for controlling employees' exposure to asbestos, lead, ionising radiations of other substances hazardous to health. See COSHH requirements.

It states that fresh air supply rate shall not be allowed to fall below 5 to 8 l/s per person. Factors to be considered include floor area per person, the processes and equipment involved and whether the work is strenuous. For mo re guidance see CIBSE publications.

Schools:

The Chartered Institution of Building Services Engineers (CIBSE) Guide A4 - 14 Air Infiltration.

Empirical values for air infiltration and ventilation allowance for buildings on normal sites in winter:

Classrooms	2 ach
Lecture rooms	1 ach

The Chartered Institution of Building Services Engineers (CIBSE) Guide B2 - 7 Ventilation and Air Conditioning (Requirements) From table: B2.3 Ventilation requirements.

Schools recommended fresh air supply rate: working areas should be capable of being ventilated at least up to 8.3 l/s per person.

The UK Building Regulations 1991 – revised 1995 Approved Document F Means of Ventilation

Non domestic buildings

Table 2 Ventilation of rooms containing openable windows (i.e. located on an external wall)

Room	Rapid ventilation (eg opening windows)	Background ventilation	Extract ventilation fan rates
Occupiable room	1/20th of floor area	For floor areas: Up to $10m^2$ - $4000mm^2$ greater than $10m^2$ at the rate of $4000/m^2$ of floor area	-
Kitchen (domestic type)	Opening window (no minimum size)	4000 mm^2	30 litres/second adjacent to a hob or 60 litres /second elsewhere
Bathroom (including shower rooms)	Opening window (no minimum size)	4000 mm^2 per bath/shower	15 litres/second per bath/shower
Sanitary accommodation (and/or washing facilities)	1/20th of floor area or mechanical extract at 6 litres/second per WC or 3 air changes per hour	4000 mm^2 per WC	-

The terms used in the above tables are defined:

Rapid ventilation: one or more ventilation openings with some part of the ventilation opening at high level (typically 1.75m above the floor level, e.g., an opening window

Background Ventilation: a ventilation opening(s) e.g., trickle ventilators air bricks with a “hit and miss” ventilator or where appropriate suitably designed opening windows. The ventilation openings should be reasonably secure, adjustable and located (typically 1.75 m above the ground level) so as to prevent rain ingress

Extract ventilation by mechanical extract ventilation operated manually and or automatically by sensor or controller.

C2.15 United States of America

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 62-1999 Ventilation for acceptable indoor air quality.

ASHRAE 62 has been revised and published as 62-1999. The new version of 62 sets values in non smoking areas only, and makes it clear that except for smoking lounges, bars, casinos, the rates outlined do not account for any smoking. Another clarification is that is does not consider CO2 as a contaminant, but an indicator of bioeffluents and only as an increment over outdoors, not as an absolute. Because the rates in 62 only partially depend on bioeffluents, it does not make sense to talk about a target level of CO_2.

Office 10 l/s person
Reception spaces 8 l/s person
Telecommunications centres 10 l/s person
Conferences rooms 10 l/s person

Classrooms 8 l/s per person.
Laboratories 10 l/s person
Auditoriums 8 l/s person
Libraries 8 l/s person

Appendix D Thermal Insulation Requirements

D1 Belgium

Thermal requirement in Belgium

References :
Decree of Flemish Government of 18 September 1991 concerning thermal requirements of buildings (application from 1 September 1992).
Decree of Walloon Government of 15 February 1996 concerning thermal requirements of buildings (application from 1 December 1996).
Decree of Brussels Government of 3 June 1999 concerning thermal requirements of buildings (application from 1 January 2000).

Application domain :
- Residential buildings: dwellings, apartments, homes, hotels,... (all Regions)
- School buildings (only Walloon and Brussels Region)
- Office buildings (only Walloon and Brussels region)

For new construction and retrofitting

Requirements
Global thermal insulation level (K-level)

The global thermal insulation level of the building is calculated following the Belgian standard NBN B 62-301 "Thermal insulation of buildings. Global thermal insulation level", must be lower than the K levels given in the following table.

The global thermal insulation level is calculated as a function of the compactness of the building, i.e. the ratio V/A_t, wherein V is the volume of the building (V in m³) and A_t is the total heat loss surface of the building envelope (A_t in m²), and the weighted mean U-value (U_s in W/m².K) of the walls of the total heat loss surface.

	New construction		Retrofitting with function change	
	Residential buildings	School and office buildings	Residential buildings (3)	School and office buildings (4)
Brussels	K55	K65	$55 + 10.A_t/s$ (1)	$60 + 10.A_t/s$ (1)
Flanders	K55	-	-	-
Wallonia	K55 or BE_{max} (2)	K65	K65	K70

A_t (m²) = total heat loss surface of the building, according to NBN B 62-301.
s (m²) = sum of the surfaces of the retrofitted walls.
(2) Building must comply with the K level requirement or with the BE 450 requirement (determination of the energy needs of the building)
(3) Only if a non residential building becomes a residential building after the retrofitting.
(4) Only if a building becomes a school or an office building after the retrofitting

Maximum U-values of walls

U-values of walls are calculated following the Belgian standard NBN B 62-002 “Calculation of heat transmission coefficients of walls”.

Type of wall (new or retrofitted buildings – residential, school and office buildings)	U_{max} (W/m²K)		
	Brussels	Flanders (1)	Wallonia
External walls Walls next to unprotected spaces, but frost free Walls in contact with the ground	0.6 0.9 0.9	0.6 0.9 0.9	0.6 0.9 0.9
Roofs	0.4	0.6 (2)	0.4
Floors above spaces which are not frost free Floors above spaces which are frost free Floors directly touching ground	0.6 0.9 1.2	0.6 0.9 1.2	0.6 0.9 1.2
Windows and doors	2.5	3.5	3.5
Common walls between two buildings	1.0	1.0	1.0
(1) only for residential buildings (2) in case of retrofitting, the requirement is 0,4 W/m²K			

Remarks

A revision of the thermal requirements for dwellings is planned by the Flemish Government. The following principles will be applied :

The requirements for the global thermal insulation level and for the maximum U-values of certain walls will be replaced or extended with a new requirement, whereby an energy performance coefficient, calculated for the building and its technical equipment, must not exceed a fixed maximum energy performance coefficient. This requirement will not only evaluate the energy needs of the building (heat losses, ventilation losses, solar gains, internal gains, …), but also the energy performances of the technical equipments (efficiencies of heating, ventilation, cooling, lighting, electrical devices, …)

Requirements for good ventilation of the building (according to NBN D 50-001) will also be introduced, in order to guarantee an acceptable indoor climate and to avoid condensation problems.

D2 Denmark

Section taken from Danish Building Regulations.

Energy Consumption for Heating of Buildings

The chief requirement of the Building Regulations in Denmark [1] as to thermal insulation is that buildings shall be insulated in order to avoid unnecessary energy consumption and to ensure adequate health conditions. The requirements to the thermal insulation of large buildings like for instance multi-storey buildings, industrial and commercial buildings and institutions are included in Chapter 8 Thermal insulati on of the Building Regulations.

The transmission coefficients of the building components, the so called U-values, are to be calculated according to DS 418: Calculation of the heat loss of buildings [2]. The Building Regulations require that building components, including windows and outer doors facing the open, should only to a limited extent have thermal bridges in order to avoid condensation. Also the energy influence of thermal bridges shall to be included when calculating the U-value of the individual components. In otherwise well-insulated buildings, thermal bridges can be of great importance to the resulting transmission loss. It is therefore very important to estimate and calculate the effect of the thermal bridges. Another requirement of the Building Regulations is that buildings and building components, including windows and doors, shall be manufactured so that the heat loss does not increase substantially as a consequence of humidity, wind or unintentional air permeability.

The chapter of the Building Regulations Thermal insulation offers 3 possibilities to buildings heated to 18 °C of fulfilling the requirement to avoid unnecessary energy consumption:

Compliance with the U-value requirements to the individual building components and simultaneously a limitation of the area for windows and outer doors of max. 22% of the heated gross floor area.

Compliance with the heat loss frame for the building with altered U-values and area of windows and outer doors.

Compliance with the energy frame as to the building's energy need for heating and ventilation.
The best energy economy and the highest flexibility regarding the choice of U-values and area of windows and outer doors are to be obtained by using the energy frame. If the heat loss frame or the energy frame is used to prove that the requirements to thermal insulation of a building have been complied with, the minimum requirements to the thermal insulation of the individual building components must be fulfilled. The minimum requirements for thermal insulation of the individual building components are valid for all building components around rooms heated to a minimum of 5 °C. These requirements are also valid for rooms heated to between 5 and 18 °C.

U-values

One way of fulfilling the requirements of the Building Regulations is that all building components have U-values below or equal to the magnitudes in table 1, and that the total area of windows and outer doors towards the open is max. 22 per cent of the heated gross floor area of the building.

Table 1. U-value-requirements for building components around rooms heated to min. 18°C according to BR.

Building Component	U (W/m² K)
Outer walls below 100 kg/m².	0.20
Outer walls above 100 kg/m² and basement walls against earth.	0.30
Partition walls towards unheated rooms, or heated to a temperature more than 8 °C lower than the temperature of the actual room.	0.40
Storey partitions against unheated rooms or heated to a temperature more than 8 °C lower than the temperature of the actual room.	0.30
Concrete slabs, basement floors against the ground and storey partitions over a ventilated space or the open air.	0.20
Ceiling and roof constructions including sloping roof walls.	0.15
Flat roofs and sloping walls directly against roof.	0.20
Windows and outer doors, including skylight, glass walls, gates and hatches facing the open or unheated rooms or rooms heated to a temperature more than 8 °C lower than the temperature of the actual room.	1.80

Outer walls weighing less than 100 kg/m² are characterised as light outer walls, whereas walls weighing more than 100 kg/m² are characterised as heavy. When calculating the weight of outer walls only the part of the construction situated within a possibly ventilated cavity is included. In the heated floorage is included the gross floorage of all rooms which are heated to at least 18 °C. The window and outer door area is calculated by the capacity measures, i.e. the opening in the outer walls into which the window or the door is built. The floorage and the area of window and outer door in shops and the like on the ground floor are not included in the calculation of the window and outer door percentage. When calculating the window and outer door area, only the area of windows and doors against the open and not the area of windows and doors against unheated or partly heated rooms is included.

Heat Loss Frame

One or several building components are allowed to have a higher U -value than indicated in table 1, or the total area of windows and outer doors facing the open may be more than 22 per cent of the heated floorage if the total heat loss of the building during transmission is within the so called heat loss frame. By heat loss frame is meant the design heat loss during transmission, calculated for a reference building whose building components possess U-values as indicated in table 1 and where the area of windows and outer doors is 22 per cent of the heated floorage.

When calculating the heat loss frame, DS 418 [2] section 5.2 “Preliminary calculation of the total transmission loss”, is applied. In the following some of the calculation rules of DS 418 are given. When calculating the same room temperature, normally 20 °C is applied everywhere, for instance in bathrooms and behind radiators too. The design outdoor temperature is normally -12°C. For oblique and horizontal roof a 15 per cent increase of the heat loss is anticipated owing to radiation towards the sky in clear weather. The design ground temperature is 8 °C, and is applied when calculating, for instance, basement floors and basement outer walls below buildings. For other basement outer walls the design outdoor temperature is applied when calculating the heat loss. For slabs of approximately the same U-value for the marginal and middle area a temperature of

+1 °C for floor areas between 100 and 200 m²,
+3 °C for floor areas between 200 and 500 m²,
+5 °C for floor areas between 500 and 2000 m².

For floor areas below 100 m² the design outdoor temperature of -12°C is applied. For floor areas exceeding 2000 m², the design ground temperature of 8°C is applied. The design temperature of the ventilation space for ordinary, heavily ventilated ventilation spaces can be set at -5°C. The temperature in other ventilation spaces can be calculated by drawing up the heat balance. In unheated rooms the temperature can be fixed at random, but when in doubt it should be controlled afterwards drawing up a heat balance for the room.

The transmission areas are calculated as if partition walls do not exist. The outer wall area is calculated as the product of inner, horizontal measures and the gross floor height from finished floor to finished floor. On the top floor of the building the height is calculated from finished floor to the intersection of the inner wall surface and the upper surface of the thermal insulating layer in ceiling or roof. The area of floors and ceilings is calculated according to the inner measures and is determined as if there are no partition walls. When it is a question of unheated attics, the area of the ceiling is applied.

When calculating the heat losses the distribution of the components in the actual building and in the reference building should be the same. For instance, there should be the same distribution of light and heavy outer walls, of flat roofs, oblique walls and ceiling constructions with attics and of windows facing the open and against unheated rooms. If for example the heat loss frame is used for enlarging a window, the area of the component in which the window is placed should be reduced correspondingly.

The heat loss frame can, among other things, be used for obtaining larger windows in a building than approximately 22 per cent window and outer door area in proportion to the unheated floorage.

Minimum Thermal Insulation

All building components adjacent to rooms heated to 5 °C or more must have U -values below or equal to the figures indicated in table 2. The minimum requirements for thermal insulation are thus valid also for building components, where the heat loss frame or the energy frame has been applied to reduce the insulation in relation to the U-value requirements stipulated in the Building Regulations for buildings heated to at least 18°C. There are no specific requirements in the Building Regulations as to the thermal insulation of rooms that are just kept frost-free in winter, but they have to adhere to the general requirement as to avoiding unnecessary energy consumption. As to rooms which are kept frost-free in winter one is to understand rooms, which are heated to no more than 5 °C, and where the heat is turned off at higher room temperature.

Table 2. U-value requirements for building components around rooms heated to at least 5 °C according to BR.

Building Component	U (W/m^2 K)
Outer walls below 100 kg/m^2.	0.30
Outer walls above 100 kg/m^2 and basement walls against earth.	0.40
Partition walls towards unheated rooms, or heated to a temperature more than 8 °C lower than the temperature of the actual room.	0.60
Storey partitions against unheated rooms or heated to a temperature more than 8 °C lower than the temperature of the actual room.	0.40
Concrete slabs, basement floors against the ground and storey partitions over a ventilated space or the open air.	0.30
Industrial floors meant for heavy load.	0.60
Ceiling and roof constructions including sloping roof walls.	0.25
Flat roofs and sloping walls directly against roof	0.25
Windows and outer doors, including skylight, glass walls, gates and hatches facing the open or unheated rooms or rooms heated to a temperature more than 8 °C lower than the temperature of the actual room.	2.90

Energy Frame

The third possibility of fulfilling the stipulations of the Building Regulations is to determine the thermal insulation of the building based on the energy frame and a calculation of the total thermal requirements of the building for room heating and ventilation. The energy frame indicates the maximum permissible total net thermal requirements per year for heating and ventilation per m² heated floorage.

The proof that the energy frame has been observed is based on a simplified calculation applying average monthly values of, for instance, weather data. When calculating the thermal requirements, the sun incident, body heat, and the thermal accumulating properties of the building might be taken into account.

Energy Frame for Residential Buildings

The Building Regulations concerning dwellings stipulate that the total net heat requirement for room heating and ventilation per m² of heated floor space should not exceed

$$q_r = 160 + \frac{110}{e} \qquad (1)$$

and that the heat requirement should not exceed

$$q_r = 250 \qquad (2)$$

where q_r is the energy frame in MJ/m² annually,
e is the number of storeys.

The number of storeys is a decimal number calculated as

$$e = \frac{A_e}{A_{byg}} \qquad (3)$$

where A_e is the heated floor space in m²,
A_{byg} is the heated built-up area in m².
The size of the energy frame for dwellings with an air change of 0.5 h^{-1} is indicated in table 3.

Table 3. Energy frame for residential buildings with an ach. of 0.5 h^{-1}.

Storeys,e	1	1½	2	3	5
Energy frame, q_r MJ/m² pr. year	250	233	215	197	182

In some dwellings the requirement of the Building Regulations are mechanical exhaust from kitchen, bathroom and toilet, might cause the air change of the building units to exceed 0.5 h-1. In dwellings where the heat surplus of the discharged air is not used for heating the incoming outdoor air, the energy frame is increased corresponding to the heat requirement for heating the volume flow rate which, according to the BR requirement to exhaust, exceeds an outdoor air change of 0,5 h-1. The increase of the energy frame is to be calculated as follows:

$$\Delta q_r = 400(q_{vm} - 0{,}3) \qquad (4)$$

where Δq_r is the increase of the energy frame for mechanical exhaust in MJ/m² annually,
q_{vm} is the exhausted volume flow rate of the dwellings in l/s pr. m² heated gross area.

When calculating the increase, only the gross area covered by the or the exhaust exceeds 0.3 l/s per m² heated gross area, is included. If the mechanical ventilation of mechanical exhaust and only the dwelling units where the outdoor air change exceeds 0.5 h-1 the dwelling has both air supply and air exhaust, the increase of the energy frame is not given. According to the requirements of the Building Regulations, such installations should be furnished with effective heat recovery, e.g. plate heat exchanger or heat recovery heating surfaces. If only heat recovery from the exhaust air for the heating of hot domestic water, e.g. with a heat pump, exists, and no mechanical air supply is at hand, the increase is given in dwellings covered by the requirement of the Building Regulations as to mechanical exhaust.

Energy Frame for other buildings

The Building Regulations concerning other buildings stipulate that the total net heat requirement for room heating and ventilation per m² of heated floor space should not exceed

$$q_r = 110 + \frac{5000}{A_{byg}} + \frac{110}{e} \qquad (5)$$

and that the heat requirement should not exceed

$$q_r = 250 \qquad (6)$$

where q_r is the energy frame in MJ/m² annually,
A_{byg} is the heated built-up area in m²,
e is the number of storeys (calculation as for dwellings).

In other buildings than dwellings with a mechanical balance, as far as calculation of heated area and built-up area, where ventilation and heat recovery are concerned, an increase of the energy frame is given if the outdoor air change by mechanical ventilation exceeds 2.0 h^{-1} during the heating season. In ventilation systems with heat recovery with a temperature efficiency of 0.6, the increase just covers the extra heat requirement for mechanical ventilation. The increase can be calculated as follows:

$$\Delta q_r = 1{,}0 T_d (q_{vm} - 1{,}2) \quad (7)$$

where Δq_r is the increase of the energy frame for mechanical ventilation with heat recovery in MJ/m² annually,
T_d is the operation time in the heating season in hours/week,
q_{vm} is the outdoor air flow in the ventilation system in l/s per m² heated gross area.

When calculating the increase, only the gross area of the building sections covered by the ventilation system, and where the outdoor air change exceeds 2.0 h^{-1} or 1.2 l/s per m² heated gross area is included. The calculation might be made simultaneously for several ventilation systems.

In ventilation systems where no heat recovery can be established for security or health reasons, or where the heat content of the discharged air cannot be utilized, the energy frame is increased as follows:

$$\Delta q_r = 2{,}4 T_d (q_{vm} - 0{,}6) \quad (8)$$

where Δq_r is the increase of the energy frame for mechanical ventilation without heat recovery in MJ/m² annually,
T_d is the operating time during the heating season in hours/week,
q_{vm} is the outdoor air flow in the ventilation system in l/s per m² heated gross area.

When calculating the increase, only the gross area of the building sections covered by the ventilation system and where the outdoor air change from the ventilation system exceeds 1.0 h^{-1} or 0.6 l/s per m² heated gross area is included.

D3 France

Ventilation in the RT 2000 new French thermal regulation

A new Regulation has been approved at the end of November 2000 (réglementation thermique 2000, so called RT2000) . Its aim is to reduce the energy consumption of new buildings. It will be applicable to all new buildings in June 2001.

The regulation stipulates that the conventional primary energy consumption of a given building (C coefficient), must be less than or equal to a reference value Cref. A calculation method (called Th C) has been defined according to CEN standards in order to calculate the C Value. The Cref value is calculated by the same method and by replacing the actual characteristics of the building by reference ones, defined in the regulation.

The ventilation impact on energy needs in taken into account more precisely and widely than in the previous regulation. The basis of it is to calculate the different airflows by using an implicit calculation method on the basis of the prEN 13465 (TC 156WG2). The calculation method takes into account mechanical (extract only and balanced system), passive duct systems and window airing.

The different building and system characteristics are as follows :

Building airtightness
The reference value is the air flow at 4 Pa, divided by the area of the envel ope (and so expressed in $m^3/(h.m^2)$). The reference values vary from 0.8 to 2.5 depending on the type of construction. If no actual suitable value, a default value can be applied by adding 0,5 to the reference one.

Ducts airtitghtness
The reference value is the class A. If actual value is available, a default value equal 2.5 times the reference one is applied

Ventilation system

The characteristic of the ventilation system (air inlet and outlet for example) is based on pressure/flow measured values, simplified to condensed parameters (for example the air flow at 20 Pa for the air inlets). Works are in progress to validate the values of ventilation components characteristics through certification processes. This point is taken account by taking a safety coefficient if the product is not certified. Other components or effects taken into account are for example heat recovery systems, air preheating, and thermal loss of ducts.

Regulation of the ventilation system is part of the calculation method (with reference values) either for residential and non -residential buildings.

The reference value of fan power is 0.25 Wh/m^3. It can be increased if it can be assumed that this increase is due to air filter or cooling coils.

These references makes it possible to build the ventilation reference part of the reference building, based on the calculation of the Cref value. For residential buildings, the reference system is a mechanical exhaust only system and for non residential building it is a mechanical balanced system. The reference air flow rate to be provided to (or extracted from) the rooms are the ones stipulated by the sanitary regulation.

For the ventilation side of this new regulation, as for the other sides, the basis of this new approach was :

To be as close as possible to the physics of the phenomena,
To base the calculation on characteristics available or possible to verify,
To push designers to use the most efficient available technologies and industry to improve them in the future,
By means of the global C coefficient, to leave the designer to choose the most efficient compromise between the different ways to improve the energy efficiency of a building.

D4 Greece

THERMAL INSULATION REGULATION

The Presidential Decree 1-6/4-7/1979, titled "Thermal Insulation Regulation", makes obligatory the application of insulation in every new structure and it deals with the thermal insulation requirements and the measures that should be taken for ensuring satisfactory thermal insulation in building structures. It is comprised by 10 articles.

The Regulation divides the country into three zones on the criterion of the external temperature during winter time as well as the duration of the heating period. It defines two criteria for the calculation of the thermal insulation demanded on each occasion :

the first one is the climatic zone to which the building under construction belongs and
the second one is the ratio of the external surface of the building [F] to its volume [V].

For the calculation of the minimum required insulation and the heating installation sizing, calculation of the heat transmittance coefficient of the envelope is demanded.

A detailed presentation of the Decree, article by article follows:

In the *First Article* the Thermal Insulation Regulation defines the objects and declares the importance of thermal insulation. According to this, well-constructed thermal insulation ensures:

healthy and pleasant stay of residents,
rational consumption of energy for heating and air-conditioning,
reduction in the construction and installation expenses of the heating installation, and
reduction of the environmental pollution due to exhaust gases.

Article 2 deals with some related aspects to thermal insulation such as the thermal losses through the envelope and design details of buildings.

Article 3 gives the definitions of :

thermal insulation
conductive heat transfer
convective heat transfer
radiative heat transfer
unit of heat
thermal conductivity
equivalent thermal conductivity in air cavities
thermal conduction
surface thermal transmittance (external or internal)
thermal transmittance
thermal capacity
specific thermal capacity
relative air humidity
dew point
condensation water
mean thermal transmittance of the envelope

Article 4 sets the basic principles of thermal insulation. According to article 4, thermal insulation depends on:

the total thermal resistance of the construction elements [walls, roof, etc.],
the air permeability of the construction elements [joints, cracks, etc.], and
the thermal capacity of the envelope elements.

Article 5 defines the methodology for calculation of the thermal resistance of non-homogeneous materials, (1/Λ or R_t) and of the thermal transmittance (k or U). The article presents the mathematical formulas and tables to perform the necessary calculations.

Article 6 presents the division of Greece into three climatic zones according to the external air temperature during winter time and the duration of the heating period. Meteorological Tables providing the mean minimum ambient temperature of different Greek places which can be used in the calculations are given.

Article 7 is referred to the insulation requirements of buildings. It thus, gives :

definition of the indoor space temperature and recommended values,
determination of the thermal transmittance limits of the different construction elements (walls, floors, etc.),
determination of the limits of the thermal transmittance of the envelope,
determination of the heat losses through infiltration, and
criteria for the optimum applied thermal insulation.

The estimation of the maximum permitted heat transmittance coefficient is a function of two parameters: the climatic zone where the building belongs and the ratio F/V, where F is the external surface through which heat is transferred and V the volume of the building. For each climatic zone, the maximum permitted thermal transmittance of the envelope is given in the following Table 1.

Table 1: Maximum permitted thermal transmittance of the envelope.

	K_m (in Kcal/m^2h °C)			K_m (in W/ m^2K)		
F/V (m^{-1})	ZONE A	ZONE B	ZONE C	ZONE A	ZONE B	ZONE C
≤ 0.2	1.335	1.015	0.807	1.553	1.180	0.938
0.3	1.245	0.955	0.760	1.448	1.111	0.884
0.4	1.160	0.897	0.715	1.349	1.043	0.831
0.5	1.092	0.845	0.675	1.270	0.983	0.785
0.6	1.030	0.795	0.635	1.198	0.924	0.738
0.7	0.985	0.750	0.600	1.145	0.872	0.698
0.8	0.947	0.717	0.575	1.101	0.834	0.669
0.9	0.927	0.695	0.550	1.078	0.808	0.640
≥ 1.0	0.920	0.680	0.530	1.070	0.791	0.616

Article 8 determines some measures for ensuring the good condition and performance of thermal insulation. It specifically refers to construction ways of walls, doors, windows, roofs and floors so as thermal insulation purposes to be attained.

Article 9 gives some examples of calculation of the thermal insulation requirements for different floor, roof and walls constructions, according to the principles set in the 7th article.

Article 10 also gives some examples for the calculation of the thermal transmittance of the envelope for different types of buildings.

D5 Netherlands

Mentioned in Building Decree

The required energy performance criterion (epc) level right now is 1.0 for dwellings.
The required energy performance criterion (epc) level right now is 1.9 for offices.
The required energy performance criterion (epc) level right now is 1.5 for schools.

The energy performance criterion (EPC) has to be determined according to NEN 5128 for dwellings and NEN 2916 for other buildings

NEN 5128 – Energy Performance Standard

Overview of the level of the requirements in the different countries (Bron: TIPVENT)

Levels	Aspects	B	CH	F	UK	NL	P	S
Law	Energy		g	g	r		g/r	g
	Comfort		g	r	r		g	g
	Cost		-		-		-	-
Building regulations	Energy		r/s	r/s	r	r	r	r
	Comfort		r	r	r	r	g	r
	Cost		-		-	-	-	-
Standards	Energy		r		s	t	-	t
	Comfort	r/s	r		r	t	-	t
	Cost		-		-	-	-	-
Guidelines	Energy	s	t/s		r/s	-	g	t/s
	Comfort	s	t/s		r/s	s	g	t/s
	Cost		t/s		s		-	s
Code of practice	Energy		t/s		r/s		-	t/s
	Comfort		t/s		r/s		-	t/s
	Cost		s		s		-	s
g: general requirement; r: requirements; t: test methods; s: solutions								

D6 New Zealand

New Zealand has insulation standards but they are quite complex in terms of the variations and different compliance paths. NZS 4218 applied to small buildings, NZS 4305 to hot water systems, and NZS4243 to large buildings. Over the top of this is the New Zealand Building Code clause H1 which sets a building performance index (defined in terms of a passive solar calculation tool used called ALF). The Code also allows compliance via the above standards and this is the most popular approach to compliance.

D7 Norway

Insulation regulations

Fairly detailed requirements are formulated in the new Norwegian regulations and can be read in "§ 8-21 Energy and power" chapter in the following web-site (in English): http://www.be.no/beweb/english/englishtop.html. This is outlined below:

Use of energy

§ 8-2 Use of energy

Construction works with installations shall be executed in such manner as to promote a low demand for energy and power which does not exceed the overall limitations established in this Chapter. The demand for energy and power shall be such as to ensure a justifiable indoor environment.

The construction works and its installations shall be executed in such manner as to minimize the need for cooling and so as to avoid an unnecessary cooling demand.

§ 8-21 Energy and power

Requirements for the need of energy and power for a building may be established in one of the three alternative ways:

by the use of overall energy limitations adapted to various categories of buildings
by satisfying requirements for the heat insulating performance of each and every element of the building, or
by the use of overall limitations to heat loss based on a redistribution between the different building elements.

The alternatives are given in the following subsections No. 1, 2 and 3.

1. Overall energy limitations

The energy demand of buildings for heating and ventilation shall not exceed the overall limited values resulting from calculations by a recognized method. The overall energy limit is to be given per year and m2 of net floor area (NTA) for the heated parts of the building. In the case of more than one temperature zone in the construction works, the overall energy limit shall be calculated for each zone and distributed over the net area of each zone.

Limitations on the energy demand for heating are to be calculated from a given reference temperature, the heat loss of transmission given in No. 2, and heat loss of infiltration. Overall energy limit for the use of ventilation are obtained through the requirements defined for indoor climate. In establishing the overall energy limitation the energy gain obtained in terms of internal heat and solar radiation shall be considered.

The real need for energy in a building is to be calculated on the bases of the different building elements coefficient of heat transfer (U), window areas and their locations, solar factor, air quantities, amount of internal heat, heat capacity, operation periods, etc. applying to the works in question. Where such values are not known, calculations are to be made according to the rules in Norwegian Standard.

2. Thermal insulation

The thermal insulation ability of each part of the works shall be calculated with the coefficient of heat transfer as given in the table below. The tabulated values apply as long as the total area of windows, glass roofs and walls, and exterior doors does not exceed 20% of the net area of the building within 10 m from the external wall, for the heated parts of the construction works. If the construction works is permanently divided into temperature zones, then the relevant parts of the works in each zone shall be thermally insulated relative to the room temperature of the zone.

The effect of thermal bridges caused as a result of poor or non-existent local insulation shall be taken into account in the calculation of the coefficient of heat transfer, U, of building elements and shall be considered in planning the indoor climate.

Table: Highest average U-values for exterior building elements

Building element	Indoor temperature and heat transfer coefficient (W/m^2K)			
	T>20°C	15°C<T<20°C	10°C<T<15°C	0°C<T<10°C
External walls 1)	0.22	0.28	0.40	0.60
Roofs, floors on ground and toward the open	0.15	0.20	0.30	0.60
Floors toward unheated space	0.30	0.40	0.50	0.60
Windows 2), doors	1.60	2.00	2.50	3.00
Glass walls and glass roofs	2.00	2.00	3.00	3.00

1) External walls in an unheated basement may have U(0,8)
2) Windows in commercial premises may have U=2,0 for T(20°C)

3. Overall heat loss limitations

The overall heat loss limitations may be established by calculating the total transmission loss of the building using the coefficients of heat transfer in No. 2.

The heat transfer properties and the window area of each building element may be changed relative to the values in the table of No. 2, provided that the transmission loss does not exceed the overall heat loss limitations for the construction works.

§ 8-22 Air tightness

Buildings shall be so impervious that the effect of thermal insulation is not reduced by unintentional flow of air through them.

Moisture shall not be allowed to penetrate and reduce the effect of thermal insulating or worsen the design life of the building.

Buildings shall be so impervious that the indoor climate is not negatively affected and in such manner that unpleasant draught does not occur.

§ 8-23 Materials favourable to energy and the environment

Where it is documented that a building is made from materials requiring low energy consumption in their production and abolishment, and the materials otherwise have good environmental qualities, it may be accepted that the building consumes more energy in its period of operation than what follows from § 8 -21 No. 1.

It must be shown as being probable that the total energy consumption for production of materials, operation of the building and abolishment of the materials does not exceed the general level expressed in this Chapter.

Indoor climate

§ 8-3 Indoor climate

Buildings with installations shall be planned, designed, constructed, maintained and operated in such manner that the indoor climate is perceived satisfactory. No health hazard and unsatisfactory hygienic conditions shall occur, neither for the users of the building nor for its neighbours, when the rooms are used as intended.

§ 8-31 Documentation of indoor climate

Compliance with the requirements for indoor climate as presented in this Chapter may be documented in two ways, either:

by the construction works being designed in accordance with pre-accepted solutions, or
by calculations and/or analyses documenting safe and healthy conditi ons.

§ 8-32 Air quality

1. Quality of outdoor air

The building and the ventilation plant of the building shall be located and designed with regard to the quality of the outdoor air. In the case of the outdoor air not being sufficiently clean with respect to health hazards or risk of fouling the ventilation installations, the air shall be cleaned before being fed into the building.

2. Quality of indoor air

The air quality in a building shall be satisfactory. The indoor air shall not contain contaminati on in concentrations known to be harmful with respect to health hazards and irritation.

§ 8-33 Contamination

1. General requirements

Building structures on the ground shall be so designed that contamination from the ground cannot penetrate into the construction works and cause health injuries.

Special care shall be taken to prevent moisture and radon from penetrating into the construction works. In the case of construction on ground polluted by waste or industrial activity, the source of the pollution shall be fully eliminated or the construction works be designed so that the contamination does not penetrate into it.

2. Contamination from materials

Building and surface coating materials shall not emit contamination to the indoor air, in concentrations known to be harmful with respect to health hazards and irritation. Building and surface coating materials shall be produced, handled, stored and applied in such manner that emissions of contamination and smell to the air in rooms become as low as possible. The materials shall withstand normal use.

3. Contamination from processes and activities

Contaminating activities and processes shall as far as possible be enclosed, equipped with spot ventilators and/or be performed in rooms with suitable, separate ventilation.

4. Radon

Building design shall ensure that human occupants of a construction works will not be exposed to such radon concentrations in the indoor air as may increase the risk of health injuries.

§ 8-34 Ventilation

1. General requirements

Buildings shall have ventilation able to cope with the contamination and moisture in the rooms. Consideration shall be given to type of room, interior fittings and equipment, materials and processes, and moisture from people and animals.

Ventilation plants shall be made in such manner that a good air quality is achieved and so that contamination from people, building materials, processes and activities, and undesirable moisture, smell and harmful substances is removed from the construction works.

Recirculated air shall not be used if this leads to spread of pollutants.

The air flow shall be from rooms with higher requirements for air quality to those with lower requirements.

In rooms for human occupation, at least one window or one door shall be able to be opened towards open air. In a room where no windows are wanted because of its use, a corresponding possibility of forced ventilation shall exist.

2. Ventilation in residential buildings

Dwellings shall have ventilation which ensures a proper indoor climate for the occupants. The ventilation shall be adapted to the function of each room.

Kitchens and sanitary rooms shall have air vents.

3. Ventilation in commercial and public buildings

Commercial and public buildings shall have ventilation which ensures a proper indoor climate in each room where people are staying. The necessary air supply is to be determined from the use of materials, the number of occupants and the activities.

§ 8-35 Light

All rooms shall have satisfactory lighting without unpleasant heat load. Rooms for permanent occupation shall be provided with daylight, unless the dwelling or working situation should indicate otherwise.

§ 8-36 Indoor thermal climate

The indoor thermal climate in rooms for permanent occupation shall provide satisfactory health conditions and perception of comfort for their intended use.

§ 8-37 Moisture

1. General requirements

Construction works shall be so designed as to prevent rain or snow, surface water, ground water, supply water and air moisture from penetrating and causing moisture damage, mould, fungi or other hygienic problems.

2. Moisture protection

The ground surface around construction works shall have a sufficient slope away from the construction works, unless other measures have been taken for surface water drainage. Around any building element below ground level, and below floor structures on the ground, necessary measures must be taken to divert seeping water and prevent moisture from penetrating into the structures.

Façade covers, windows, doors, and installations passing through walls shall be so designed as to allow harmful moisture to dry out.

Roofs shall have sufficient slope for the runoff of rain and melted snow. If condensation can occur under the roofing, or the roofing is not sufficiently water tight, then the underlying structure must be protected by means of a water -tight layer.

3. Sanitary rooms

Bathrooms and washing rooms shall have an outlet. Rooms with outlets shall have floors with sufficient slope on those parts of the floor which must be assumed to become regularly exposed to water.

Floors, walls and roofs which will be exposed to water spills, leaking water or condensation shall be made with moisture resistant surfacing materials. Structures behind them, and rooms which may be negatively affected by moisture, shall be protected by impervious surfacing material or a suitable impervious layer. Materials are to be so chosen that the risk of fungi and mould formation is minimal.

4. Moisture in building

Materials and structures shall be so dry at the time of placing/ sealing that problems of growth of micro-organisms, decay of organic materials and increased gas emission do not arise.

D8 Sweden

BFS 1993:57, with amendments BFS 1995:17, BFS 1995:65
Building Regulations BBR 94
Section 9 Energy Economy and Heat Retention

BFS 1995: 17
9 Energy economy and heat retention

9:211 Thermal insulation

9:2111 maximum permissible average thermal transmittance

The average thermal transmittance Um, determined in accordance with the mandatory provisions in subsection 9:2112, shall not for the elements of the structure which enclose dwellings and non-residential premises exceed the values which can be calculated from formula (a) or (b) below:

$U_{m.krav}$ for dwellings = 0.18+0.95 A_f/A_{om} (a)

$U_{m.krav}$ for non-residential premises = 0.24+0.95 A_f/A_{om} (b)

The maximum proportion of the area A_f which may be taken into consideration is 0.18 A_{upp}.

NOTATION

$U_{m.krav}$ maximum permissible average thermal transmittance

A_f aggregate area (m^2) of windows, doors and simular calculated over their external frame dimensions.

A_{om} aggregate area (m^2) of the surfaces, in contact with the heated indoor air, of enclosing elements of the structure. The term enclosing elements of the structure refers to elements which separate the heated parts of dwellings or non residential premises from the external air, the ground or partly heated or unheated spaces.

A_{upp} heated usable floor area (m^2) as defined in Swedish Standard SS 02 10 52 (1).

9:2112 Calculation of average thermal transmittance

The average thermal transmittance Um shall be calculated for the aggregate area, in contact with the heated air, of the elements of the structure which separate a space fronm the external air, the ground and partly heated or unheated spaces. Um is to be calculated from formula (a):

$$Um=\sum_{i=1}^{n}\frac{UiAi}{Aom}. \qquad (a)$$

For the area, in contact with heated indoor air, of each enclosing element of structure the thermal transmittance Ui is to be calculated from formula (b)

$$Ui=\alpha_1\alpha_2\left(U_p-\alpha_3\right). \qquad (b)$$

D9 United Kingdom

Building Regulations June 2000 – Proposals for Amending the Energy Efficiency Provisions

Domestic Buildings

Table 1 Elemental Method U –values (W/m^{2}K) for construction elements.

	Type of heating system			
Exposed element	Gas or oil central heating with boiler SEDBUK[1] not less than the relevant entry in table 2		Other gas or oil central heating, or any electric heating system or solid fuel heating [2] or undecided.	
	With effect from T[1]	With effect from T+18months	With effect from T[1]	With effect from T+18months
(a)	(b)	(c)	(d)	(e)
Pitched roof[3 4] with insulation between rafters	0.25	0.2	0.22	0.18
Pitched roof[4] with insulation between joists	0.2	0.16	0.18	0.16
Flat roof	0.25	0.25	0.22	0.22
Wall	0.35	0.3	0.31	0.27
Floor	0.3	0.25	0.27	0.22
Windows. Doors and rooflights (overall average)	2.2	2.0	2.0	1.8

Notes to Table 1

1.SEDBUK is the Seasonal Efficiency of a Domestic Boiler in the UK, defined in the Governments Standard Assessment Procedure for the Energy Rating of Dwellings 1998 Edition. For boilers for which the SEDBUK is not available the appropriate value from table 4b of the same publication may be used.

2.A solid fuel boiler should have an efficiency not less that that recommended for its type in the HETAS certification scheme.

3.Any part of a roof having a pitch of 70 degrees or more can be considered a wall.

4.For the sloping parts of a room-in the roof constructed as a material alteration a U value of 0.3 W/m^{2}K would be reasonable.

Central heating system fuel	**SEDBUK %**	
	With effect from T[1]	**With effect from T +18 months**
Mains natural gas	75	78
LPG	82	85
Oil	85	88

[1] *T is the date when this Approved Document comes into effect.*

Non Domestic Building
Table 2.1 Standard U – Values (W/m^{2}K) of construction elements

When these values come into effect	T1	T+18months
Roofs with horizontal insulation between/over joists	0.20	0.16
Roofs with integral insulation	0.35	0.25
Walls	0.35	0.30
Exposed floors and ground floors	0.3	0.25
Windows, roof lights and doors (area weighted average for the whole building)	2.2	2.0
Vehicle access and similar large doors	0.7	0.7
T1 is the date this Approved Document comes into effect		

D10 United States of America

ASHRAE 90.2 1993 Energy Efficient Design of New Low Rise Residential Buildings

ASHRAE 90.1 1999 Energy Standard for Buildings Except Low Rise Residential Buildings

ANSI/ASHRAE/IES 100.2-1991 Energy Conservation in Existing Buildings – High Rise Residential

ANSI/ASHRAE/IES 100.5-1991 Energy Conservation in Existing Buildings – Institutional

ANSI/ASHRAE/IES 100.6-1991 Energy Conservation in Existing Buildings – Public Assembly

ANSI/ASHRAE/IES 100.3-1991 Energy Conservation in Existing Buildings – Commercial

ANSI/ASHRAE/IES 100.4-1991 Energy Conservation in Existing Buildings – Facilities and Industrial

ASHRAE/ANSI 55 "Thermal Environmental Conditions for Human Occupancy"

ASHRAE 105-1984(RA-90) "Standard Methods of Measuring and Expressing Building Energy Performance"

ASHRAE 90.1 1999 Energy Standard for Buildings Except Low Rise Residential Buildings
In normative appendix B Building Envelope Criteria are given for each climate in the US.

APPENDIX E Indoor Air Quality Requirements

E1 Belgium

Requirements for workplaces (Regulation for Labour Protection - valid in whole Belgium)

Pollutant	MAC ppm	Peak limit (15 min)ppm
CO_2	5000	30000
HCHO	1	2
NO_2	3	5
CO	50	400

E2 Denmark

Building Regulations, Danish Housing and Building Agency, 1995.

Contamination from building materials

General

Building materials must not emit gases, vapours, particles or ionising radiation that can cause an unhealthy indoor climate.

Formaldehyde

Chipboard, wood-fibre and plywood panels and similar containing synthetic resin binder that emits formaldehyde may only be used provided they are subject to a control scheme approved by the Ministry of Housing. (Guidance: The general aim of this provision is to ensure that the concentration of formaldehyde in air, corresponding to room air with realistic use of the building materials in question and prescribed ventilation, temperature and relative humidity, does not exceed 0,15 mg/m^3.) An approved inspection and testing scheme has been established under the Danish Control Organization for Wood-based Panels. Methods and test conditions are prescribed in the organizations approval and inspection rules.

Thermal insulation materials, which are made by foaming urea and formaldehyde may only be used provided they are subject to a control scheme approved by the Ministry of Housing. The materials may only be used for insulating external wall structures. (Guidance: The general aim of this provision is to ensure that the concentration of formaldehyde in air, corresponding to room air with realistic use of the building materials in question and prescribed ventilation, temperature and relative humidity, does not exceed 0,15 mg/m^3.)

Asbestos

Materials containing asbestos must not be used indoors. (Guidance: Use of asbestos is generally prohibited in pursuance of Ministry of Labour Order No. 660 of 24. September 1986 with amendment of 11. December 1992 on asbestos.)

Mineral Wool

Materials containing mineral wool shall be coated or otherwise covered, encapsulated or sealed on the surface in contact with the indoor climate. Mineral wool bats in suspended ceilings shall be coated on all sides and edges. (Guidance: This provision applies to products made of mineral wool, i.e. products with a woolly consistency made of melted stone, clinker or glass. The provision applies for example to acoustic ceilings, injection ducts and sound dampers in injection systems. The provision does not apply to thermal insulation materials that are not in direct contact with the indoor climate).

Fly ash and clinker from coal firing

Fly ash and clinker from coal firing, which is used as a base for buildings shall be covered with a layer of gravel with a thickness of at least 0.20 m. (Guidance: The residuals from coal firing, e.g. from power stations can contain radioactive substances from the coal which emit gamma radiation. The contribution from this to radiation can be reduced by covering the base course with a gravel course. See the National Building and Housing Agency's Instruction Sheet of 21 February 1992 on use of fly ash base coursesin building works.)

Other Contaminants

Nitrogen oxides

Nitrogen oxides emitted to the indoor climate from combustion in stoves, central heating boilers and similar shall be limited by removal of the flue gases. (Guidance: For kitchens, this requirement may be deemed to be met by extraction through a hood, see section 2.2.)

Radon

Building structures that are in contact with the subsoil shall be made airtight. (Guidance: Radon is a radioactive gas which can move from the subsoil into buildings. Radon must be prevented from moving into buildings by making the foundations, ground supported floors, floors and basement floors and external walls of basements airtight by using concrete for these structures and constructing them carefully to achieve good, uniform and crack-free structures, and by sealing around pipes and ducts where these pass through openings in the buildings. See "Radon in Dwellings", National Building and Housing Agency's "Radon-guidance on protective measures for new buildings".)

Other contaminants from the subsoil

Contaminants from former landfill and other waste disposal sites, gasworks, contaminated industrial sites must not cause an unhealthy or unsafe indoor climate. Building structures next to the subsoil must be made both airtight and impermeable if the site is built on without complete decontamination of the soil. In special cases, in which the soil is not decontaminated partially for the purpose of protecting ground water and the upper soil strata, the local authority may stipulate other measures. (Guidance: See Act on Waste Depositories and Act on Environmental Protection. The potential contaminants can pass from soil into buildings, particularly by convection and diffusion through foundations, ground supported floors, floors, basement floors and external walls of basements. Convection is prevented by making the structure airtight, e.g. by using concrete for these structures and constructing them carefully to achieve good, uniform and crack-free structures. Diffusion is reduced by making the structures impermeable, e.g. by use of concrete of the quality required for moderate environment class, with a content of up to

5% porous particles. See the National Building and Housing Agency's "Radon-guidance on protective measures for new buildings" and DS411: Code of practice for structural use of concrete.)

Temperature

Buildings shall be so constructed that healthy temperatures can be maintained in rooms occupied for prolonged periods of time during normal use of the building, having regard to the human activity in the rooms. (Guidance: Functional requirements and methods for specification, verification and inspection and testing of thermal indoor climate are given in DS474: Code of practice for indoor thermal climate.)

{DS474 Code for Indoor Thermal Climate

The code is a set of requirements, which aims to secure an acceptable thermal climate for the occupants. The code applies to the thermal climate in all occupied spaces with moderate thermal climate. The code is in accordance with ISO 7730 "Moderate thermal Environments – Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort." and with the Nordic guidelines NKB Report no. 41 "Indoor Climate".

Demands to Thermal Comfort

General Influences

Operative temperature in occupied space (clothing about 1 clo) $20\ ^{o}C < t_o < 24\ ^{o}C$
Summer conditions (clothing about 0,5 clo) $23\ ^{o}C < t_o < 26\ ^{o}C$
Exceeding of limits
In periods, where the outdoor temperature or other conditions are extreme and exceed the design criteria, temperatures outside the above limits can be accepted. For hot days with light summer clothing and sedentary activity the acceptable condition could be that the operative temperature must not exceed 26 ^{o}C in more than 100 hours and not exceed 27 ^{o}C in more than 25 hours in a typical year.}

In the planning of buildings and in the choice of materials and window sizes, orientation and sun-shading of windows, it shall be ensured that appropriate temperatures are achieved in the summer period as well and that problems from direct solar radiation are avoided.

E3 France

Carbon Dioxide (CO_2)

1000 ppm in office buildings (1300ppm in no smoking area)

E4.Germany

Taschenbuch fur Heizung und Klimatechnik einschlieBlich Warmwasser und Kaltetechnik 1999

Pollutant	MAC values ppm	mg/m^3
Carbon dioxide (CO_2)	5000	9000
Carbon monoxide (CO)	30	33
Formaldehyde (HCHO)	1	1.2
Ozone (O_3)	0.1	0.2
Nitrogen dioxide (NO_2)	5	9
Sulphur dioxide (SO_2)	2	5

E5 Greece

Maximum permitted concentration of pollutants in working places.

Pollutant	Instantaneous or very quick death mg/1	Dangerous for inhalation from 1/2 to 1 hour mg/1	Dangerous for many hours inhalation mg/1	Concentration perceivable by smell mg/1	Max permitted concentrations in working spaces (values MAC)	
					mg/1	cm^3/m^3
HCHO	-	0.8	-	-	0.006	5
CO_2	360-550	90-120	20-30	odourless	9.0	5000
CO	6-12	2-3	0.2	odourless	0.055	50
NO_X	0.45	0.05-0.1	-	0.010	0.009	5
Ozone	-	0.03	0.001	0.00002	0.0002	0.1
SO_2	5.5	1.0-1.7	0.02-0.03	0.008-0.013	0.013	5

E4 Italy

There are no threshold levels for contaminants in non-industrial spaces established by Italian Standards or Laws. A value reported for CO_2 (1500 ppm) probably refers to a Regional Law of Region Emilia-Romagna.

E5 Netherlands

CO2
Schools 1500ppm
Dwellings 1200 ppm
Offices 1000 ppm

HCHO
1.2 mg/m^3 Building Decree

E6 New Zealand

As far as pollutant concentrations are concerned there are no fixed criteria for residential buildings although there are criteria for industrial workplaces. Mostly WHO table ASHRAE 62 is the one that is used as far as HCHO, HO_2 and CO are concerned. This is at the 1984 level.

Pollutant	Concentrations reported (mg/m^3)	Concentrations of limited or no concern (mg/m^3)	Concentration of concern (mg/m^3)	Remarks
HCHO	0.05-2	<0.06	>0.12	*Long and short term*
NO_2	0.05-1	<0.19	>0.32	
CO		2% COHb	3% COHb	*99.9% According to the Environmental Health Criteria No 4 Geneva World Health Organisation 1977.*

Source: Table C-4 WHO Working Group consensus of concern about indoor air pollutants at 1984 levels of knowledge. ASHRAE 62 -1999

E7 Norway

The following is a translation of Table 12 from Building details sheet no. G 421.502 Requirements to air quality (based on recommend values from the National Institute of Public Health in Norway):

Pollutant	Requirement
Nicotine	in non-smoking areas < 1.0 mg/m³ in non-smoking sections in restaurants etc. < 10 mg/m³
Radon	>200 Bq/m³ *Simple and reasonable actions should bee taken* > 400 Bq/m³ *Actions should bee taken*
Formaldehyde	< 100 mg/m³ *(30 min. average)*
Asbestos	< 0.001 fibres/ml
Synthetic mineral fibres	< 0.01 fibres/ml
Particles	< 20 mg/m³
Carbon dioxide CO_2	< 1 800 mg/m³ 1000 ppm
Carbon monoxide CO	25 mg/m³ (1 hr. average) 10 mg/m³ (8 hr. average)
Nitrogen dioxide NO_2	100 mg/m³ (1 hr. average)

Indoor air pollutants

There are no formal requirements to the pollutant contents but recommend values from the National Institute of Public Health in Norway are commonly used (see also http://www.folkehelsa.no/english/). These have been publicized in tables in building details sheets from NBI (G 421.502 and G 421.505, in Norwegian).

E8 Sweden

Indoor Air Quality

Pollutant	MAC ppm	Peak limit ppm	Ref	AIC ppm	Ref	Remarks
Carbon dioxide, CO_2	5000 (1)	10000 (1)	/A/	1.000 (2)	/B/	Concentration CO_2 in supply air < 1/10 of MAC /B/ (2)
Formaldehyde, HCHO	0.5 (1)	1 (15 min) (1)	/A/	0.01-0.04 (2)	/C/	Concentration HCHO in supply air < 1/20 of MAC /B/ (2)
Nitrogen dioxide, NO_2	2 (1)	5 (15 min) (1)	/A/	0.04-0.06 (2)	/C/	Concentration HCHO in supply air < 1/20 of MAC /B/ (2)
Carbon monoxide CO	35 (1)	100 (15 min) (1)	/A/	5 (8h) 52 (24h) (2)	/C/	Concentration CO in supply air < 1/10 of MAC /B/ (2)

References

A. *National Board of Occupational Safety and Health, Sweden. AFS 1996:2.*
B. *National Board of Occupational Safety and Health, Sweden. AFS 1993:5.*
C. *The Swedish Society of HVAC Engineers (SWEDEVAC). Classification of Indoor Climate Systems – guidelines and specifications.*

Level of compliance

1. Requirements
2. Recommendations

E9 United Kingdom

#NO 7694 EH40/94 (1994), Occupational Exposure Limits 1994.Health and Safety Executive. UK, 1994

Pollutant	Long term exposure limit (8 hour TWA reference period)		Short term exposure limit (15 minute reference period)	
	ppm	mg m^{-3}	ppm	mg m^{-3}
CO_2	5000	9000	15000	27000
CO	50	55	300	330
NO_2	3	5	5	9
NO	25	30	35	45
HCHO	2 (MELl)	2.5 (MEL)	2 (MEL)	2.5 (MEL)

NOTE: HCHO IS Maximum Exposure Limit everything else is Occupational Exposure limit.

Pollutants	Standard		Objective
	Concentration	Measured as	To be achieved by 2005
	5ppb	Running annual mean	5ppb
Benzene	1ppb	Running annual mean	1ppb
Carbon monoxide	10ppm	Running 8-hour mean	10ppm
Lead	0.5 $\mu g/m^3$	Annual mean	0.5 $\mu g/m^3$
Nitrogen dioxide	150ppb 21ppb	1-hour mean annual mean	150ppb 21ppb
Ozone	50ppb	Running 8-hour mean	50 ppb as 97th %tile
Particles	50 $\mu g/m^3$	Running 24 hour mean	50 as $\mu g/m^3$ 99th %tile
Sulphur dioxide	100ppb	15 minute mean	100 ppb as 99%tile

Summary of National Air Quality Strategy
From Stephanie Coster DETR Controlling Particles from Construction and Demolition – A new Code of Practice

E10 United States of America

REF ASHRAE 62-1999 Ventilation for acceptable Indoor Air Quality

REF: Standards applicable in the United States for common indoor air pollutants ASHRAE 62-1999 C-1

Pollutant	Indoor Standards	Outdoor Standards	Industrial Workplace Standards
Carbon monoxide (CO)		National Ambient Air Quality Primary Standard 10 mg/m³ (9 ppm) 8hr avg. 40 mg/m³ (35 ppm) 1 hr avg. (EPA, 40 CFR 50.8) (C9) State air quality limits : CT 1000 µg/m³ 8hr NV 1.2100 mg/m³ 8hr (NATICH Data Base, 1986) (C-8)	55 mg/m³ (50ppm) 8hr (OSHA, 29 CFR 1910.1000, Table Z-1)(C-12) (C30 CFR 57.5001 (a)) (C-13)
Formaldehyde (HCHO)	Federal : 0.4 ppm target ambient level, HUD standard for manufactured homes, achieved through product emissions standards of .2 and .3ppm (HUD, 24 CFR 3280.308, 1984) State: 0.4ppm standard for indoor exposure	No federal standard State air quality limits:CT 12.00 µg/m³ 8hr IL 0.0150 µg/m³ 1 yr IN 18.00 µg/m³ 8hr MA 0.2000µg/m³ 24hr NC 300.00 µg/m³ 15min NV 0.0710 µg/m³ 8hr NY 2.000 µg/m³ 1hr VA 12.000 µg/m³ 24hr (NATICH Database, 1986) (C-8)	1ppm 8hr TWA-PEL 2ppm 15 min STEL OSHA, 29 CFR 1910.1lth000 Table Z-2 OSHA issued a final rule Dec 4 1987 (52 FR 46168) lowering a previous standard to the above level, which was effective on Feb 1988) Mine Safety and Health Admin uses ACGIH

	(MN statute 144.495, 1985) (C-15)		TLVs (30 CFR 57.5001 (a) (C-13)
Ozone (O_3)	FDA prohibits devices (e.g. germicides, deodorisers) that result in more than 0.05 ppm in occupied enclosed spaces such as homes, offices or hospitals, or that result in any releases in places occupied by the ill or infirm. (21 CFR 801.415) (C-16)	National Ambient Air Quality Primary and Secondary standards: 235 µg/m^3 (0.12 ppm) max hourly avg. (EPA, 40 CFR 50.9) (C9) State air quality limits: CT 235.0 µg/m^3 1 hr NV 0.005 mg/m^3 8hr (NATICH Database, 1986) (C-8)	0.2 mg/m^3 (0.1 ppm) 8hr TWA (OSHA, 29 CFR 1910.1000, Table Z-1)(C-12) Mine and Safety and Health Admin. uses ACGIH TLV (30 CFR 57.5001(a) (C-13)
Sulphur dioxide (SO_2)		National Ambient Air Quality Primary Standard: 80 µg/m^3 (0.03 ppm) annual arithmetic mean 365 µg/m^3 (0.14 ppm) 24 hr Secondary Standard: 1300 µg/m^3 (0.5 ppm) 24 hr (EPA, 40 CFR 50.4, 50.5) (C-9) State air quality limits: CT 860.0 µg/m^3 8hr NV 0.119 mg/m^3 8hr TN 1.200 µg/m^3 1 yr (NATICH Database 1986) (C-8)	13 mg/m^3 (5ppm) 8 hr TWA (OSHA, 29 CFR 1910.1000, Table Z-1) (C12) Mine Safety and Health Admin . uses ACGIH TLV (30 CFR 57.5001 (a)) (C-13)
Particulates		National Ambient Air Quality Primary Standard: 75 µg/m^3 annual geom. mean 260 µg/m^3 maximum 24hr Secondary standard: 60µg/m^3 annual geom. mean 150µg/m^3 maximum 24hr. (EPA, 40 CFR 50.6, 50.7)(C-9)	

(a) Most ACGIH TLVs are referenced in Western nations standards, including Canada, Western Europe and Australia.

Table C 2
Guidelines used in the United States for Common Indoor Air Pollutants

Pollutant	Indoor Standards	Industrial Workplace Standards
Carbon monoxide (CO)		55 mg/m^3 (50 ppm) 8 hr TLV-TWA 440 mg/m^3 (400 ppm) 15 min STEL (ACGIH, 1986-87) (C-1)
Formaldehyde (HCHO)		1.5 mg/m^3 (1ppm) 8hr TLV-TWA 3 mg/m^3 (2ppm) 15min STEL (ACGIH, 1986-87) (C-1) 1.2 mg/m^3 (1ppm) 8 hr TWA mg/m^3 (2ppm) 15min STEL (American Industrial Hygiene Assn, 1986)(C20) NAS recommendations for manned spacecraft (C-18) mg/m^3 (1.0ppm) 60 min 0.1 mg/m^3 (0.1ppm) 90 days mg/m^3 (0.1ppm) 6mo. Navy Submarine Atmospheric Control Manual , levels set by Navel Research Laboratory (C-19) 3.0 ppm 1 hour 1.0 ppm 24 hour 0.5 ppm 90 days
Nitrogen dioxide (NO_2)		6 mg/m^3 (3ppm) 8hr TLV-TWA 10 mg/m^3 (5ppm) 15 min STEL (ACGIH 1986-87)(C-1) NAS recommended for manned spacecraft: C-18 4mg/m^3 (2.0ppm) 60min 1.0 mg/m^3 (0.5ppm) 90days 1.0 mg/m^3 90.5ppm) 6 months.
Ozone (O_3)		0.2 mg/m^3 (0.1ppm) 8hr TLV-TWA 0.6 mg/m^3 (0.3ppm) 15 min STEL (ACGIH, 1986 - 87)(C-1)
Sulphur dioxide (SO_2)		5 mg/m^3 (2ppm) 8hr/ TLV-TWA 10 mg/m^3 (5ppm) 15 min. STEL (ACGIH, 1986-87)(C-1) NAS recommendation for manned spacecraft (C-18) 13 mg/m^3 (5.0ppm) 60min 3mg/m^3 (1.0 ppm) 90 days 3 mg/m^3 (1.0 ppm) 6 months.

Note Standards in Tables C1 and C2 from ASHRAE 62 1999 are in the process of being updated but no changes have officially been verified. Therefore the values currently in standard 62 1999 have been taken as correct at the time this publication was complied.

E11 WHO (World Health Organisation)

Guidelines are set at levels below which adverse health effects from air pollutants are thought unlikely.

Pollutant	Guideline	Averaging Time
Outdoor Air		
Ozone (O_3)	120 μg/m^3	8hr
Nitrogen Dioxide (NO_2)	200 μg/m^3 40 μg/m^3	1hr annual
Carbon monoxide (CO)	100 μg/m^3 60 μg/m^3 30 μg/m^3	15 min 30min 1 hr
Sulphur Dioxide (CO_2)	500 μg/m^3 125 μg/m^3 50 μg/m^3	10 min 24 hr annual
Particulate matter	Effect response	
Benzene	$6x10^{-6}$ (μg/m^3) –1	Lifetime
Lead (Pb)	0.5 μg/m^3	Annual
Indoor Air		
Radon	$3\text{-}6x10^{-5}$ (μg/m^3) –1	Lifetime
Environmental Tobacco Smoke	No guideline	
Ecotoxic Effects		
SO_2 critical level	10-30 μg/m^3 (a)	Annual
SO_2 cirtial load	250-1500 eq/ha/yr (b)	
NO_X critical level	30 μg/m^3	Annual
NO_X critical load	15 – 35 kgN/ha/yr (b)	
Ozone – critical level	0.5-10 ppm.h(a)	5 d-6 m
(a) depending on type of vegetation		
(b) depending upon type of soil and ecosystem		

**No guideline values have been set for particulate matter as there is no threshold of duration or concentration of exposure associated with effects.*

SOURCE: NSCA WEB SITE (http:www.mistral.co.uk/cleanair/fs1_6.htm)

E12 Other International Standards and Guidelines (Ref #12356)

Pollutant	**Recommendations**
Sulphur Dioxide (SO_2)	**WHO Air quality Guidelines (1987)** 10 min 175 ppb (501µg/m^3) 1 hr 122 ppb (349 µg/m^3) **Revision of WHO AQGS: 1996 Expert Group recommendations** (1 hour guideline and link with smoke abandoned) 10 min 175 ppb (500.5 µg/m^3) 24 hr: 45 ppb (128.7 µg/m^3) Annual 17 ppb (47 µg/m^3) **EC Directive : limit values** *Annual median of daily means* 30 ppb (UK equiv 34 µg/m3) if smoke > 40µg/m^3 45 ppb if smoke < 40 µg/m^3 *Winter median of daily means:* 48.8 ppb (UK equiv 51 µg/m^3) if smoke > 60 µg/m^3 67.5 ppb if smoke < 60 µg/m^3 *98%ile of daily means:* 93.8 ppb (UK equiv 1281 µg/m^3) if smoke >150µg/m^3 131.3 ppb if smoke <150 µg/m^3 *Guide values:* Annual Average: 15-22.9 ppb (43-65 µg/m^3) Daily average: 37.5 0 56.4 ppb (107-161 µg/m^3)
Nitrogen Dioxide (NO_2)	**WHO Air Quality Guidelines (1987)** 1 hr 210 ppb (385 µg/m^3) 24hr 80 ppb (150µg/m^3) Revision of WHO AQGS 1996 - Expert Group recommendations (24 hr guideline abandoned) 1 hr 110 ppb (207 µg/m^3) Annual : 21 ppb (40 µg/m^3) The change in the 1 hour guideline reflects the increasing concern that NO_2 may play some adjuvant role in asthma both in terms of the provocation of attacks by allergens and , though less likely , in terms of the initiation of the disease. The introduction of an annual guideline reflects the results of epidemiological studies which show a negative association between long term average concentrations on NO_2 and indices of lung function. There is some room for doubt in the interpretation of the results of these studies as regards which pollutant or combination of pollutants is responsible for the described eff ect and the annual guideline is less firmly founded than some other WHO Air Quality Guidelines. **EC Directive Limit Values** Limit value:

	98%ile hourly mean: 104.6 ppb (197 μg/m^3) Guide values: 98%ile hourly mean: 70.6 ppb (133 μg/m^3) 50%ile hourly mean : 26.2 ppb (49 μg/m^3)
Ozone (O_3)	WHO Air Quality Guidelines (1987) 1hr : 76 – 100 ppb (152-200 μg/m^3) 8hr: 50-60 ppb (100-120 μg/m^3) **Revision of WHO AQS: 1996 Expert GROUP recommendations:** 8 hr : 60 ppb (120 μg/m^3) (1 hr guideline abandoned) + tables of exposure response for 1 hr and 8 hr because there was little evidence of a threshold for effects. **EC Directive** Health protection threshold 8hr: 55ppb (110 μg/m^3) Population information threshold 1hr: 90 ppb (180 μg/m^3) Population warning value 1hr : 180 ppb (360 μg/m^3)
Particulate Matter	WHO Air Quality Guidelines (1987) Based on epidemiology and therefore done in conjunction with SO_2 Short term (24hr) SO_2 125 μg/m^3 (44 ppb); BS 125 μg/m^3 (TSP 120 μg/m^3; TP 125 μg/m^3) Long term (1yr) SO_2 50 μg/m3 (17.5 ppb); BS 50μg/m^3 (No figures suggested for TSP/TP) Recommendations made to WHO by expert group 1994 (link with SO2 abandoned) Non threshold effect. Provides a dose response table for PM10. PM2.5 and aerosol sulphate, for mortality and other outcomes

Health Effect Indicator:	Estimated change in daily average concentration needed for given effect (µg/m³)		
	Sulphates	$PM_{2.5}$	PM_{10}
Daily mortality	8	29	50
5% change	16	55	100
10% change	30	110	200
20% change			
Hospital admissions - respiratory conditions			
5% change	8	10	25
10% change	16	20	50

Particulate Matter continued ….	EC directive (EC Blacksmoke not identical to UK BS = 0.85 EC BS) **Limit values:** Annual median of daily means : 80 µg/m³ (UK BS equivalent 68 µg/m³) Winter median of daily means: 130 µg/m³ (UK BS equivalent 111 µg/m) 98%ile of daily means throughout year: 250 µg/m³ (UK BS equivalent 213 µg/m³) **Guide values** Annual average : 40-60 µg/m³ (UK BS equivalent 34-51 µg/m³) Daily average : 100 - 150 µg/m³ (UK BS equivalent 85 - 128 µg/m³) **US primary standard for protection of human health:** 24 hr mean not to be exceeded more than once a year : 150 µg/m³ PM10 Annual arithmetic mean : 50 µg/m³ PM10
Benzene (C_6H_6)	WHO Air quality Guidelines (1987) No safe level of airborne benzene can be recommended, as benzene is a carcinogenic to humans and there is no known safe threshold level. WHO calculated that at an air concentration of 1 µg/m³ (equivalent to 0.313 ppb) the estimated lifetime risk of leukaemia is $4 x 10^{-6}$. There are many problems inherent in this mathematical estimate and the EPAQS standard is set pragmatically at a level at which health risks are exceedingly small and effectively merges with the background level of risk among non exposed groups. Revision of WHO AQGS 1995 Expert Group recommendations. Unit Risk (risk associated with 1 µg/m³ lifetime exposure) = $4.4x10^{-6}$ – $7.5x10^{-6}$
Carbon Monoxide (CO_2)	**WHO Guidelines (1987)** 15 min: 87 ppm (109 mg/m³) 30 min 50 ppm (62.5 mg/m³) 1 hr 25 ppm (31.25 mg/m³) 8 hr 10ppm (12.5 mg/m³) The WHO guidelines are calculated such that a normal subject engaging in relatively heavy work will not exceed a COHb level of 2.5%.

E13 International Air Quality Standards and Guidelines Specifically relating to Schools

This information has been supplied by the UK DFEE -

Review of International Regulations and guidelines for Indoor climate and indoor air quality: room temperatures (include type of temperature specified eg, air temp, dry resultant, etc); ventilation; carbon dioxide levels, radon levels, humidity. See tables 3 and 4 for review of all temperature and ventilation parameters.

E13.1 Austria:

Indoor climate

Requirements for air temperature in Winter were formulated in a decision of the Austrian government in the 1980s.

Ventilation

The fresh air rate in class rooms for under 10-year-old pupils is 15 m^3/h; and for older pupils, 20 m^3/h, during the school hours. This should be achieved with natural ventilation. If mechanical ventilation is inevitable, the air flow velocity should not exceed 0.1 m/s in winter and 0.25 m/s in summer (according to the guideline ÖNORM H 6000/3).

Water/Humidity:

Guidelines of the Austrian Institute of Standards refer to the diffusion of vapour through walls to avoid condensation problems (ÖNORM B 8110/2). The Austrian Institute for the Construction of Schools and Sports Facilities recommends to keep the humidity above 30% at 20°C and below 55% in the long range (draft 1998).

Carbon dioxide:

No limit or guideline for the carbon dioxide level. In a current working group of the Ministry for Education and Science, dealing with Indoor Air Quality, a requirement of 1000ppm or 1500ppm is being discussed. But it is not sure whether this will be a recommendation or a requirement and what the consequences will be when this limit is exceeded. As in other countries, in Austria the CO_2 levels in classrooms are often very high (often over 2500ppm and even higher). The working group will present a result in 1 or 2 years time.

E13.2 The United Kingdom

School Premises Regulations:

The heating system shall be capable of maintaining in the areas set out in column (1) of the Table below the air temperature set out opposite thereto, in column (2) of that Table, at a height of 0.5m above floor level when the external air temperature is -1°C:

Area	Temperature
Areas where there is the normal level of physical activity associated with teaching, private study or examinations.	18^{o}C
Areas where there is a lower than normal level of physical activity because of sickness or physical disability including sick rooms and isolation rooms but not other sleeping accommodation.	21^{o}C
Areas where there is a higher than normal level of physical activity (for example arising out of physical education) and washrooms, sleeping accommodation and circulation spaces.	15^{o}C

(1) All occupied areas in a school building shall have controllable ventilation at a minimum rate of 3 litres of fresh air per second for each of the maximum number of persons the area will accommodate.
(2) All teaching accommodation, medical examination or treatment rooms, sick rooms, isolation rooms, sleeping and living accommodation shall also be capable of being ventilated at a minimum rate of 8 litres of fresh air per second for each of the usual number of people in those areas when such areas are occupied.
(3) All washrooms shall also be capable of being ventilated at a rate of at least six air changes an hour.
(4) Adequate measures shall be taken to prevent condensation in, and remove noxious fumes from, every kitchen and other room in which there may be steam or fumes.

The Health and Safety Executive guidance given in the Advisory Code of Practice to the Workplace (Health, Safety and Wefare) Regulations 1992 states "The fresh air supply rate should not normally fall below 5 to 8 litres per second, per occupant. Factors to be considered include the floor area per person, the processes and equipment involved, and whether the work is strenuous".

Recommended Constructional Standards as given in Building Bulletin 87 Guidelines for Environmental Design in Schools:

During the summer, when the heating system is not in operation, the recommended design temperature for all spaces should be 23^{o}C with a swing of not more than +/- 4^{o}C. It is undesirable for peak air temperatures to exceed 28^{o}C during normal working hours but a higher temperature on 10 days during the summer term is considered a reasonable predictive risk.

The heating system shall be capable of maintaining the required room air temperatures with the minimum average background ventilation of 3 litres per second of fresh air per person.

Spaces where noxious fumes or dust are generated may need additional ventilation. Laboratories may require the use of fume cupboards, which should be designed in accordance with DfEE Building Bulletin 88. Design technology areas may require local exhaust ventilation.
All washrooms in which at least 6 air changes per hour cannot be achieved on average by natural means should be mechanically ventilated and the air expelled from the building.

E13.3 France:

SBI 182 uses dry resultant temperatures to specify temperatures and asymmetric radiation. See table 3.

SBI 182: Air velocity 0.05-0.15 m/s

Réglement sanitaire départemental type gives mechanical ventilation rates:

Nursery	> 10 m^3/h per m^2 floor area
Primary school	> 10 m^3/h per m^2 floor area
Secondary school	> 12 m^3/h per m^2 floor area
Humidity/condensation:	No guidelines or rules

E13.4 Germany

DIN 4701 Regeln für die Berechnung des Wärmebedarfs von Gebäuden=Rules for the calculation of the heating energy demand of buildings
VDI 2067 Berechnung der Kosten von Wärmeversorgungsanlagen. Kühlanlagen=Calculation of the costs of heating systems. Cooling systems
DIN 4108 Wärmeschutz im Hochbau=Thermal insulation in building constructions
Arbeitsstättenverordnung; Regulation of workshop places.

winter:
indoor air temperature:20 - 23°C
relative humidity: 40 - 60%
air velocity: <=0,15 m/s
summer:
indoor air temperature: <26°C caused by internal gains, with solar radiation a higher temperature is allowed.

Recknagel/Sprenger: Taschenbuch für Heizung + Klimatechnik. Guidelines for heating and air-conditioning engineering. ISBN 3-486-262214-9.
vertical temperature difference: < 2 K/m
maximum temperature of hot ceiling: 35°C
maximum temperature of floor heating system: 29°C
asymmetric to cold services: <= 3 K

DIN EN 832 Wärmetechnisches Verhalten von Gebäuden. Berechnung des Heizenergiebedarfs=Thermal performance of buildings. Calculation of energy use for heating. Residential Buildings
n_{Lmin}=0.5 h^{-1}

DIN 4108-Part 6 Wärmeschutz im Hochbau. Berechnung des Jahresheizwärmebedarfs von Gebäuden=Thermal insulation in building constructions. Calculation of the yearly heating energy demand of buildings
$n_{LStandard}$=0.8 h^{-1}
mechanical ventilation: 0.4-0.56 h^{-1}

DIN 1946- Part 2 Raumlufttechnik. Gesundheitstechnik (VDI-Lüftungsregeln)=Ventilation systems. Health technology (VDI-Ventilation-Rules) - Recommendations:
20 - 60 m³/h.person
4 - 20 m³/(m²h)
classrooms/lecture halls: 20 m³/h.person
15 m³/(m²h)

Carbon dioxide level not to exceed 0.15 percent of the volume (1500ppm), 0.1 percent (1000ppm) is recommended.

Humidity/condensation:
DIN 4108, P. 3
By using the u-values of DIN 4108, P. 2 (s. energy) you avoid moisture with normal room temperatures and relative humidity.
In special cases you have to calculate the necessary u -value
For calculating the amount of moisture you have to use:
During the dew period:
outdoors: -10 °C, 80 % rel. humidity
indoors: 20 °C, 50 % rel. humidity
During the evaporation period:
outdoors: 12 °C, 70 % rel. humidity
indoors: 12 °C, 70 % rel. humidity

E13.5 Denmark:

The Indoor Climate Guide (In Danish). Ove Valbjørn et al. (ed). SBI Direction 182, BR 95 and 1972 Guidance.

Mechanical ventilation (BR 95):
For ventilation systems with a constant air output, the annual electricity consumption for air transport must not exceed 2500 J/m^3 of fresh air.
If special building measures are used, e.g., larger room volumes per person and provision of several possibilities for airing rooms, including possibilities for cross-ventilation, the requirement of mechanical ventilation may be waived provided a healthy indoor climate can be maintained.

There are no guidelines or rules for humidity.

E13.6 Norway:

The following guidelines are taken from an article[2] about the *Recommended guidelines for indoor air quality* updated recently and published by the National Institute of Public Health:

Tobacco smoke

The Norwegian government has determined by law which rooms should be smoke free and where smoking is permitted. In this context two practical guidelines have been established:
For areas that are supposed to be smoke free: Nicotine concentration not exceeding 1.0 micrgrammes/cubic metre
For areas where smoking is permitted: Nicotine concentration not exceeding
10 microgrammes/cubic metre

Dampness: excessive or prolonged dampness should not occur.

Mould: Visible mould damage or odour of mould should not occur.

Suggested guideline for house dust mites: 1 microgramme DerI allergen/gram dust (50 mites/gram dust)

Radon: At radon concentrations between 200 and 400 Bq/m^3 simple measures should be undertaken. At concentrations above 400Bq/m^3 , measures should be taken even if the costs will be high. Radon concentrations in future buildings should not exceed 200 Bq/m^3.

Formaldehyde: suggested guideline 100 microgrammes/cubic metre (30 minutes sampling time).

Asbestos: The risk for lung cancer from exposure to asbestos indicates that free asbestos fibres should not be found in indoor environments. A practical guideline is free asbestos fibres should not be found in indoor air at concentrations above 0.001 fibers/ml air.

Man made mineral fibers
Free MMMF should not be found in indoor air at concentrations above 0.01 fibers/ml air.

Suspended particles: ($PM_{2.5}$) suggested guideline 20 microgrammes/cubic metre, (24 hours sampling time).

Carbon dioxide: (CO_2) suggested guideline based on its quality as an indicator for poor indoor air quality 1800 microgrammes/m^3 (1500ppm) (maximum value).

"The scientific basis for the CO_2-criterion of 1000ppm is on studies of acceptability of air quality for persons entering the room - that is perceptions of non-adapted persons. There is not sufficient or conclusive evidence for effects on health or productivity when controlled for temperature, humidity and other pollutants. Such studies are needed."[3]

Carbon monoxide (CO) suggested guidelines:
10 microgrammes/ cubic metre (8hrs sampling time)
25 microgrammes/ cubic metre (1hr sampling time)

Nitrogen dioxide (NO_2):
suggested guideline 100 microgrammes/m^3 (1hr sampling time)

E13.7 Finland: National Building

Code of Finland, D2: Air temperature and effective temperature plus draft characteristic used to determine maximum air velocity from a graph. Maximum velocity increases with space temperature, eg, classrooms < 0.15m/s. See Figure 1 in Building Code D2.
Humidity/condensation: No regulations (guideline: winter 25-45%, summer 30-60%)
Carbon dioxide levels: The levels are 1500 ppm and 0800 ppm if CO_2-controlled system.
The classification of indoor air is in progress (3 different levels).

E13.8 Poland:

Polish Code, PN-82/02402 gives summer and winter temperatures.
DE-3/2121-3/90 (Dept. of National Education), specifies natural ventilation to be provided for all classrooms and mechanical ventilation provided for:
chemical labs (exhaust system);
sport centre (showers, cloak rooms); and
dining areas.
Polish Code PN-83/B-03430: min. 20 m^3/h person.
Humidity/condensation: No guidelines or rules.

E13.9 USA and Canada:

The minimum standard is to comply with ASHRAE Standard 62 -1989.
ASHRAE Standard 62-1989 is the current standard (minium standard) used in the US when dealing with Ventilation for IAQ. This standard sets minimum levels of ventilation (outside air input) per student or occupant. Like any standard that has varied rates or requirements the standard has to be appropriately and correctly applied. There have been instances where the standards have been taken literally and significant energy has been wasted due to oversizing of equipment.

Current requirements:
A classroom has a minimum requirement of 15 cfm or 8 litres/sec per student;
A laboratory -- 20cfm/p or 10 L/s/p;
Auditoriums --15cfm/p or 8 L/s/p; the minimum is 15 cfm or 8 L/s.
It should be noted that in restrooms the requirement is 20cfm or 10L/s continuous.
The carbon dioxide levels should be less than 1000 ppm.

Note: ASHRAE Standard 62-1999 has proposed an addendum to reduce minimum classroom ventilation rates for schools from the current 8L/s to 3 L/s per person. There is considerable oposition to this from IAQ experts. It is being proposed by the industry in the interests of energy reduction particularly in extreme climates (e.g., Florida or Alaska) where it is a very serious problem to condition large volumes of air. Hence the above comment about not taking standards too literally.

Radon Levels in schools should be less than 4pci/L.

Canada

Reference 1 gives the following information for Canada

Currently there are no regulated standards for IAQ, but certain guidelines have been issued for pollutant exposures and ventilation rates by several government and professional organizations, some of which are shown in Table 1. The only widely accepted national standards addressing the issue are ANSI (American National Standards Institute) and ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) Standard 62-1999, "Ventilation for Acceptable Indoor Air Quality."

The ANSI/ASHRAE standard establishes minimum outdoor air requirements for ventilation. These requirements are stated in cubic feet per minute (cfm) of outdoor air per person occupying the space, which are called ventilation rates (see Table 2)

Guidelines for IAQ pollutants

Pollutant	Concentration	Remarks
Asbestos	0.2 fibers/cm^3	OSHA Standard set in July 1986
Carbon Dioxide (CO_2)	800ppm 1000ppm 5000ppm	Ontario Hydro Standard - Workday Average ASHRAE Standard Ministry of Labor Standard (TWAEV)
Carbon Monoxide (CO)	5ppm 9ppm 35ppm	Ontario Hydro Standard - Workday Average ASHRAE- Average over 8 hours Ministry of Labor Standard (TWAEV)
Formaldehyde (HCHO)	0.4ppm 1ppm	ASHRAE Standard Ministry of Labor Standard (TWAEV)
Nitrogen Dioxide (CO_2)	3ppm 0.05ppm	Ministry of Labor Standard (TWAEV) Annual national ambient air quality standard (USA)
Ozone (O_3)	0.1ppm 0.08ppm	Ontario Hydro and Ministry of Labor Standards - Peak Concentration WHO - Criteria Document
Particulates	120mg/m^3 150mg/m^3 260mg/m^3	Ontario Hydro Standard - one hour average National Ambient Air Quality standard - 24 hours average mean (USA) ASHRAE - 24 hours average mean
Radon	4pCi/L 20pCi/L	ASHRAE Standard Health & Welfare Canada
Volatile Organic Compounds (VOC)	1 to 5 mg/m^3	US Environmental Protection Agency guidelines
Microbial Fungi:	<50 CFU/m^3 <150 CFU/m^3 <500 CFU/m^3	2 spices or 3 spices or Agriculture Canada Standard
Others Temperature Relative Humidity	Winter 20-24^{O}C Summer 22-26^{O}C 30-70%	ASHRAE Standard ASHRAE Standard

The occupancy levels below are those in the ANSI/ASHRAE standard which correlate these ventilation rates with the maximum occupancy in the net occupiable space, which is likely to be different from fire and safety occupancies required by local codes. The occupancy of schools also varies greatly.

Table 2: Key Ventilation Rates and Occupancy Levels

Area	Density of occupation People/1000ft^3	Outdoor Air cfm/person
General Classrooms	35	15
Science Laboratories	25	20
Wood/Metal Shop	20	20
Reception Area	30	15
Office space	6	20

USA:

Recommendations to avoid indoor air quality problems[4]:
- provide adequate outdoor air ventilation on a continuous basis (15cfm per student equivalent to 7.08 litres per second per student);
- control the space relative humidity between 30 and 60%; and
- provide effective particulate filtration of the outdoor air supplied via HVAC systems.

Total suspended particulates	<120microgrammes/cubic metre	National outdoor air guideline

Radon: Radon levels in schools should be less than 4pci/litre.

Humidity/condensation: Incorporated in the Local building codes and design of HVAC systems

E13.10 Japan

Carbon dioxide levels: Minimum standard of 1500ppm, 1000ppm for acceptable Indoor Air Quality.

E13.11 New Zealand

New Zealand building code requirements[6] for naturally ventilated buildings can be satisfied when openable window area exceeds 5% of the floor area. While this option has remained constant over many years, the airtightness of buildings has increased, occupant management of windows is likely to have changed and design fresh air delivery rates for mechanically ventilated buildings have changed. The standard for mechanically ventilated buildings, NZS 4303 “Ventilation for acceptable indoor air quality”[7] currently calls for 8l/s per person for classrooms with an assumed occupancy of 50 people per 100m ^{2} floor area.

Total Fungi	<400 cfu/m^3	Biodet Laboratory New Zealand, in-house database, private communication[5].
Total Bacteria	<100 cfu/m^3	Biodet Laboratory New Zealand, in-house database, private communication[5].
Formaldehyde	<0.1ppm	NZS 4303 *Ventilation for acceptable indoor air quality*[7].
Total Volatile Organic Compounds	0.5 mg/m^3	Australian National Health and Medical Research Council, Interim level of concern for volatile organic compounds in air[8].
Carbon dioxide in mechanically ventilated buildings	<1000 ppm	NZS 4303 *Ventilation for acceptable indoor air quality*[7].

E13.12 European Technical Note: CEN CR 1752:1999:

Operative temperature (approximately equal to air temperature in spaces with moderate heating or cooling loads)**:**
Summer:Kindergarten category C: 23.5^{0}C+/- 2.5 ,
Classroom category C: 24.5^{0}C+/- 2.5
Winter: Kindergarten category C: 20^{0}C+/- 3.5 ,
Classroom category C: 22^{0}C+/- 3.
Radiant asymmetry: "Radiant asymmetry may cause discomfort. People are most sensitive to radiant asymmetry caused by warm ceilings or cool walls(windows). Radiant asymmetry is rarely a problem in ventilated/air conditioned spaces, except at high illumination levels and at large window areas."
Radiant asymmetry for a category C building:
Warm ceiling $<7^{0}$C
Cool wall $<13^{0}$C
Cool ceiling $<18^{0}$C
Warm wall $<35^{0}$C
Maximum mean air velocity:
Summer: Kindergarten category C: 0.24m/s,
Classroom category C: 0.25m/s.
Winter: Kindergarten category C: 0.19m/s,
Classroom category C: 0.21m/s.
Ventilation rate:
Kindergarten category C: 2.8 $l/s.m^2$,
Classroom category C: 2.4 $l/s.m^2$

Air tightness
UK: No standard at present, It is under consideration for inclusion in the National Building Regulations to be measured during construction.
France: < 0.2 Vol/h over the heating period
Germany: DIN EN ISO 9972 Wärmeschutz Bestimmung der Luftdichtheit von Gebäuden. Differenzdruck-Verfahren=Thermal Insulation. Determination of airtightness.
Fan pressurisation method DIN EN 832: Very rarely measured during construction. Measured by the blower-door-method.
Denmark: No standard.
Finland: No requirements.

E13.13 References and International researchers in the field of ventilation and *IAQ in schools*

1. Indoor air quality solutions for school buildings, Proceedings of 8th International Conference Indoor Air, 1999, Rishi Kumar, P.Eng. Global Educational & Consulting Services, Mississauga, Ontario, Canada

2. Revised guidelines for indoor air quality in Norway, Proceedings of 8th International Conference Indoor Air, 1999, R.Becher[a], J K Hongslo[a],J V Bakke[b], J F Kvendbo[c], T Sanner[d], P E Schwarze[a] and E Dybing[a]
[a] National Institute of Public Health, Department of Environmental Medicine
[b] Directorate of Labour Inspection
[c] Trondheim municipality
[d] The Norwegian Radium Hospital, Department of Environmental and Occupational Medicine.

State-of-the-art report on requirements and recommendations for indoor climate in schools. A report to the Norwegian asthma and allergy association and the Norwegian Teachers Association, J V Bakke, The Labour Inspection, Norway, Proceedings of 8th International Conference Indoor Air, 1999.

4. Causes of Indoor Air Quality Problems in Schools, Summary of scientific research, 1998, Prepared by the Energy Division, Oak Ridge National Laboratory for the US Department of Energy.

Indicators of natural ventilation effectiveness in twelve New Zealand schools, MR Bassett[1] and P Gibson[2],
a Proceedings of 8th International Conference Indoor Air, 1999
[a] Building Research Association of New Zealand
[b] Paragon Health and Safety Ltd New Zealand

6. Building Industry Authority of New Zealand. 1998. New Zealand Building Code, Approved Document G4, Ventilation. Wellington.

7. New Zealand Standard NZS 4303:1990 Ventilation for Acceptable Indoor Air Quality. Standards New Zealand, Wellington.

Australian National Health and Medical Research Council NHMR. 1993. Interim level of concern for volatile organic compounds in air, Journal of Occupational Health and Safety - Australia and New Zealand, 9(3).

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Hironori HADANO, Yazaki Meter Co. Ltd
Toshimitsu MURATA, Yazaki Senssor Research & Marketing Co. Ltd.

Appendix F Standard Issuing Organisations

Country	Organisation
F1 Belgium	Belgisch Institut voor Normalisatie (IBN) Institiut Belge de Normalisation (IBN) Avenue de la Brabançonne, 29 1000 BRUSSELS - BELGIUM e-mail : info@ibn.be (http://www.ibn.be) (Produce Belgian Standards)
F2 Canada	Associate Committee on the National Building Code National Research Council of Canada Ottawa Ontario K1A OR6 *(Produce Canadian National Building Code)* (www.nrc.ca) Canadian General Standards Board (CGSB) C\o Ottawa Canada K1A 1G6 (w3.pwgsc.gc.ca) *(Produce Canadian Standards)* Standards Council of Canada 270 Albert Street, Suite 200 Ottawa, ON K1P 6N7 Canada (www.scc.ca)
F3 Denmark	The Danish Standards Association (DS) Aurehojvej 12 DK-2900 Hellerup (www.ds.dk) *(Produce Danish Standards)* Danish Society of Engineers (DIF) Organisation for Norms and Standards Vester Farimagsgade 31 DK-1606 Copenhagen V *(DOF norms, some being published as Danish Standards)* The Danish Ministry of Housing an d Urban Affairs Slotsholmsgade 1 1216 Kobenhaven K Denmark *(Produce Danish Building Regulations)* (www.bm.dk)
F4 Germany	The German Standards Institute (DIN) Burggrafenstrabe 4-10 Postfach 1107 1000 Berlin 30 Germany

	(www.din.de) *(Produce German Standards)* The German Institute of Engineers (VDI) Postfach 1139 4000 Dusseldorf 1 Germany (www.vdi.de) *(Produce Technicial Guidelines)*
F5 Finland	Finnish Standards Association SFS Maistraatinportti 2 FIN-00240 Helsinki Finland (www.sfs.fi) The Ministry of the Environment PO Box 306 SF 00531 Helsinki 53 Finland *(National Building Code)*
F6 France	The French Standards Institue (AFNOR) Tour Europe cedex 7 92049 Paris La Defense France (www.afnor.fr) *(Produce National Standards)* CSTB 84 Ave Jean-Jaures Champs-sur-marne 77421 Marne-La-Vallee cedex 2 France (www.cstb.fr)
F7 Greece	ELOT Acharnon 313 111 45 Athens Greece (www.elot.gr)
F8 Italy	UNI – Ente Nazionale Italiano di Unificazione, Via Battistotti Sassi 11, 20133 Milano, Italy. Telephone +39-02-70106914. (www.uni.com)
F9 Netherlands	The Netherlands Standards Institute (NEN) Vlinderweg 6 P O Box 5059 2600 GB Delft Netherlands (www.nen.nl) *(Produce Dutch Standards)*
F10 New Zealand	Standards Association of New Zealand (SANZ) 155 the Terrace Private Bag 2439 Wellington New Zealand (www.standards.co.nz) *(Produce New Zealand Standards)*

	Dept of Health P O Box 5013 Wellington New Zealand *(Produce The Drainage and Plumbing Regulations 1981.)* Department of Labour Private Bag Wellington New Zealand *(Produce The Factories and Commercial Premises Act 1981.)*
F11 Norway	Norwegian Standards Association (NSF) Drammensveien 145, POBox 353 Skoyen N-0213 Oslo Norway (www.standard.no) *(Produce Norwegian Standards)* The Norwegian Council for Building Standardisation Forskningsveien 3b POBox 129 Blindern N-0314 Oslo Norway (www.nbr.no) *(Produce Construction Standards)* The Royal Ministry of Local Government and Labour P O Box 8112 Dep. Oslo 1 Norway *(Produce the Norwegian Building Code (BF))*
F12 Sweden	Building Standards Institution, St Eriksgatan 46 C, S-100 28 Stockholm, Sweden. *(Produce Swedish Building Standards)* The National Board of Housing, Building and Planning. Box 534, S-371 23 Karlskrona, Sweden. *(Produce Swedish Building Regulations: BBR, a collection of decrees, BFS, and recommendations)* The National Board of Occupational Safety and Health. S-171 84 Solna, Sweden. The Swedish Society of HVAC Engineers (SWEDEVAC). Storgatan 19, Box 5501, S-114 85 Stockholm. Sweden (www.siki.se)

F13 Switzerland	Swiss Standards Association (SNV) Kirchenweg 4 8032 Zurich Switzerkand *(Produce Swiss Standards)* Swiss Association of Engineers and Architects (SIA) Postfach 8039 Zurich Switzerland (*Produce Swiss Standards on thermal protection and heating ventilation and air conditioning problems)* Swiss Association of Heating & Cooling Engineers (SWK1) Postfach 2327 3001 Berne Switzerland (Produce Recommendations for heating installations, ventilation etc)
F14 United Kingdom	British Standards Institute Linford Wood Milton Keynes MK14 6LE United Kingdom (www.bsi.org.uk) *(Produce British Standards)* HMSO Books P O Box 569 London, SE1 9NH United Kingdom *(Produce Building Regulations for England, Wales and Scotland)* Greater London Council The County Hall London, SE1 7PB United Kingdom *(Produce London by-laws)* Chartered Institute of Building Services Engineers (CIBSE) 222 Balham High Street London SW12 9BS United Kingdom (www.cibse.org)
F15 United States of America	The American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) 1791 Tullie Circle NE Atlanta GA 30329 United States of America (www.ashrae.org) *(Produce HVAC Standards)* American Society for Testing and Materials (ASTM) 1916 Race St Philadelphia PA 19103 United States of America (www.astm.org)

	(Produce Standards on materials, products, systems and services) US Department of Housing and Urban Development (HUD) 451 Seventh St SW Washington DC 20410 United States of America (www.hud.org) *(Produce Minimum Property Standards)* American National Standards Institute 1819 L Street NW Washington, DC 20036 United States of America (www.ansi.org)
F16 International Organisations	International Standards Organisation (ISO) 1 rue de Varembe Case Postale 56 CH 1211 Geneva 20 Switzerland (www.iso.ch) *(Produce International Standards)* European Standardization Committee (CEN) 5 Boulevard de l'Empereur B 1000 Brussels Belgium (www.cenorm.be) *(Produce European Standards (EN))*

Appendix G Web Pages of Relevant Organisations.

American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)
(www.ashrae.org)

Chartered Institution of Building Services Engineers (CIBSE)
(www.cibse.org)

North American Insulation Manufacturers Association (NAIMA)
(www.naima.org)

Canadian mortgage and Hosuing corporation (Cmhc)
(www.cmhc-schl.gc.ca)

US Environmental Protection Agency
(www.epa.gov/iaq/airduct.html)

Building Services Research Information Association (BSRIA)
(www.bsria.co.uk)

APPENDIX H Rationale of standard terminology.

H1 Belgium

In Belgium the standards are made at national (i.e. federal) level by the Belgian Standardisation Institute (the indicative of a Belgian standard always begins by 'NBN').
There are 2 types of standards : 'ratified standards' and 'registered standards' (BIN-IBN, 1999)
The Belgian Order of Council of 30.07.76, modified by the Belgian Order of Council of 23.10.86, gives the following specifications with respect to the role of standards (BBRI, 1992):
Article 5 :

> *'The State and all statutory persons can impose compliance with by the King ratified standards in their decisions, administrative matters, specifications by simple reference to the indicator of these standards'.*

Article 7 :

> *The State and other statutory persons, private persons and other interested parties consider the by the King ratified standards and the by the Belgian Standardisation Institute (BIN-IBN) registered standards as rules of good workmanship.'*

It means in practice that Belgian standards can have an important impact on the building process, even if they are not explicitly imposed in the framework of building regulations or by the technical specifications of a project.

It is important to indicate that there are important differences between Belgian standards. A generic classification is made in the following table. Standards of type b. and c. have an impact on the building process, even without being part of a legislation or project specific requirements.

a. Many standards include no performance requirements at all. This is e.g. the case with NBN B62-002 (BIN-IBN, 1987) for the calculation of the U-value and with NBN B62-301(BIN-IBN, 1989) for the calculation of the thermal insulation level of a building. It is evident that these standards have no impact at all on the building process unless a performance level is specified: ▪ by a regulation applicable to the region where the building is situated; ▪ in the technical specifications of a project, in which case the imposed level must be strictly met; ▪ in a general available publication from a recognised body. This is the case for Technical Notes of BBRI as well as for articles published in the BBRI revue. In this case, there is not the need for strictly meeting the proposed levels but a performance of similar level is advisable.
b. Some standards describe calculation methods as well as typical design assumptions (e.g. NBN B62-003(1986) for the calculation of the nominal heating power at room level) but it is allowed to use other design values. These standards directly influence the building procedures.
c. Finally, certain standards include nearly all the requirements. An example is NBN D50-001(1991) concerning ventilation requirements for dwellings.

Classification of Belgian standards according their impact on the building process

In order to comply with the EU rules, the Management Committee of BIN/IBN can register or submit for ratification European standards without a positive advice of the qualified commission. In fact, Belgium is obliged, as all other members of CEN, CENELEC and ETSI, to convert European standards into national standards within a delay of 6 months.

For the rational use of energy and the ventilation in buildings it is the Regions (Flemish, Walloon, Brussels) who are competent. If Belgian standards are available, they make reference to these standards, but if not available, they can include the procedure in the regulation. Health related issue are a federal domain. There is no hierarchy between the Federal and Regional Governments.

Dwellings

Flemish Region

At present, the requirements in relation to energy efficiency are expressed at the level of the U-value (NBN B62-002) and at the level of the overall thermal insulation level (NBN B62 -301).

There is no expression in relation to the overall energy efficiency and no specific attention is given to the ventilation performance.

The Government intends to evaluate the possibilities and problems with the concept of Energy Performance Standardisation (EPN) as presently operational in the Netherlands.

Walloon Region

The Walloon Region adopts to a certain extent the same approach as the Flemish Region. However, it allows as an alternative for the global insulation level that the requirement of a net heating demand is realised. This procedure takes into account the solar gains in the building and the ventilation losses. However, the ventilation rate is a fixed value and the performances of the system are not considered.

Brussels Region

At present, the requirements in relation to energy efficiency are expressed at the level of the U-value (NBN B62-002) and at the level of the overall thermal insulation level. (NBN B62 -301).

There is no expression in relation to the overall energy efficiency and no specific attention is given to the ventilation performance.

Offices

At present, only the Walloon Region has a requirement with respect to the global insulation level and the ventilation rate. The Brussels Region has a requirement with respect to the global insulation level.

Other types of buildings

At present, only the Walloon Region has a requirement with respect to the global insulation level and the ventilation for schools and accommodation buildings. The Brussels Region has a requirement with respect to the global insulation level.

Enforcement is not a special concern. Actually a building authorisation can not be delivered without the formal commitment of the owner to respect the regulation (insulation and ventilation). But only a few elementary controls are made on site at the end of the construc tion.

Nonetheless the three Regions are now working together to develop a more practical and acceptable way to control and enforce the application of the regulations (insulation and ventilation).

The lack of enforcement and the economical situation in Belgium does not stimulate the application of the regulations and standards. Moreover, when they are applied, their weakness does not promote the installation of performance oriented systems.

H2 Greece

The Greek code for ventilation is a Technical Note issued by the Technical Chamber of Greece. This note is valid only for air conditioned buildings. For non A/C buildings there is no code at present. Note that the Technical Notes of the Technical Chamber of Greece are official documents accepted by the State. The new building code of the country is now ready and it will be published during 2001.

H3 Netherlands

In the Netherlands, Standards contain the test methods (measurement and calculation methods), and the Building Decrees contain the requirements. These requirements then feed into the standards (Test methods). The final and ultimate regulations are contained within the Building Act. Solutions to the requirements are contained within the various codes of practice.

The requirements are really the minimum. When applying for a building permit it has to be made clear to the local municipality officers that the system fulfils the requirements. Users of the building must be able, as they so wish, to use the provisions in the way they think is right according to their own interpretation. The requirements are based on human effluents only. Emissions from building materials are to be handled in terms of source control. The maximum allowable level of building and furniture material concentrations may never be reached at ventilation levels that are only $1/6^{th}$ of the required value. Smoking is not taken in account.

H3 New Zealand

The New Zealand Building Code is the controlling document as far as issues of building health and safety are concerned. The scope of the Code does extend to issues of building durability and energy efficiency but its focus is mostly health and safety. The ventilation requirements in section G4 of the Code give some functional requirements of ventilation in general terms and the performance targets the ventilation must achieve are presented as "adequate number of air changes to maintain air purity". More detailed requirements are given in G4/VM1 and G4/AS1. These are verification methods and acceptable solutions respectively which sit outside but are referenced by the Building Code. G4/VM1 references CIBSE methods for measuring fresh air supply and distribution and the "Workplace Exposure Standards and Biological Exposure Indicies for New Zealand 1992" to define adequate air purity. G4/AS1 gives natural ventilation requirements (expressed as openable window and door areas) and for mechanically ventilated buildings it references several standards. These are NZS4303;1990 ventilation for Acceptable Air Quality (Similar to ASHRAE 62:1989) and AS1668: Part 2:1991 Mechanical Ventilation for Acceptable indoor-air-quality.

H4 Sweden

Reference: TIPVENT - Impact of Standards and Regulations on the Performance of Ventilation Systems.

Standardisation and regulation is mainly a national, public duty and appears in a very compact form of about six main papers including regulations, guidelines, job descriptions, and specifications. It covers all topics from general building, health, comfort to performance checks.

H5 Switzerland

Reference: TIPVENT - Impact of Standards and Regulations on the Performance of Ventilation Systems.

Standardisation and regulation is very complex. Public law and regulations are made on federal, state and municipality level and show a wide spread from national to very local approaches. Standards are mostly developed by publicly recognised or authorised societies and commissions and apply throughout the country.

H6 United Kingdom

Reference: Ewan MacGregor Employer – Designer – Contractor: Legal Liabilities and Indoor Air Quality.

Two principal sources of official regulations exist these are **Primary legislation** (Statues) and **Secondary legislation** (Regulations). Although the primary statutory provisions are readily available and well codified it is perhaps the regulations which are of more importance. Unfortunately the regulations being secondary are often released some years after their primary source and are broken down into specific topics which address the primary requirements.

In the United Kingdom a standard is a technical specification or other document available to the public, drawn up with the co-operation and consensus or general approval of all interests affected by it based on the consolidated results of science, technology and experience, aimed at the promotion of optimum community benefits and approved by a body recognized on the national regional or international level.

A guideline is a document that can include everything a standard can, however it recommends rather than requires.

A code or regulation is a binding document which contains legislative, regulatory or administrative rules and which is adopted and published by an authority legally vested with the necessary power.

The British Standards Institute (BSI) defines a standard in BSI 0-1 1997 as:

A document established by consensus and approved by a recognised body, that provides for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given con text.

In the UK standards are issued by the BSI as voluntary guidelines which are sometimes made mandatory if legislation is passed by the UK Government to that effect.

Standards were officially first introduced into the UK towards to end of the nineteenth century following the expansion of the railways. This result was to introduced consistency into the size, shape and quality of products which enabled industry to become more efficient.

The main benefits of standards are

- Economy and efficiency – in the use of materials, energy and human resources, control of variety, standardization of dimensions.
- Fitness for purpose - ensures a consistent quality of products, processes or services
- Health, safety and environment – allows improvements in the quality of life through personal protection and protection of the environment.
- International trade – facilitates trade by removing differences in national practices which might constitute barriers to trade.
- Communication – encourages the consistent use of termin ology and symbols.

There are three main categories of standards in the UK :
National: standards intended primarily for use within a particular country BS (British Standards)
Regional Standards: produced by cooperation between a number of countries eg CEN (European Committee for standardisation)
International : Standards applicable worldwide eg ISO (International Standards Organisation).

Increasingly standards are becoming less national and more European or International.

British Standards fall three main categories:

Specification: Sets out detailed requirements to be satisfied by a product, material, process or system and procedures for checking conformity to these requirements.
Method: details how a particular activity is performed, the results analysed and conclusions reached.
Code of practice: recommends good, accepted practice in terms of safety, quality, efficiency and economy.

British standards are publicly available documents and are normally voluntary in use. In certain cases a standard becomes binding:

- If it is made mandatory by government legislation, in which case failure to comply with it would constitute an offence.
- If a party is contracted to work to it.
- If a claim of compliance with it is made. If a product is falsely described as complying with a standard, it could contravene the Trade Descriptions Act, 1968.

The European Union's new approach to technical harmonisation and standards has resulted in standards taking on greater significance as a means of showing compliance with the law. Under the new approach a number of directives have been issued which lay down only the essential requirements with which products must conform before being placed on the market. Supporting technical requirements are covered by harmonised standards which are issued by the European standards organisations CEN, CENELEX and ETSI and adopted as national standards within the individual European Union countries. These standards still have a voluntary status, but conformance with them is a method by which a manufacturer can show that a product meets the essential requirements of the directive which is legally binding document.

There are several types of European Standards

EN European standard (norm) - these have to be implemented at national level by being given the status of a national standard and by withdrawal of any conflicting national standard. Implementation involves either publication of the full text of the EN as a national standard (in the UK this would be a BS EN) with no alteration to the context or layout of the standard, or issue of an endorsement notice stating that the EN is a national standard.

HD Harmonisation Document – Not to be confused with harmonised standards, these are issued mainly by CENELEC, in situations where it may not be possible to implement a full EN standard due to national conditions within some of the participating countries. HD's must be implemented at national level either by issue of a corresponding national standard or at least by public announcement of the HD number and title and, as in the case of EN's conflicting national standards are required to be withdrawn within a certain time. The main difference between an HD and an EN is that the former allows national deviations from the standard to exist for a limited period of time. CENELEC has now opted for a policy of ceasing to issue new HDs and to convert or withdraw existing HD's.

ENV – European Pre-standard – these are produced where there is an urgent need for guidance in a particular area, eg fast moving industries such as information technology, and insufficient time to develop a full EN standard. They are prospective standards prepared either by a technical body of CEN or CENELEC which will adopt the document at a special voting meeting, or through a questionnaire procedure confirmed at a special voting meeting, or through a questionnaire procedure confirmed by a written vote. Member countries are required to make ENV's available at national level and to announce their existence in the same way as for an EN or HD. In the UK this is done by publishing them as DD ENV's. Conflicting national standards may be kept in force until the ENV is converted into an EN.

Draft European standards are normally prefixed Pr meaning *projet* (French for draft).

H7 United States of America

In the United States, there are codes, model codes, standards and guidelines. Each of them has a different role to play in the process.

CODES: Codes are part of regulations. They are legal requirements passes by an authority who has jurisdiction over the appropriate area. Most building codes in the US are quite local, normally at the city or country level. There are thousands of jurisdictions in the US who can pass codes. Some States in the US have explicit energy codes (e.g. CA, MN, WA); most do not.

MODEL CODES: Because there are so many small jurisdictions, there are groups who create model codes. These are codes that a local authority could adopt as they are and become the code for that jurisdiction.

STANDARDS: Standards are sets of requirements that have no force of law, but are created by a professional or trade group who has the technical expertise to determine what should be done to achieve a desired objective. In the US the American National Standards Institute (ANSI) is the sole authority that can accredit organizations to write American National Standards. For example, ASHRAE is an ANSI-accredited organization who can write in the field of HVAC, energy-efficiency in buildings etc. Standards are sometimes adopted by cod es or model codes, but by themselves have only the authority derived from the reputation of the institution that writes them. A professional, however, is normally expected to follow the standards of his profession and can be held liable in court if he does not. Standards may be test methods (e.g. ASTM E741 ASTM E779, ASHRAE 136, ASHRAE 152), which simply describe how to measure a certain quantity or may set limits or requirements on specific quantities. ASHRAE Standards 55, 62, 90, 119, fall into the category of GUIDELINES: Guidelines are similar to standards, but are normally less specific. Guidelines are often sets of recommendations that might be appropriate in certain circumstances or lists of issues. Guidelines are normally addressed to the practitioners in that field.

H8 European Standards

The European Union's new approach to technical harmonisation and standards has resulted in standards taking on greater significance as a means of showing compliance with the law. Under the new approach a number of directives have been issued which lay down only the essential requirements with which products must conform before being placed on the market. Supporting technical requirements are covered by harmonised standards which are issued by the European standards organisations CEN, CENELEX and ETSI and adopted as national standards within the individual European Union countries. These standards still have a voluntary status, but conformance with them is a method by which a manufacturer can show that a product meets the essential requirements of the directive which is legally binding document.

There are several types of European Standards

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EU-TIPVENT Project Report

Overall Context of Standardisation & Regulation

Definitions Vary

The systems of standardisation and regulation are very different in all European countries. This variety shows on one hand, that different approaches are possible with in many cases very similar results and on the other hand it makes the situations hard to compare.

This chapter indicates the range of approaches used in Europe to show over view to get familiar with the overall context for all further investigations. The understanding and the definitions differ much between the countries. Hardly any two countries are talking about the same, when using the word «standard». As, for example, the Dutch standard is consists mostly of test methods whereas the SIA standard in Switzerland contains everything from requirements to test procedures and sometimes even solutions. As far as units are concerned despite the existence of international standards, the standards are very difficult to compare. In this work the expression standards and regulations stands for the whole system which may range from the constitution to the state of the art literature in ventilation technology.

National vs Regional Approaches

In most European Countries the same standards are used nationwide (e.g. France, Sweden). The requirements may vary according to the climatic region. Some countries have a very regional approach in their standards and regulations. Especially in the German speaking part of Europe (D, A, CH) the standards and regulations vary between the states (Bundesländer, Kantone). On the base of the national standards and regulations the requirements are adapted to local situations and may be much more stringent. On one hand very advanced standards become possible with far more innovative areas, but on the other hand the situations tend to become very complex and difficult to survey if every municipality has its own regulation. These countries try to harmonise their standards on a high level.

European Standardisation.

The development of European standards and regulations is confronted with the same duty to harmonise all these standards but to allow regional needs and variety at the same time.

Levels of Standardisation

The standardisation of ventilation is made on various levels. Although the levels are for all countries very similar there are big differences in what is regulated how and on what level. From indirect standardisation forms like guidelines or the code of practice over standards or regulations it may reach to law and sometimes even to the constitution (e.g. energy act in CH).

Table 3.: Levels of standardisation

Levels	Aspects	NL	CH
Law	Airflow		
	Comfort		
	Noise		
	Energy		
Building regulations	Airflow	r	r/t/s
	Comfort	r	r/t/s
	Noise	r	r/t/s
	Energy	r	r/t/s
Standards	Airflow	t	r/t/s
	Comfort	t	r/t/s
	Noise	t	r/t/s
	Energy	t	r/t/s
Guidelines	Airflow	s	r/t/s
	Comfort	s	r/t/s
	Noise	s	r/t/s
	Energy	-	r/t/s
Code of practice	Airflow		r/t/s
	Comfort		r/t/s
	Noise		r/t/s
	Energy		r/t/s

r: requirements; t: testmethods; s: solutions

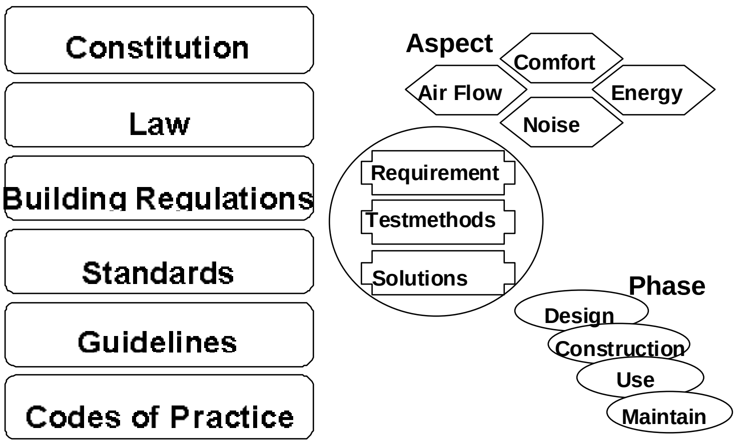

Figure 1.: Levels of standardisation

Responsibilities

According to the geographic approach and the level of national or regional standardisation, public or private bodies are responsible for standardisation. Besides the governmental bodies which are responsible on law and regulation level, most countries have an official body which is responsible for standardisation. This body may be a public national institute for standardisation like in France (AFNOR), or a public authorised private institution, like in Switzerland (SIA). In most cases national standardisation organisations develop the standards in close co-operation with the main public, private or semi-private institutions and industry in their respective countries. These institutions are mainly industry- and research associations and –institutes.

Technological levels of standardisation

Ventilation is standardised on very different technological levels. The most important codes are the building code and the energy code, but other standards for components and for testing methods, material standards or the health- and environmental codes have to be met by the ventilation. The range of standards and regulations which influence the performance of ventilation systems is very wide.

Complex procedures

Standards and Regulations are in most countries a complex structure of interacting instruments. Referencing to each other or repeating and citing is very common. Due to very different procedures for the development of the standards and regulations the status of many instruments may sometimes be unclear: Is it in force or not? Is it updated? Due to the very complex standardisation procedure it comes for example in Switzerland to the paradoxical situation, that the legislation (which is believed to be slow) produced new requirements before the standards are updated.

The work of CEN TC 156 Ventilation within Buildings

CEN/TC 156 Ventilation for buildings
Work programme – July 2000

The European Union wishes to encourage free trade within the Union and as part of this role created a Construction Products Directive to enable the member countries to harmonise standards. The European Committee for Standardisation (CEN) set up a Technical Committee on Ventilation for buildings (CEN TC 156) in 1989. The scope was 'Standardisation in the field of ventilation and air conditioning systems for buildings subject to human occupancy'. Each country is invited to have a representative on the Technical Committee and the British Standards Institution represents the United Kingdom. The Technical Committee has nine groups of experts who are preparing the draft standards and the technical guidelines. The Groups submit their reports to the Technical Committee for approval.

The nine working groups are
1. Terminology
2. Residential ventilation
3. Ductwork
4. Terminal units and air terminal devices
5. Air handling units
6. Design criteria
7. System performance
8. Installation (modelling commissioning)
9. Fire and smoke protection (for the ventilation system)

Working Group 6 Design Criteria, convened by Professor Ole Fanger, prepared a draft document in 1993 which the Technical Committee agreed should be developed as a CEN Pre-standard prENV 1752 Pre-standards are publicly available for three years and then reviewed to determine whether or not they should be adopted as full standards. In the meantime individuals can choose to use them if they wish.

See new items in annex (March 2001)

Items published

Work item	Reference	Title
156029	CR 1792	Symbols, units and terminology
156034	EN 1505	Sheet metal air ducts and fittings with rectangular cross-section - Dimensions
156039	EN 1506	Sheet metal air ducts and fittings with circular cross-section – Dimensions
156045	ENV 12097	Ductwork - Requirements. for ductwork components to facilitate maintenance of ductwork systems
156037	EN 12220	Ductwork – Dimensions of circular flanges for general ventilation
156052	EN 1886	Air handling units - Mechanical performance
156046	EN 1751	Air terminal devices - Aerodynamic testing of dampers and valves
156056	CR 1752	Design criteria for the indoor environment
156059	EN 12599	Test procedure and measuring methods for handling over installed ventilation and air conditioning system

49. Available for the formal vote

Work item	Reference	Title
156065	prEN 13264	Floor mounted air terminal devices - Tests for structural classification
156038	prEN 13180	Ductwork - Dimensions and mechanical requirements for flexible ducts
156047	prEN 12238	Air terminal devices - Aerodynamic testing and rating for mixed flow applications
156053	prEN 13053	Air handling units - Rating and performance for units, components and sections
156060	prEN 12239	Air terminal devices - Aerodynamic testing and rating for displacement flow applications
156061	prEN 13181	Terminals - Performance testing of louvres subject to simulated sand

48. With Secretary for forwarding to CMV for formal vote

156050	prEN 13030	Terminals - Performance testing of louvres subject to simulated rain

46. Report on enquiry with WG for a ction

Work item	Reference	Title
156030	prEN 13141-1	Performance testing of components/ products for residential ventilation - Part 1. Externally and internally mounted air transfer devices
156031	prEN 13142	Components / products for residential ventilation – Required and optional performances characteristics
156033	prEN 13465	Calculation methods for the determination of air flow rates in dwellings
156036	prEN 12236	Ductwork hangers and supports - Requirements for strength
156049	prEN 12589	Air terminal units - Aerodynamic testing of constant and variable rate terminal units
156057	PrEN 13779	Performance requirements for ventilation and air-conditioning systems
156063	prEN 13182	Instrumentation requirements for air velocity measurements in ventilated spaces
156066	prEN 13141-2	Performance testing of components/products for residential ventilation - Part 2. Exhaust and supply air terminal devices
156067	prEN 13141-3	Performance testing of components/products for residential ventilation - Part 3. Range hoods for residential use
156068	prEN 13141-4	Performance testing of components/products for residential ventilation - Part 4. Fans used in residential ventilation systems
156069	prEN 13141-5	Performance testing of components/products for residential ventilation - Part 5. Cowls and roof outlet terminal devices
156070	prEN 13141-6	Performance testing of components/products for residential ventilation - Part 6. Exhaust ventilation system packages used in a single dwelling
156074	prEN 13403	Non-metallic ducts – Ductwork made from insulation ductboards

46/42. Second enquiry document circulated

156040	prEN 1507	Ductwork - Rectangular sheet metal air ducts - Requirements for testing strength and leakage
156041	prEN 12237	Ductwork - Circular sheet metal air ducts - Requirements for testing strength and leakage

40. Sent to CMC for enquiry

156075	PrEN 13141-7	Performance testing of mechanical supply and exhaust units (including heat recovery) for mechanical ventilation systems intended for single family dwellings

34. Being prepared for formal vote

Work item	Reference	Title

32. Approved for enquiry

Work item	Reference	Title
156032	N544	Performance testing and installation checks of residential ventilation systems

32. Being examined by the CEN/TC

Work item	Reference	Title
156042		Ductwork - Determination of mechanical energy loss in ductwork components

11. In a first programming phase

Work item	Reference	Title
156035		Ductwork - Measurement of duct surfaces
156051		Terminals - Comfort criteria
156058		Cooling load
156064		Residential ventilation - Design and dimensioning of systems
156071		Air terminal devices - Method for airflow measurement by calibrated sensors in ATD/plenum boxes
156072		Chilled ceilings and beams - Testing and performance requirements
156073		Fire precautions for air distribution systems in buildings
156076		Symbols, units and terminology
156077		Calculation methods for air flow rates in commercial buildings
156078		Calculation methods for energy losses due to ventilation and infiltration in commercial buildings
156079		Calculation methods for energy losses due to ventilation and infiltration in dwellings
156080		Air terminal devices – Aerodynamic testing and rating for mixed flow applications for non-isothermal testing

APPENDIX I Conversion Factors

Unit From	Unit to
1 CFM	0.47 l/s
1 CFM	1.7 m^3/hr
1 l/s	2.12 CFM
1 l/s	3.6 m^3/h
1 m^3/h	0.28 l/s
1 dm^3=1 litre=0.001m^3	
1 ft^2	0.093 m^2
1 ft^3	0.028 m^3

THE AIR INFILTRATION AND VENTILATION CENTRE was inaugurated through the International Energy Agency and is funded by the following countries:

Belgium, Denmark, Germany, Greece, Finland, France, Netherlands, New Zealand, Norway, Sweden, United Kingdom and United States of America.

The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.

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