International Energy Agency

IEA ECBCS Annex 27
Evaluation and Demonstration of Domestic Ventilation Systems

Simplified Tools Handbook

Energy Conservation in Buildings
and Community Systems

Simplified Tools Handbook
Evaluation and Demonstration of Domestic Ventilation Systems

Edited by Lars-Göran Månsson

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Preface

International Energy Agency (IEA)

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 24 IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of 46 current Implementing Agreements (IA).

Energy Conservation in Buildings and Community Systems Programme

One of the areas of IEA sponsored RD&D co-operation is the IA Energy Conservation in Buildings and Community Systems Programme. The activities within this IA include 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 behaviour. There are 22 participating countries, as well as the Commission of the European Communities (CEC).

Member Countries of the Implementing Agreement
Australia, Belgium, Canada, CEC, Czech Republic, Denmark, Finland, France, Germany, Greece, Israel, Italy, Japan, The Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, Switzerland, Turkey, UK, USA.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures that all projects fit into a pre-determined strategy without unnecessary overlap or duplication but with effective liaison and communication.

To date, the following projects (Annexes) have been initiated by The Executive Committee. Completed projects are identified by *

Annex Number	Project Title
1*	Load Energy Determination of Buildings *
2*	Ekistics and Advanced Community Energy Systems *
3*	Energy Conservation in Residential Buildings *
4*	Glasgow Commercial Building Monitoring *
5	Air Infiltration and Ventilation Centre
6*	Energy Systems and Design of Communities *
7*	Local Government Energy Planning *
8*	Inhabitant Behaviour with Regard to Ventilation *
9*	Minimum Ventilation Rates *
10*	Building HVAC Systems Simulation *
11*	Energy Auditing *
12*	Windows and Fenestration *
13*	Energy Management in Hospitals *

14*	Condensation and Energy *
15*	Energy Efficiency in Schools *
16*	BEMS 1 – Energy Management Procedures *
17*	BEMS 2 – Evaluation and Emulation Techniques *
18*	Demand Controlled Ventilating Systems *
19*	Low Slope Roof Systems *
20*	Air Flow Patterns within Buildings *
21*	Thermal Modelling of Buildings *
22*	Design of Energy Efficient Communities & Urban Planning *
23*	Multizone Air Flow Modelling (COMIS) *
24*	Heat Air and Moisture Transport in Envelopes *
25*	Real Time Simulation of HVAC systems *
26*	Energy Efficient Ventilation of Large Enclosures *
27*	Evaluation and Demonstration of Domestic Ventilation Systems *
28*	Low Energy Cooling Systems*
29*	Daylight in Buildings *
30*	Bringing Simulation to Application
31	Environmental Impact of Buildings
32*	Integral Building Envelope Performance Assessment
33*	Advanced Local Energy Planning
34*	Computer Aided Evaluation of HVAC Systems Performance
35	Hybrid Ventilation in New and Retrofitted Office Buildings
36	Retrofitting Educational Buildings
37	Low Exergy Systems for Heating and Cooling
38	Solar Sustainable Housing
39	High Performance Thermal Insulation
40	Commissioning of Building HVAC Systems to Improve Energy Performance

Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems

The main motivation for initiating this Annex was the need to develop tools to better evaluate domestic ventilation systems in various situations. Different systems in various climates must handle situations with a large range of residential behaviour. With the use of the most complex models and development of new ones a large number of combined situations enable us to develop simplified tools, that can be used by practitioners in specific cases.

This report presents the various simplified tools and an application of the use of the tools on a specific case. In more elaborated background reports the detailed results on which the simplified tools are based can be found. Also more precise values can often be calculated by using the background reports.

Participation
Participating countries have been:
Canada, France, Italy, Japan, The Netherlands, Sweden, UK, USA.

Acknowledgements

This work has been made possible by funds from different organisations within the participating countries. I would like to address my thanks to all these funding bodies: private companies, governmental, institutes and others that made it possible to us in the Annex to make the results come out of our effort.

I would also like to give my thanks to the reviewers of the work and who were: Stanislaw Mierzwinski (Silesian Technical University, Gliwice, Poland), Veijo Matilainen (ENERTEK OY, Finland), and Conny Rolén (Swedish Council for Building Research, Sweden).

Lars-Göran Månsson
Operating Agent for ECBCS Annex 27

Contents

1 Introduction

This introductory chapter gives the background and the reasons for starting an international collaboration on domestic ventilation systems. The objectives are given and the means to fulfil these goals are briefly described. This report is a concluding work and a summary of all the background reports. For a reader interested in the details of the work, they should read the detailed background reports which describe the reasoning behind the assumptions, the chosen parameters, the measurements, the simulation results, etc.

1.1 Background

Ventilation is of major importance for the well-being of people in their homes. The rate of outdoor air supply as well as comfort aspects associated with air distribution and the ability of a system to remove pollutants are important factors to be considered at the design stage, during the commissioning procedure and when using the building during its life-time.

The two main purposes of ventilation are to obtain an acceptable indoor air quality and to avoid degradation of the building fabric e.g. rot in wood, rust on steel. The definition of “acceptable indoor air quality” is not easy to define, especially in dwellings. However, everyone should have the right to an acceptable indoor air quality at home. As distinct from a workplace, residents’ sensitivity can vary across a wide span from an allergic infant to a well trained sportsman, from an active person spending most of their time outdoors to an elderly person confined to a life indoors.

During the lifetime of a building, its occupancy patterns vary. This results in a varying need for outdoor air to obtain acceptable indoor air quality (IAQ) and avoid degradation of the fabric. Emissions from building materials are also time dependant. When the building is new or recently refurbished it may be necessary to dilute the emissions by increased flow rate. In standards and codes the supply air needed in a dwelling is generally based on the maximum number of persons living in the dwelling defined by the possible number of beds contained therein. Statistics from various IEA countries indicate that, in general, about 50 % (range 46 – 71 %) of the dwellings have only one or two residents.

Dwellings represent about 25 – 30 % of all energy used in the OECD countries, and domestic ventilation will in the future represent up to 10 % of the total energy use. Thus even a relatively small reduction in the overall ventilation levels could give significant savings in the total energy use. Of course, the great potential for savings is in the existing buildings.

Today there is a vast range of different ventilation strategies in the different OECD countries. In some countries the only ventilation present is adventitious ventilation and window airing, while in others natural stack ventilation systems are more or less in common use. In countries with colder climates, mechanical systems have been installed in new buildings during the last 15 – 20 years. The systems are either exhaust only or balanced, with or without heat recovery units. However, the majority of the dwellings still have natural ventilation even in countries with colder climates.

Improvement of residential ventilation is of concern in both existing and future buildings. The functioning of the ventilation systems may deteriorate at all stages of the building process and during the life-time of the building.

1.2 Objectives

The overall objective has been to develop -tools for better selection of domestic ventilation systems, that can better predict the expected indoor climate and make a choice for the most likely situations in dwellings. The work within this IEA Annex 27 have been to:

- Develop tools for evaluating domestic ventilation systems
- Validate that the methods - work-
- Demonstrate the tools

The main aim with this report is to give guidance on how to use the tools for evaluating domestic ventilation systems in different situations.

1.3 Subtasks

The Annex has been divided into subtasks dealing with specific topics. The main goal to give tools usable for practitioners has resulted in splitting up the work in the following way:

First the background data was collected in a State of the Art report (Månsson 1995) which included statistical data on housing, frequently used systems, standards and codes, reviews of recent research reports on material emissions, residents' behaviour, and evaluation methods. The report was a collection of background material for the assumptions needed in the ensuing work.

Simplified tools were developed for evaluation of ventilation systems. Tools have been developed for energy, thermal comfort, noise, inside to outside pressure difference, life cycle cost, reliability, user and building aspects, indoor air quality for constant emission sources, CO_2, tobacco smoke, cooking products, water vapour in habitable rooms and the bathroom.

There was a need to validate the developed simplified tools. Hence measurements have been performed in a range of dwellings both to validate the tools and give background material.

1.4 Target Audience

Decisions on ventilation are made in all countries by standards bodies, policy makers, companies involved in the housing industry, and others. But these decisions have been made without a comprehensive evaluation method. Research in recent years described in the IEA Annexes, for instance, now makes it possible to formulate such methods to evaluate domestic ventilation systems. The tools developed can be used both for new and for renovating existing dwellings, and for detecting, analysing and solving problems.

1.5 Handbook Use

In general the handbook can be used for new dwellings, renovation of existing buildings and to find explanations for certain situations for existing systems. A very easy way to handle the tools is to follow the flow chart in figure 2.1. For each of the tools, there are tables that provide results mostly in a qualitative way. The selection of one parameter may give an excellent quality for one tool whilst giving an adverse effect on another one. This might result in an iterative procedure, necessitating going through the flow chart more than once, to come to a final satisfactory result.

The easiest way is to look at the Chapter 11 'Application' and then go back to each of the tool chapters to find the result of your own chosen example.

For those that are interested in detailed analysis where the number of residents varies over the life-time of the dwelling and different sizes of the dwelling we recommend you read the more detailed background reports. This is also the case if you want to use your own experienced values for e.g. reliability of system performance and life cycle cost calculations.

2 System Selection Procedure

Simplified tools have been developed to evaluate each of the different major aspects that have to be taken into account when selecting a ventilation system for dwellings. Figure 2.1 is a flow chart that shows a systematic procedure to address all these major aspects. In Chapters 3 – 10, each of the aspects is addressed and a description given of how to use the simplified tools. The tool application is demonstrated in Chapter 11 on a specific case. All the tools have been developed for all three climates.

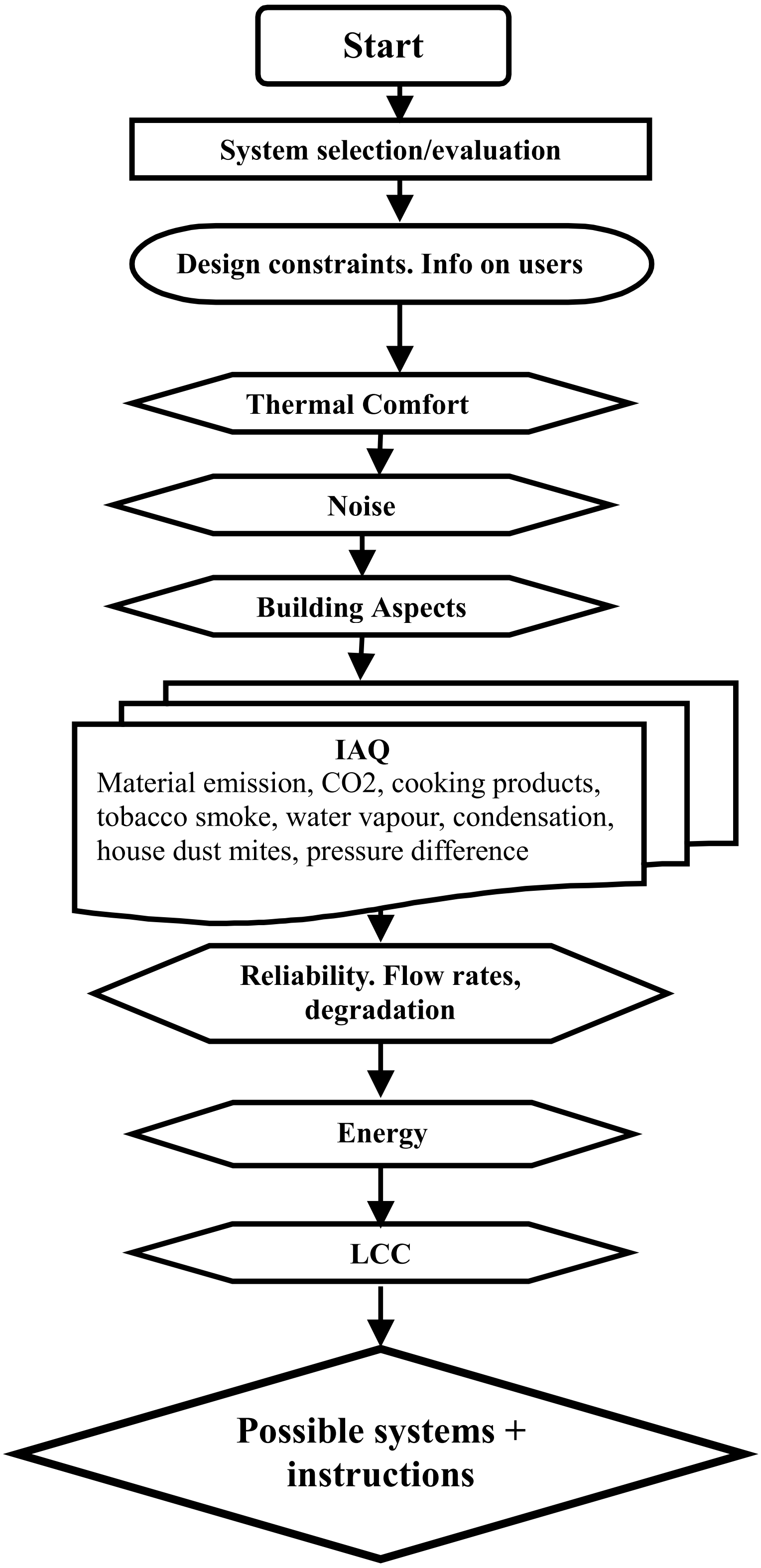


Figure 2.1 Tool Flow Chart

3 Design Constraints

Definitions

The definitions and abbreviations of the various ventilation systems used in this document are:

• Natural Window Airing (NWA)	Natural supply and exhaust through windows. Purpose provided openings, inlets, in external walls or windows can be installed
• Passive Stack Ventilation (PSV)	Natural supply through windows. Purpose provided openings, inlets, in external walls or windows can be installed. Exhaust through vertical ducts giving the stack effect
• Mechanical Exhaust Only (MEO)	Natural supply through windows. Purpose provided openings, inlets, in external walls or windows can be installed. Mechanical exhaust air by using a fan.
• Mechanical Supply and Exhaust (MSE)	Mechanical exhaust and supply by fans. Sometimes a heat exchanger is also installed to recover the heat (MSE-X)

Other expressions abbreviations etc are to be found in “Air Infiltration and Ventilation Glossary” Technical Note 36 from the AIVC.

3.1 National Codes and Standards

In the design process the standards and codes have to be identified. By using this method presented here it might be easier to motivate and use alternative methods.

3.2 User Aspects

3.2.1 Introduction

What we mean by ‘user aspects’ is the interaction between the residents and the ventilation system itself. As everyone lives somewhere, the variation between residents is much wider than in the work place. Also, people can be sick, occasionally or permanently, and still be at home. Indoor activities range from being fairly inactive, e.g. sleeping, to being very highly active e.g. wrestling. The pollutants given off vary from emissions from plants, detergents, benzene, to glue etc. aside from the more common pollutants like water vapour, tobacco smoke and emissions from the building fabric. Background material on residents’ habits have been collected in a state of the art report, Månsson (1993) and is used to define the variation in behaviour.

3.2.2 Input information

When applying the tools on a real case some knowledge of the user is needed. A description of the household that focuses on the aspects that have influence on the use of ventilation is also required. The most crucial influencing habits must be identified.

The user aspects are split into three groups: behaviour, lifestyle and user characteristics. When the tool is only used for evaluation, a faster selection process can be made by considering the most influential user aspect for each group.

3.2.3 Output

With the user information, the tool provides 'warning flags' to highlight the influence of particular user aspects on the operation of the ventilation system. The rating ranges from no warning flags, which means that the particular user aspect is insensitive to the operation of the ventilation system, to three warning flags, which mean the particular user aspect is very sensitive to the operation of the ventilation system. If as described above, one user aspect is chosen for each group, and all three aspects have three warning flag, one must be aware that the ventilation system is very sensitive to the user.

3.2.4 Tool

The tool is based on the values in Table 3.1. The table gives the relative impact of the characteristics of the residents on the four ventilation systems. It includes many types of human behaviour and reactions to different situations, which is in fact a series of attitudes in the user's interaction with the system. The three main aspect groups are:

- Behaviour
- Life style
- User characteristic

Table 3.1 Influence of user on the ventilation systems

Group	**Aspect**	**Ventilation system**			
		Natural Window Airing (NWA)	Passive Stack Ventilation (PSV)	Mechanical Exhaust Only (MEO)	Mechanical Supply and Exhaust (MSE)
Behaviour	User influence	✋✋✋	✋✋	✋	✋
	Maintenance	✋	✋	✋	✋
	Furniture and decoration	✋✋✋	✋✋✋	✋✋	✋✋
	User reaction	0	✋	✋	✋✋
Lifestyle	Cooking	✋✋✋	✋✋	✋	✋
	Smoking	✋✋✋	✋✋✋	✋✋	✋✋
	Hygiene	✋✋✋	✋✋✋	✋✋	✋
	Redecoration interval	✋✋	✋✋	✋	✋
	Other equipment installed	✋	✋	0	0
	Pets	✋✋	✋✋	✋	✋
	Pot Plants	✋	✋	0	0
User Charac teristics	Involvement	✋✋	✋✋	✋	✋
	Knowledge	✋✋	✋✋	✋	✋
	Physical capability, operation	✋✋✋	✋✋	✋	0
	Physical capability, maintenance	0	✋✋	✋	✋

✋✋✋ Very Sensitive, ✋✋ Sensitive, ✋ Slightly sensitive, 0 Neutral

Behaviour is the first groups of user aspects and these affect the ventilation system directly. Each of these actions inside the dwelling may affect in a considerable way the correct operation of the system.

Lifestyle is the second group of user aspects. These affect the immediate environment of a system user, which will in turn require an increase or decrease in the ventilation loads and efficiency. Examples include cooking, smoking etc.

User characteristics is the third group of user aspects and includes features of the user. It is particularly related to the self characteristics of the owner of the system. It involves aspects linked to culture, interest, manual capability and income. In case of a single family house may be the same as the resident, but for multifamily buildings it involves the occupant, the property owner and the person at the organisation responsible for the operation and maintenance.

3.2.5 Further information

There is a trend progressing from designing ventilation systems with fixed flow rates that are independent of the user towards varying system designs to meet the needs of the user. In order to best achieve this, investigations are being performed to increase the knowledge of people's basic living attitudes (incorporating all three groups of user aspects). This is discussed further in the background paper.

3.3 Dwelling Types Used

A survey of typical dwellings was made in both the participating countries and some other IEA countries. Together with the information about average dwelling sizes and the area per person a first selection of dwellings for this task was made. We found that some dwelling sizes were very similar in different countries. Then we contrived a series of dwellings for single family houses and for flats in multi storey buildings ranging from one room to five rooms. As we had to limit the number of combinations considered, we selected two dwelling sizes. A one room flat with one person residing could be covered by cases also for a four or five room flat with four or five persons living there. The reason for that is also that the number of rooms per person is similar in most IEA countries, see Månsson (1995). The worst cases can be found also in the selected dwelling types. Those dwellings were selected for the statistically selected combinations. For the simplified IAQ tools only four habitable room dwellings have been used (i.e. a living room plus 3 bedrooms in each case).

The three types of dwellings that were selected are:

- A four room flat on ground floor in four storey building. D4A
- A four room flat on top floor in four storey building. D4A
- A two storey detached single family house with four rooms. D4C.

If you have larger dwellings in your case, you may be able to use our cases but compare with fewer residents in one of our selected dwellings. For smaller dwellings you may be able to compare with our selected cases and choose more residents than in your case. However, there is no extreme case chosen for the number of residents in a dwelling. The maximum is 5 persons in a dwelling. When studying the frequency of how many persons a household have, it is not very likely that there is more than 5 persons besides a few percentage of the total.

The height of the building can be disputed. Here we have chosen to exclude high rise buildings. The initial surveys showed that this type of building is not particularly common. Most apartments are in lower buildings. We have selected a four storey building. If a higher building is selected the ground floor apartment is more affected by the stack effect If a one storey house (bungalow) is your case, you may be able to compare with a flat on a top floor position and also check with the detached house case.

The room height is 2.5 m and the construction height is 2.8 m defined to be from the top of the floor on one storey to the top of the floor in the next storey.

3.4 Climate

Three climates have been chosen represented by the following cities Nice, London, and Ottawa. The data used from the weather stations are outdoor temperature, wind speed, wind direction, and water vapour content. For comparisons with other climates, see Chapter 7.

3.5 References

1. Limb M. (1992). *Air Infiltration and Ventilation Glossary*. TN 36 AIVC. ISBN 0 946 075 58 1
2. Månsson L-G (1995). *Evaluation and Demonstration of Domestic Ventilation Systems. State of the Art.* Swedish Council for Building Research A12:1995. ISBN 91-540-5731-0.
3. Giorgiantoni G. (1998). *Background report on User Aspect.*

4 Thermal Comfort

4.1 Introduction

The supply of outdoor air by a ventilation system to an indoor space can have an impact upon the thermal comfort of the occupant(s) especially in winter. Research performed for this IEA Annex has shown that different methods of air supply have a different impact on thermal comfort, even for the same supply rate and temperature. Thus the risk of draughts due to ventilation can be reduced or eliminated by a careful choice of the method of air supply. Furthermore, the thermal comfort impact due to the ventilation system is directly related to the performance of the ventilation system. For example, if an occupant feels a cold draught from air coming through an air vent, he or she may close it to avoid poor thermal comfort, although the indoor air quality is equally as important as thermal comfort.

This simplified tool allows the user to compare the thermal comfort impact of different types of air inlet or ventilation system. This tool uses the results from an experimental program that was performed for this IEA Annex.

4.2 Tool Description

4.2.1 Input data

The user needs to select choices for five input parameters. These parameters are: (a) the type of ventilation system, (b) the method of air supply, (c) the outdoor temperature, (d) the air supply rate and (e) natural ventilation rates.

Ventilation system
There are four choices of ventilation system:

1. Natural Window Airing (NWA)
2. Passive Stack Ventilation (PSV)
3. Mechanical central exhaust and natural supply (MEO)
4. Mechanical central supply and exhaust (MSE)

Method of air supply:
There are three choices of air supply:

1. **Background leakage (infiltration).**

Supply air is provided through cracks that are distributed on the exterior walls, roof and floor. The distribution of supply air cannot be controlled easily like air supply devices for which the location can be selected. In the experimental program, the background leakage was simulated by deep slits as shown in Figure 4.1 (g). Ten or twenty slits were distributed on the wall depending upon the air tightness of the building envelope.

2. **Window airing or low-induction natural supply vents**

These openings are used to supply outdoor air at a low velocity. In the experiments, openings with equivalent leakage area of 62.3 cm^2, which are shown in Figures 4.1(d), (e) and (f), were used to simulate these two methods of air supply.

3. **High-induction natural supply vent**

This type of opening is used to supply air at a high velocity. In the experimental research program, it was shown that the direction of the supply air was critical to the thermal comfort. Thus for this method of air supply, the user also needs to select the air supply direction from three choices: upward, radiant and horizontal. These three choices are shown in Figures 4.1 (a), (b) and (c) respectively.

- **Outdoor temperature**

Thermal comfort is a more important problem at lower outdoor temperatures. Therefore for this tool an outdoor temperature should be chosen such that for 90% of the time the temperature is above this value. The tool provides a choice of seven outdoor temperatures: -15 °C, -10 °C, -5 °C, 0 °C, 5 °C, 10°C, 15°C.

- **Air supply rate**

This tool allows a choice of two air supply rates: 4l/s (15m^3/h) and 10l/s (35m^3/h). It is sufficient to only have two values as the air supply rate has a limited impact on thermal comfort.

(e) Prediction of natural ventilation rate from leakage

The prediction is made for a two storey detached house. The equation is

$$\log Q = 0.0475 + 0.859 \log\{(X_1 + X_2)\cdot S\} + 0.621 \log(0.00921 X_3 + 0.0357 \cdot X_4 \cdot X_5^2)$$

where

Q	= ventilation rate [m³/h]	
X_1	= Equivalent Leakage Area (ELA) per floor area for leakage [cm²/m²]	
X_2	= ELA per floor area for natural ventilation [cm²/m²]. (Purpose provided openings.)	
S	= Floor area [m²]	
X_3	= Temperature difference Δt [ºC]	
X_4	= Shielding related factor:	0.1 for densely built area inside cities 0.4 for dwelling area in suburbs
X_5	= Velocity [m/s]	

Conversion from n50 to X_1
n50 = $1.31\cdot X_1$

Example: Leakage n50 = 6. Openings for natural ventilation $X_2 = (70\cdot5)/100=3.5$ [cm²/m²]. , Temperature difference X_3 = 23 ºC at the indoor temperature 20 ºC and outdoor –3 ºC. Shielding factor in suburbs X_4 = 0.4. The velocity X_5 = 3 m/s

All this gives logQ = 1.698 which gives Q = 50 l/s or 179.6 m³/h

4.2.2 Output data

The tool was developed from experimental data, which was obtained in a particular room (as shown in Figure 4.2) of a research house which itself is contained inside an artificial climatic chamber. There are a number of factors that determine the risk of draughts occurring, in particular the vertical temperature profile, air velocity, turbulent intensity and surface temperature of the surroundings are very important. However, these parameters are influenced not only by the cold fresh air supply but also by the thermal insulation of the envelope, heating method etc and it has not been possible to investigate these latter effects. The shape of the room and the layout of windows are also important factors. All these factors could not be taken into account, when this simplified tool was developed.

Experiments were performed using all the combinations of input parameters described previously. These results were used to provide a simplified tool, giving a rating of five categories from "- -" to "+ +". The score for each set of input parameters can be obtained by referring to Table 4.1 and Table 4.2. The score "+ +" means the smallest impact on thermal comfort, and the score "- -" means the severest impact on thermal comfort. Further information can be found in Section 4.6.

The experiments showed that the lower part of the room is most critical for the risk of draught, as the lowest temperatures usually occur near the floor and cold air flows tends to fall down the room with higher velocity. By raising overall room temperature, draught risk for the lower part of the room can be avoided. It means that the heat supply is one of the most important factors affecting the risk of draught.

4.2.3 Evaluation procedure

The user should first follow the flow chart given in Figure 4.3 using the input data chosen previously. The user is then referred to a line in either Table 4.1 or 4.2 to obtain the result for thermal comfort.

4.3 Limitations

The impact to thermal comfort due to the supply of cold outdoor air can be reduced by correctly siting heating appliances. For example, when a radiator is placed just below the inlet, the cold air can be preheated before reaching the lower part of the room. However, in this simplified tool, such countermeasures have not been taken into account. If an inlet is used that has a more severe impact on thermal comfort, the user should note that the thermal comfort can be improved by correctly siting a heating appliance.

Table 4.1 Thermal comfort impact of fresh air supply Q=35m^3/h (10 l/s)

Type of Inlet (Vent)		Outdoor Temperature (ºC)						
Generic type	**Specific type**	**-15**	**-10**	**-5**	**0**	**5**	**10**	**15**
High induction	Upward direction flow	-	-	0	+	++	++	++
	Radiant flow	--	--	-	-	0	++	++
	Horizontally straight flow	--	--	--	--	-	+	++
Low induction or Window ajar	Horizontal opening, high position	--	-	-	0	+	+	++
	Vertical opening, middle height	--	--	--	--	--	-	-
	Horizontal opening, low position	--	--	--	--	--	-	-
Background leakage *	N50 = 1.5 ach level (relatively high speed infiltration)	--	-	-	-	-	0	0
	N50 = 2.6 ach level (relatively low speed infiltration)	--	--	--	-	-	+	++

*) Equally distributed leakage air flow path on exterior walls
Criteria for Scoring the percentage of lattice points satisfying thermal comfort conditions
(1) and (2): 100-95% “++”; 95-85% “+”; 85-75% “0”; 75-50% “-”; 50-0% “--”.

Table 4.2 Thermal comfort impact of fresh air supply Q=15m^3/h (4 l/s)

Type of Inlet (Vent)		Outdoor Temperature (ºC)						
Generic type	**Specific type**	**-15**	**-10**	**-5**	**0**	**5**	**10**	**15**
High induction	Upward direction flow	-	0	+	+	++	++	++
	Radiant flow	--	-	-	0	+	++	++
	Horizontally straight flow	--	--	--	--	-	+	++
Low induction or Window ajar	Horizontal opening, high position	--	-	-	-	+	++	++
	Vertical opening, middle height	--	--	--	--	-	-	-
	Horizontal opening, low position	--	--	--	--	-	-	0
Background leakage *	N50 = 1.5 ach level (relatively high speed infiltration)	--	--	-	-	-	0	+
	N50 = 2.6 ach level (relatively low speed infiltration)	--	--	--	-	0	++	++

*) equally distributed leakage air flow path on exterior walls
Criteria for Scoring the percentage of lattice points satisfying thermal comfort conditions
(1) and (2): 100-95% “++”; 95-85% “+”; 85-75% “0”; 75-50% “-”; 50-0% “--”.

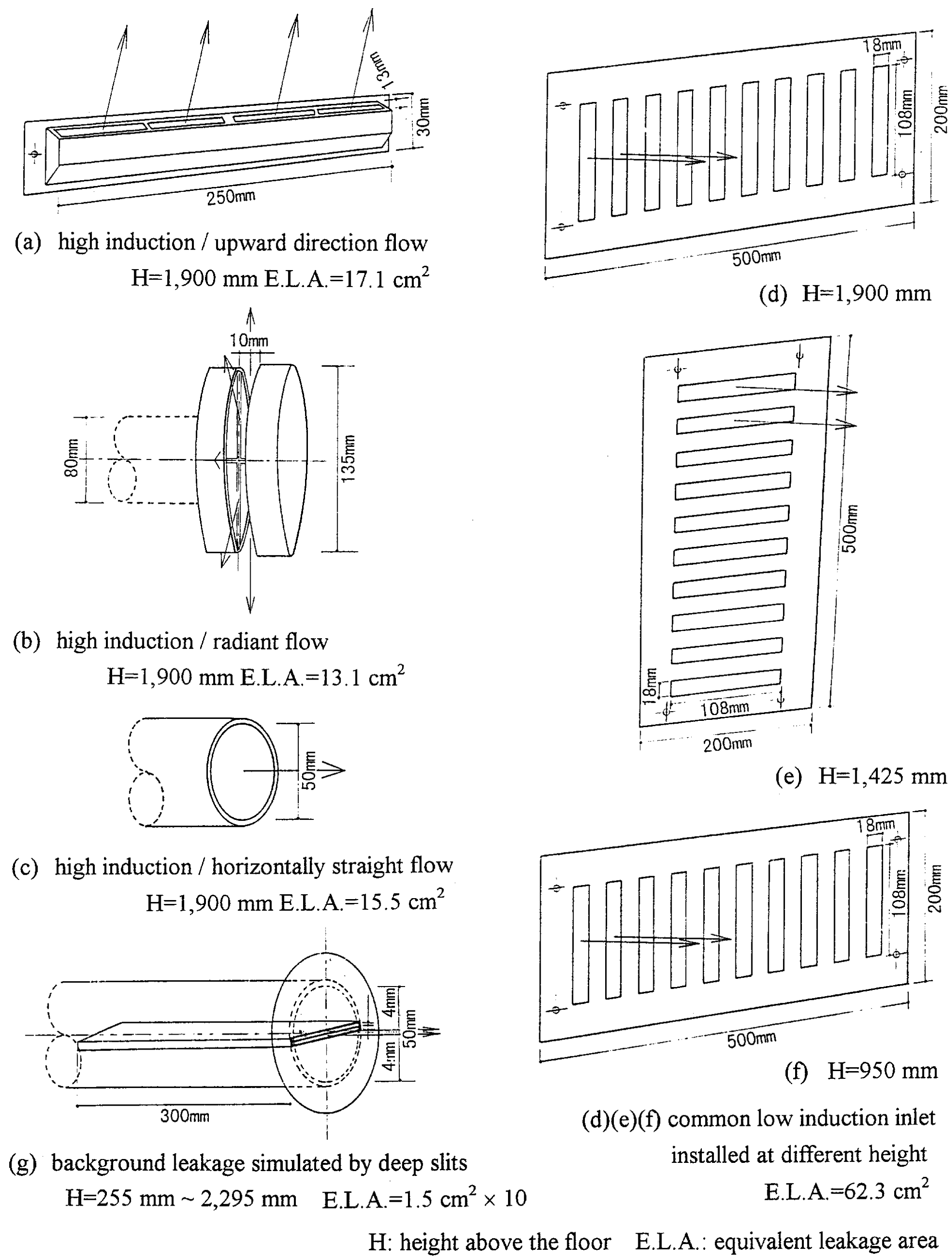


Figure 4.1 Inlet devices tested

4.4 Example

If a natural ventilation with a window open ajar as air supply at 1.9 m above floor is used, with an air supply rate of 15 m^3/h and an outdoor temperature of 10 °C, the score is "✚ ✚". The opening is considered as a low induction type inlet. If the change of supply rate due to wind is not negligible, the increase of turbulence intensity of indoor airflow can make draught risk higher than the evaluation. Therefore, in such a case, the score should be carefully interpreted.

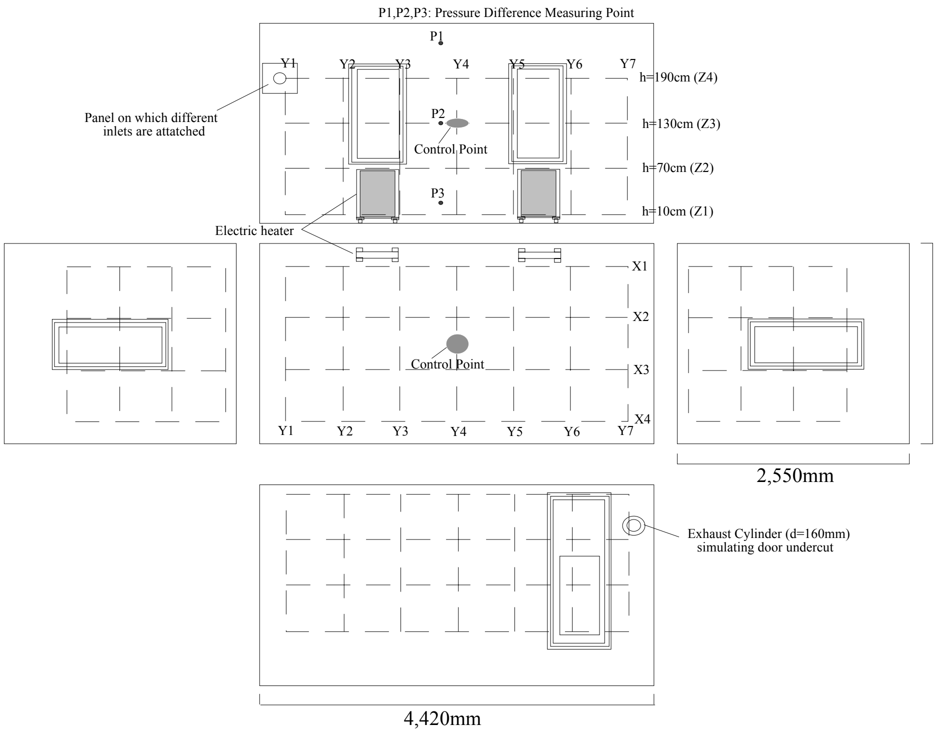


Figure 4.2 Elevation of the test room

When an exhaust only ventilation system with a high induction / radiant flow natural supply vent is used, an outdoor temperature of 0 °C and an air supply rate of 35 m^3/h, the score is “**-**”, which means the percentage of lattice point without difficulty to keep thermal comfort is 50-75%. Though thermal comfort situation depends not only upon ventilation system but also upon insulation, heating system etc., the percentage can be considered as an index for relative evaluation. The score, “-” means that there is still possibility for the improvement.

4.5 Further Information on the Design of the Simplified Tool

In the experiments, the heat supply was controlled to keep the predicted thermal sensation nearly equal to zero at a central point of 130 cm above the floor in the room. In each experiment, the thermal comfort was evaluated based on the percentage of lattice points in the room for which the difference of the predicted thermal sensation defined as PMV (Predicted Mean Vote) from the centre is within ±0.2 and the predicted draught risk defined as PD (Percentage Dissatisfied) is lower than 15%. In other words, it expresses how small the distribution of thermal comfort conditions is inside the room. This was used to give the thermal comfort evaluation index used in the simplified tool. The user of the tool should note that it gives the relative evaluation of the methods to supply fresh outdoor air with the particular choice of room design and heating system.

Further information can be obtained in the background material for this simplified tool.

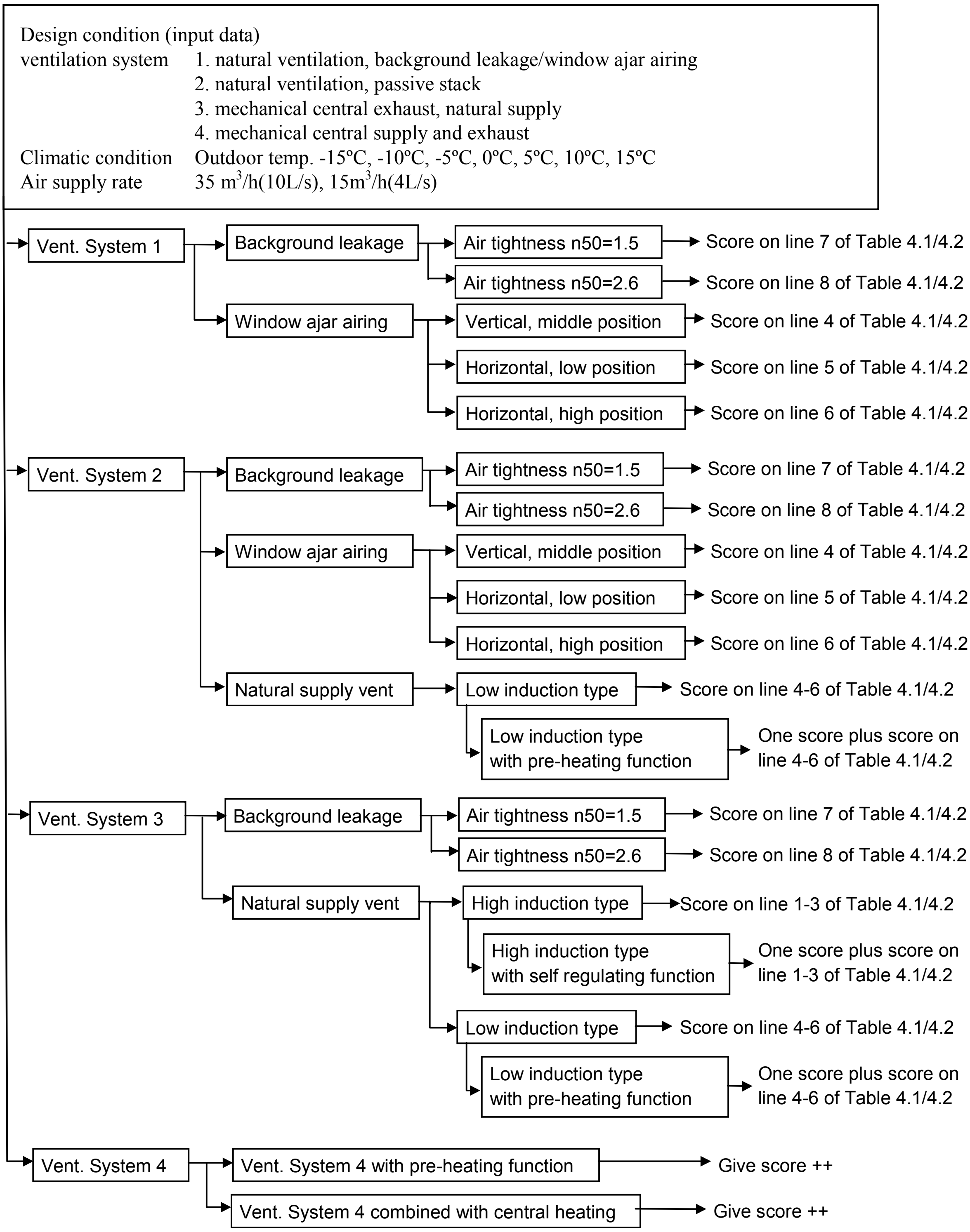


Figure 4.3 Flow chart for thermal comfort impact evaluation of outdoor air supply

4.6 References

1. Sawachi, T., Osawa, H., Seto, H., Taniguchi, Y. and Ohnishi, S. (1996) *Evaluation of Thermal Comfort Impact of Direct Fresh Air Supply in Winter,* Proceedings of INDOOR AIR '96 Vol. 3, pp1087-1092
2. Sawachi, T. and Seto, H. (1997) *Evaluation of Thermal Comfort Impact of Direct Fresh Air Supply in Winter, Part 2, Comparison of Different Ways of Air Supply to Exhaust Only Ventilation,* Proceedings of 18th Annual AIVC Conference
3. Fanger, P.O. (1970) *Thermal Comfort*, Danish Technical Press
4. Fanger, P.O., Melikov, A.K., Hanzawa, H. and Ring, J. (1988) *Air Turbulence and Sensation of Draft*, Energy and Buildings, 12, pp21-39
5. ASHRAE Handbook 1989 Fundamentals, 31.8
6. Sawachi T. (1998). Background report on Thermal Comfort.

5 Noise

This chapter contains simplified tools and guidelines for outdoor noise, system noise, and sound transmission

5.1 Introduction

The acceptance and appreciation of ventilation systems is mainly determined by the perceived indoor air quality, thermal comfort and noise. Noise in relation to ventilation systems can be divided into three categories:
- outdoor noise (entering the dwelling through ventilation openings, cracks, mechanical supply and exhaust openings etc.);
- noise generated by components of the ventilation system;
- sound transported within or between dwellings by the ventilation system.

For the consideration of noise, the four ventilation systems considered in this annex are grouped into the following three ventilation principles:
- natural air supply and natural air exhaust (NWA, PSV);
- natural air supply and mechanical air exhaust (MEO, including local and/or central systems);
- mechanical air supply and mechanical air exhaust (MSE).

Depending on the type of ventilation system and the strategy, one or more of the three areas indicated in Table 5.1 are important.

Table 5.1 Noise importance related to ventilation systems

	Natural ventilation (NWA, PSV)	**Natural supply mechanical exhaust (MEO)**	**Balanced Ventilation (MSE)**
Outdoor noise	x	x	o
System noise	-	x	x
Sound transmission	o	o	x

- irrelevant / not applicable
o slightly sensitive
x sensitive

For outdoor noise and system noise simplified tools are given. For sound transmission some guidelines are given. All tools and guidelines can be used in any type of climate.

The first tool, described in Section 5.2, makes it possible to select a ventilation principle in a noisy outdoor environment. The selection of the most appropriate ventilation system is based on the required noise reduction of the façade, the dimension of the ventilation opening, the dimension of the façade and the percentage of minor soundproofed parts of the façade.

The second tool, described in Section 5.3, gives a simplified tool for system noise, including the selection of a silencer within ventilation systems.

Section 5.4 provides some guidelines for preventing sound transmission within or between dwellings via the ventilation system (cross talk).

5.2 Simplified Tool for Ventilation and Outdoor Noise

5.2.1 Introduction

A number of decision matrices have been developed to determine the most efficient ventilation system in a noisy outdoor environment. These matrices are a simplified tool to select the most appropriate ventilation system for a room when:

- the required noise reduction of the room is known;
- the required size of the ventilation opening is known (based on the need of ventilation);
- the dimension of the façade and the percentage inferior sound proofing constructions of the façade are known.

5.2.2 Acoustic calculation

The noise reduction of a façade (G_A) is the difference between the outdoor noise level and the perceived indoor noise level:

$G_A = L_o - L_i$ [dB(A)] (1)

Where: G_A is the resulting noise reduction of a façade
L_o is the outdoor noise level
L_i is the indoor noise level

The allowable sound level in rooms caused by, for example, road traffic is 35 dB(A) according to ISO-1996. However lower indoor sound level may be required. The resulting sound reduction is determined by the overall sound reduction of the façade (R_A). Ventilation and infiltration through the building envelope is taken into account in the overall sound reduction R_A

$G_A = R_A + 10 \log A/S - 3$ [dB(A)] (2)

Where: R_A is the overall sound reduction of the façade in dB(A)
A is the room absorption of the room in m^2 sabine
S is the total surface area of the façade in m^2
-3 is the correction for direct sound field to diffuse sound field

The characteristic noise reduction of the façade ($G_{A;c}$) is obtained by transforming the noise reduction of the façade to standardized dimensions of the room. The characteristic noise reduction is with this a quantity for the performance-requirement of the façade and independent of room characteristics.

$G_{A;c} = G_A - 10 \log ((55.3 \cdot V)/(c \cdot T_o \cdot S))$ (3)

Where: V is the volume of the room in m^3
c is the velocity of sound, c = 331.8 m/s
T_o is the reverberation time in the room in s

5.2.3 Input parameters

5.2.3.1 Acoustic parameters

The user has to select the required noise reduction from equation (1). This simplified tool allows 4 required noise reductions: 20, 25, 30 and 35 dB(A).
The reverberation time in this tool is standardized to 0.5 seconds (This is an average for a standard furnished room).
The calculations are based on one noise-loaded façade.

The characteristic noise reduction of the façade is, in the simplified tool, used as variable because both the noise level on the façade and the required indoor noise level can vary.

5.2.3.2 Room parameters

The indoor noise level can be influenced by the shape of the room. In the tool, the following room parameters are standardized:

- a value of 3 m has been chosen for the ratio between volume of the room and the surface area of the façade (this is used to determine the characteristic noise reduction);
- a value of 2.5 m has been chosen for the height of the room.

The user has to select the width of the façade. The simplified tool provides a choice of 3 ranges of façade widths: 2 – 4 m, 4 - 6 m and 6 - 10 m.
The depth of the room is variable.

5.2.3.3 Construction parameters

The user has to estimate the percentage of inferior sound proofing construction parts in the façades and roofs (glazing, light weight panel constructions etc.) as a fraction of the total surface of the façade. A construction is considered as “inferior sound proofing” if the sound reduction of the construction $R_a <$ 40 dB(A).

5.2.4 Ventilation parameters

The user has to estimate the net surface opening in cm^2 of the purposed provided opening in the façade. In case of mechanical supply $A_{net} = 0$.

5.2.5 Output parameters

5.2.5.1 Assessment of ventilation systems by using the matrices

The matrices provide information about the consequences of using the ventilation systems on the required acoustic qualities of the other construction parts of the façades to achieve a given noise reduction in noisy outdoor environments. With the matrices it is possible to select a specific ventilation system in combination with certain sound proofing constructions to achieve these conditions. It is also possible to make a comparison of combinations, for instance. An inferior sound proofing ventilation system in combination with good sound proofing constructions versus an excellent sound proofing ventilation system in combination with normal sound proofing constructions. Another further possibility of improving noise reduction is to limit the net surface area of the ventilation openings. However this has consequences for the pressure difference over the ventilation openings to provide the same air flow (only possible with system MEO). This will have consequences for other aspects like thermal comfort and indoor air quality (see respective chapters).

The following rating system is used in the matrices to show the applicability of the using the ventilation systems:

-	When the system is not applicable;
0	When the system is applicable with excellent sound proofing constructions in the façade;
+	When the system is applicable with normal sound proofing constructions in the façade;
++	When the system is applicable without extra sound proofing constructions in the façade.

The following construction types are considered in this tool:

Table 5.2 Construction parameters

Construction type	**Overall sound reduction of the façade. R_A in dB(A)**	**Compares with output parameter**
Closed façade		
Brickwork	46	++ / + / 0
Glazing (casement encl.)		
4 (layered) - 12 (air) - 6 (layered) mm	28	++
6 (layered) - 20 (air) - 10 (layered) mm	33	+
10 (layered) - 16 (air) - 10 (layered) mm	37	0
Ventilation opening	**Overall sound reduction of the opening (based on A_{nett} of the opening). R_A in dB(A)**	
Without sound proofing or window ajar	-5	
With minor sound proofing	0	
With sound proofing	10	
With excellent sound proofing	15	
Weather-stripping	**Overall sound reduction of the weather-stripping factor K in dB(A)**	**Compares with output parameter**
Single weather-stripping	35	++
Good single weather-stripping	40	+
Double weather-stripping	45	0

Examples are given in the following pages of the construction types mentioned above.

Table 5.3 provides a step-by-step approach of how the matrices should be used.

Table 5.3 Steps for using the matrices

Step 1	Estimate surface area of façade ($S_{façade}$ in m^2)
Step 2	Estimate required characteristic noise reduction: $G_{a;c} = L_o - L_i$ in dB(A)
Select table	
Step 3	Estimate percentage of inferior sound proofing constructions in façade, exposed to traffic noise
Step 4	Estimate net surface area A [cm^2] of ventilation opening (in case of mechanical supply A = 0). (The parameter "A" can be estimated by the required air flow, the ξ-value and the pressure difference over the opening)
Step 5	Select the possible ventilation systems and the required sound proofing of the ventilation openings, inferior sound proofing constructions (glazing and light panels) and weather-stripping

Matrices

$S_{façade}$ = 5 - 10 m^2

Ventilation system		$G_{a;c}$ = 20 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	++	++	-	-	-	++	++	-	-	-	++	++	+	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	++	++	-	++	++	+	+	+	++	++	++	+	0
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 25 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	+	-	-	++	+	-	-	-	++	+	-	-	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 30 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	+	-	+	+	+	0	-	+	-	-	-	-
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	+	+	+	0	-	+	+	0	-	-
Mechanical supply and exhaust		++	++	++	++	++	+	+	+	+	+	+	+	+	+	+

Ventilation system		$G_{a;c}$ = 35 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	-	-	-	-	0	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	-	-	0	0	0	-	-	-	-	-	-	-
Mechanical supply and exhaust		++	++	++	++	++	0	0	0	0	0	0	0	0	0	0

$S_{façade}$ = 10 - 15 m^2

Ventilation system		$G_{a;c}$ = 20 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	++	++	++	-	-	++	++	+	-	-	++	++	+	-	-
Natural supply	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	++	++	++	++	++	++	++	+	++	++	++	++	+
Natural supply	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Natural supply	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 25 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	++	-	-	-	-	+	-	-	-	-	+	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	++	-	-	++	++	**0**	-	-	++	+	**0**	-	-
Natural supply	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Natural supply	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 30 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 0 dB(A)	**0**	-	-	-	-	**0**	-	-	-	-	-	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	+	+	+	+	**0**	+	**0**	**0**	**0**	-
Natural supply	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	+	+	+	+	**0**	+	+	+	**0**	**0**
Mechanical supply and exhaust		++	++	++	++	++	+	+	+	+	+	+	+	+	+	+

Ventilation system		$G_{a;c}$ = 35 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 0 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	-	-	-	**0**	-	-	-	-	-	-	-	-	-
Natural supply	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	**0**	**0**	**0**	-	-	**0**	-	-	-	-
Mechanical supply and exhaust		++	++	++	++	++	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

$S_{façade}$ = 15 - 25 m^2

Ventilation system		$G_{a;c}$ = 20 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	++	++	++	++	-	++	++	+	+	-	++	++	++	**0**	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	++	++	++	++	++	++	++	+	++	++	++	++	++
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 25 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	++	++	-	-	-	++	-	-	-	-	++	**0**	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	++	++	-	++	++	+	**0**	-	++	++	+	**0**	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Mechanical supply and exhaust		++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Ventilation system		$G_{a;c}$ = 30 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	++	++	-	-	-	+	-	-	-	-	**0**	-	-	-	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	++	++	++	+	+	+	+	+	+	+	+	**0**	-
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	+	+	+	+	+	+	+	+	+	**0**
Mechanical supply and exhaust		++	++	++	++	++	+	+	+	+	+	+	+	+	+	+

Ventilation system		$G_{a;c}$ = 35 dB(A)														
		Percentage of inferior soundproofing constructions in the façade exposed to traffic noise [%]														
		0					< 50					≥ 50				
		A net [cm^2]					A net [cm^2]					A net [cm^2]				
		0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400	0-50	50-100	100-200	200-400	≥ 400
Natural supply	Ventilation opening without soundproofing: R_a = -5 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 0 dB(A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 10 dB(A)	++	++	-	-	-	**0**	**0**	-	-	-	-	-	-	-	-
	Soundproofed ventilation opening: R_a = 15 dB(A)	++	++	++	++	++	**0**	**0**	**0**	**0**	-	**0**	**0**	-	-	-
Mechanical supply and exhaust		++	++	++	++	++	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

5.3 Simplified Tool and Guidelines for System Noise

5.3.1 Introduction

The use of fans in a ventilation system causes a certain noise level in rooms. This noise level is the difference between the total noise production in the system (which is the noise production of the fan, the noise production of the inlet and/or outlet and aerodynamic noise) and the total damping in the system (caused by silencers, cross-talk absorbers, bends, branches etc.). The maximum allowable sound power level in a room caused by the ventilation system is 30 dB(A) in most countries.

This simplified tool gives the consequences and guidelines for selecting silencers in duct systems depending on the duct length, number of branches and sound power level of the fans.
Also indications are given of sound pressure levels in rooms with local fans.

This tool is limited to duct air velocities below 3 m/s as this is necessary to avoid aerodynamic noise.

5.3.2 Input parameters

5.3.2.1 Acoustic parameters

The sound power level of the fan is a variable in the tool. The user has to select a sound power level from four possibilities: 55, 60, 65 and 70 dB(A).

The sound power level (L_w) of the fan can be estimated by using the following formula:

$$L_w = L_{ws} + 10 \lg q_v + 20 \log \Delta p \qquad \text{[dB]}$$

Where: L_{ws} is 1 ± 4 in dB
q_v is the flow capacity in m^3/h
Δp is the total pressure difference across the fans in P_a

The relation between L_w, q_v and Δp is also given in figure 5.1.

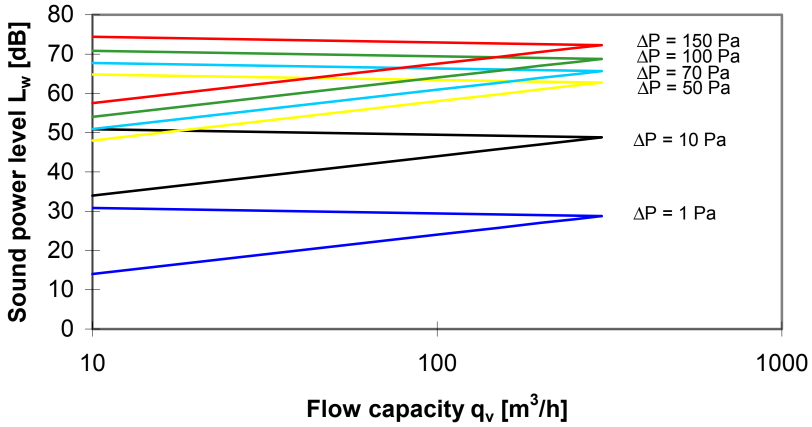


Figure 5.1 Relation between L_w, q_v and Δp

Note: For the determination of the octaveband spectrum, corrections must be applied. These corrections depend on the fan type and speed. Corrections of a fan type that is common for dwellings are given in Table 5.4. These corrections are not used in the tool.

Table 5.4 Example of octaveband corrections for fans

Frequency (Hz)	63	125	250	500	1000	2000	4000
Correction (dB)	-9	-6	-6	-7	-12	-15	-19

5.3.2.2 System and room parameters.

The duct length and the number of branches as well as the presence of the silencer and cross-talk absorber are used as input parameters.

Other parameters are standardised as follows:

Air velocity	$v \leq 3$ m/s
Duct diameter	$d \leq 150$ mm
Total capacity	$q_v \leq 200$ m^3/h
Damping inside the room:	
living room/bedroom	5 - 8 dB
kitchen	2 - 3 dB

5.3.3 Output parameters

5.3.3.1 Assessment of silencers by using the matrices

The matrices give a first estimate of the dimension of silencers which are necessary to create an acceptable noise level within the rooms of a dwelling. The applicability of the ventilation system with or without silencer is given in the matrices by :

- -- When the resulting noise level in the room is more than 40 dB(A)
- \- When the resulting noise level in the room is between 35 and 40 dB(A)
- 0 When the resulting noise level in the room is between 30 and 35 dB(A)
- \+ When the resulting noise level in the room is between 25 and 30 dB(A)
- ++ When the resulting noise level in the room is less than 25 dB(A)

Matrices

The resulting indoor noise level in dB(A) depends on the duct length and the number of branches and on the strength of a maximum sound power level of the fan as shown in the following matrices:

L_w = 70 dB(A)

5.3.3.1.1.1.1.1 Duct length ⇒	< 5 meter			≥ 5 meter		
Number of branches ⇒	0	1	2	0	1	2
No silencer	--	--	--	--	--	--
Silencer 1000 mm	-	0	0	0	0	0
Silencer 1000 mm and cross-talk absorber 500 mm	0	+	+	0	+	++

L_w = 65 dB(A)

Duct length ⇒	< 5 meter			≥ 5 meter		
Number of branches ⇒	0	1	2	0	1	2
No silencer	--	--	-	--	-	-
Silencer 1000 mm	+	++	++	+	+	++
Silencer 1000 mm and cross-talk absorber 500 mm	++	++	++	++	++	++

L_w = 60 dB(A)

Duct length ⇒	Not applicable		
Number of branches ⇒	0	1	2
No silencer	--	--	--
Silencer 1000 mm	0	0	+
Silencer 1000 mm and cross-talk absorber 500 mm	+	++	++

L_w = 55 dB(A)

Duct length ⇒	Not applicable		
Number of branches ⇒	0	1	2
No silencer	-	-	0
Silencer 1000 mm	++	++	++
Silencer 1000 mm and cross-talk absorber 500 mm	++	++	++

The resulting indoor noise levels are based on 1 inlet into the room. In case of 2 inlets, the noise levels must be increased by 3 dB.

Local mechanical exhaust systems consist of a fan in a wall or window in the room where the air is exhausted, or axial fans in ducts.

Table 5.5 provides details of the air flows and sound pressure levels for some types of window/wall fans.

Table 5.5 Air flow capacity and sound power level of window/wall fans

Fan type	**Flow capacity [m^3/h]**	**Sound pressure level L_{SPL} [dB(A)] (at 1 m of the fan)**
Axial-fan	200	51
	300	55
	750	57
	1400	65
Duct-fan	100	54

Table 5.6 gives typical ranges of sound power levels of ventilation systems.

Table 5.6 Indication of ranges of sound power levels of different ventilation systems

System	**Sound power dB(A)**				
	50	**55**	**60**	**65**	**70**
MSE			25 l/s		65 l/s
MEO		25 l/s	65 l/s		
Local fan	60 l/s		200 l/s		

5.4 Simplified Guidelines for Sound Transportation and Cross-Talk

5.4.1 Introduction

A ventilation system can be a sound channel between rooms and dwellings. This is called cross-talk. Cross-talk is of particular concern in MSE-systems (between habitable rooms) and in collective air ducts between dwellings (collective MEO and PSV systems in residential buildings). It can be brought about in the following ways:

- through the air duct system; this can take place both between rooms within the same dwelling and between rooms in two different dwellings;
- through the overflow grilles or openings underneath doors; cross-talk may occur in the case where two rooms have such openings near one another;
- through the service penetrations for ducts in walls or floors.

5.4.2 Sound reduction between dwellings

Both collective natural (PSV) and mechanical ventilation duct systems usually require sound proofing provisions. Such provisions may consist of:

- a silencer in front of each outlet or between outlets;
- a soundproofed grille at each outlet.

Acoustic measures are in most cases necessary to maintain the required noise reduction. The total minimum insertion loss of a duct between two dwellings is given in Table 5.7.

Table 5.7 Minimum insertion loss for a duct between two dwellings

Frequency [Hz]	**125**	**250**	**500**	**1000**	**2000**
Insertion loss [dB]	0	5	10	15	15

5.4.3 Sound reduction within dwellings

If rooms within a dwelling are directly linked with one another by the supply duct of a balanced ventilation system, cross-talk is a major point of concern. The effects of cross-talk in the system on the average sound reduction index (total sound reduction of the partition) is approximately 14 dB. In this case the overall sound reduction index value decreases. This may require additional methods to increase the sound reduction index.

When doors are shortened at the bottom to facilitate air transport inside a dwelling (balanced ventilation and warm air heating), the following factors should be taken into account:

- doors must be shortened by 3 mm for each 10 m^3/h of air supplied to or removed from the room;
- if the doors of two adjacent rooms are directly beside one another, the sound reduction index of the separating wall must be higher than the minimum required value in order to compensate for the transfer of noise through the gap underneath the door.

In general, constructions which separate rooms must have an average sound reduction index R_m of 34 dB. Cross-talk through a duct system can have an adverse effect here. In dwellings cross-talk is of concern mainly in the supply duct of MSE systems. Improperly constructed service penetrations for ducts may create acoustic leaks between the air duct and the separating wall. Soundproof connections between the duct and the separating wall are therefore recommended. These can be achieved by using a sealing glue or an airtight sealant.

5.5 Examples

5.5.1 Dwelling types

Three dwellings are considered:

D3b flat, 3 main rooms
D4a flat, 4 main rooms
D4c single family house, 4 main rooms

5.5.2 Outdoor noise

The input parameters are given in Table 5.8. The output parameters, this means the applicability of a ventilation system in combination with a certain sound proofing construction of the façade, is presented in Table 5.9.

Table 5.8 Input parameters

Dwelling	Considered room	Façade surface $S_{façade}$ [m^2]	Ventilation opening A_{nett} [cm^2]	% inferior soundproofing construction
D3b	Living room	5 - 10	200 - 400	≥ 50
D4a	Living room	10 - 15	200 - 400	< 50
D4c	Living room	10 -15	200 - 400	< 50

Output parameters are given in the next table:

Table 5.9 Output parameters

Dwelling	Considered room	$G_{A;c}$ [dB(A)]	Applicability ventilation system
D3b	Living room	20	Natural supply, ventilation opening without soundproofing not applicable Natural supply, ventilation opening with minor soundproofing applicable with normal soundproofing constructions Natural supply, ventilation opening with normal/excellent soundproofing applicable MSE applicable
		25	Natural supply, ventilation opening without and with minor soundproofing not applicable Natural supply, ventilation opening with normal/excellent soundproofing applicable MSE applicable
		30	Natural supply not applicable MSE applicable with normal soundproofing constructions
		35	Natural supply not applicable MSE applicable with excellent soundproofing constructions
D4a/D4c	Living room	20	Natural supply, ventilation opening without soundproofing not applicable Natural supply, ventilation opening with minor/normal/excellent soundproofing applicable MSE applicable
		25	Natural supply, ventilation opening without and with minor soundproofing not applicable Natural supply, ventilation opening with normal/excellent soundproofing applicable MSE applicable
		30	Natural supply, ventilation opening without and with minor soundproofing not applicable Natural supply, ventilation opening with normal/excellent soundproofing applicable with normal soundproofing constructions MSE applicable with normal soundproofing constructions
		35	Natural supply not applicable MSE applicable with excellent soundproofing constructions

5.5.3 System noise

The ventilation system of dwelling types D3b and D4c is schematically given in Figures 5.2 and 5.3. The input parameters are summarised in Table 5.10 and the expected noise level is presented in Table 5.11.

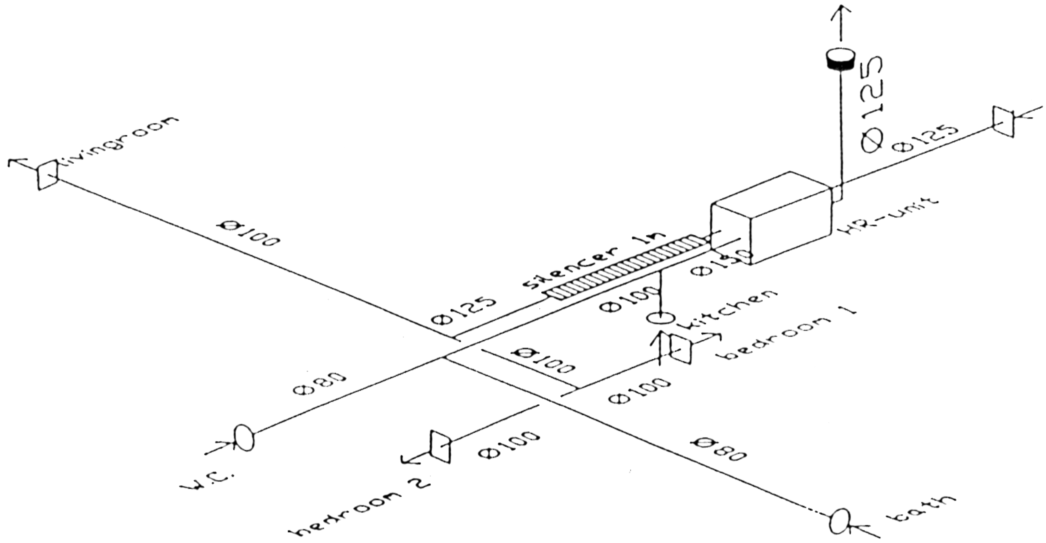


Figure 5.2: Ventilation scheme dwelling type D3b

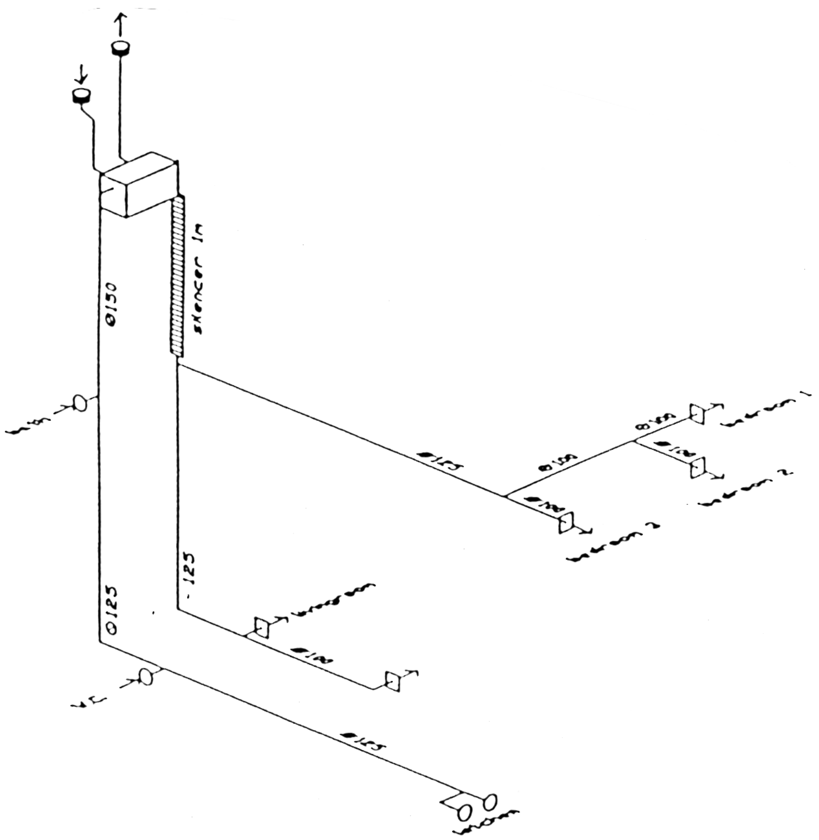


Figure 5.3: Ventilation scheme dwelling type D4c

Table 5.10 Input parameters

Dwelling type	Considered room	q_v [m^3/h]	Duct length [m]	Number of branches	Number of devices/grills
D3b	Living room	82	~3	1	1
	Bedroom	35	~3	2	1
	Kitchen	75	~1.5	0 (+ 1 through duct)	1
D4c	Living room	79	~5	1	2
	Bedroom	32	~5	2 (+ 1 through duct)	1
	Kitchen	75	~7.5	0 (+ 2 through ducts)	2

Table 5.11 Resulting noise level in the room

Dwelling type	Considered room	Noise level in the room [dB(A)], depending on the use of a silencer
D3b	Living room	no silencer: 45 - 50 silencer 1000mm: 30 - 35 silencer 1000 mm and cross-talk absorber 500 mm: 25 - 30
	Bedroom	no silencer: 45 - 50 silencer 1000mm: 30 - 35 silencer 1000 mm and cross-talk absorber 500 mm: 25 - 30
	Kitchen	no silencer: > 45 silencer 1000mm: 30 - 35 silencer 1000 mm and cross-talk absorber 500 mm: 25 - 30
D4c	Living room	no silencer: 48 - 53 silencer 1000mm: 33 - 38 silencer 1000 mm and cross-talk absorber 500 mm: 28 - 33
	Bedroom	no silencer: 45 - 50 silencer 1000mm: 30 - 35 silencer 1000 mm and cross-talk absorber 500 mm: 25 - 30
	Kitchen	no silencer: > 48 silencer 1000mm: 33 - 38 silencer 1000 mm and cross-talk absorber 500 mm: 28 - 33

5.6 References

1. Månsson L.-G. (ed.),(1995) *Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems - State of the Art*. Swedish Council for Building Research, Stockholm Sweden, A12:1995, ISBN 91-540-5731-0.
2. Recknagel, Sprenger, Hönmann, *Taschenbuch fur Heizung und Klimatechnik*, Oldenburg Verlag, München Germany, ISBN 3-486-35913-4.
3. ISSO publication 28, *Balanced ventilation in dwellings*, Rotterdam the Netherlands, 1993, ISBN 90-5044-031-2.
4. ISO-Recommendation (1996), *Assessments of noise with respect to community response*, Technical Committee ISO/TN 43, 1971.
5. Wetsontwerp Wet geluidhinder, Staatsblad 99, 1977 the Netherlands.

6 Building Aspects

6.1 Introduction

Ventilation systems both interact and influence the inside of the building in which they are installed. Their presence may also affect the external appearance of a building, depending on which type of ventilation system is chosen. We can distinguish between the following aspects:

- Architectural
- Building services
- Constructions
- Other restrictions

This tool can be usefully applied in the whole process of a building evaluation both for new constructions and renovation work. This tool can also be used as part of the total quality assurance procedure, thus avoiding mistakes and facilitate the circulation of information to various experts and managers.

Limitations
The design of the tool is based on field experience. It can also be used as a check list of information needed to be collected. The output from this tool is given as critical items or situations to be taken into account once the ventilation system is selected.

6.2 Input Information

Depending on ventilation system chosen and local regulations, fire resistance and protection must be considered. This includes consideration of both the material qualified to be used in the system and protecting from the spread of fire to adjacent spaces.

The age of a building usually places restrictions. If a new ventilation system is to be installed, we must consider the affects on the building. Renovation work can also cause problems with ventilation even though nothing has been done directly to the system e.g. tightening the external walls, removing fire places, or installing new windows. Here it must be observed that in some of the participating countries the refurbishment market will increase from 50 % to over 80 % of the non-industrial building market.

The starting point for use of this tool is to have an idea of a ventilation system to be installed. Then this tool can be used to check which aspects of the building are sensitive for the selected ventilation system.

6.2.1 Architectural

A ventilation system has an impact on both the inside and outside of a building. The choice of a ventilation system always affects the appearance in a room or the external view of a building. The components that typically need to be considered are:

- Extract flues or chimneys above the roof. Sometimes extract flues are also located on the façade of the building. Depending on the system design and ventilation principle selected, one or very many extract flues/chimneys may appear on the roof.
- A machine room can be located in different places internally or externally. The location will also affect the access way to the fan room. An easy access is essential to give way for regular

maintenance. Both aspects have to be addressed during the design stage and the space set aside varies depending on the ventilation system selected.
- The ductwork is installed both vertically and horizontally, usually in corners. Sometimes a false ceiling is used for a limited part e.g. bathroom, part of corridor

Also replacement of components has to be taken into account when selecting a system. In particular when a building is renovated and a mechanical ventilation system is replaced by a natural ventilation system.

Both supply and exhaust devices affect a room's appearance including the kitchen hood. The devices can be seen in nearly every position possible. However, it might vary depending on the system selected. Supply devices can be seen: around the window, external wall, in the ceiling, on the inner walls usually right under the ceiling, behind the heating-radiator, as a air handling unit under the window.

The lay-out of a dwelling, e.g. how adjacent rooms are linked to hallways and where the service rooms are in which the exhaust devices are located, very much influence the possibility to ventilate efficiently. Some ventilation systems are more affected by this aspect.

Sometimes a false ceiling has to be installed to hide away ducts and/or air handling units. This affects the appearance of a dwelling.

Sometimes the room height must also be considered, in particular for natural ventilation when extra height may be required. If there is a regulation of building height, it may result in less floor area to be let out, giving less income to the property owner.

The shape of the windows will also have influence on the effectiveness of opening windows to provide ventilation. . The proportion between height and width is very important.

The visual design of a ventilation device and the duct-work can make an interesting decoration in the room, but the visual design must be less important than the function of the component. Furthermore as the testing of the system must precede installation, once installed in the building the furnishings of the room are likely to affect the ventilation efficiency and the optimum operation. A ventilation system design always must foresee the resident's variety of decoration possibilities. Some solutions are more sensitive than others, sometimes also the choice of placement of the different components can meet this foreseen variety.

6.2.2 Building services

Depending on the choice of the ventilation system there is a need for support services. Electricity is required for fans and control systems, plumbing for water supply and drainage from heat exchangers or heat pumps and heating systems for pre-heating supply air.

One must also consider the possibility of conflict between the various service installations, which are usually designed by different experts. The more complex a ventilation system, the greater the need for co-ordination prior to construction to ensure different service systems do not clash. In particular the ductwork should not conflict with the load bearing structure.

6.2.3 Construction

When a building is constructed or renovated there is a need for detailed checking at site, in particular for the more complex ventilation systems. A review is required to ensure that all the openings for services including ventilation are provided and in the correct position. Furthermore, the components should be well protected before being built in and kept clean and protected during installation. When the building is handed over from the contractor to the property owner a commissioning process should take place with specialists inspecting each of the service provisions.

6.2.4 Output

The output of the tool gives the user information that different ventilation systems have consequences that might be costly, and involve more co-ordination between designers, and the managers at the construction site.

Depending on the system selected, the tool will give the user information on the impact due to various building aspects and also give warning signals. Safety aspects during the construction phase are not given in the tools but might result in other restrictions that limit the use of a certain system.

The impact of legal aspects may have great variation depending on the system chosen. This involves test runs and maintenance contracts and guarantees.

Also aspects on the compliance with the surroundings might in some locations need official approval that could take time depending on the system chosen.

6.3 Tool

The tool is given in three tables, each one dealing with a particular building aspect. The impacts are given as weighted judgement and are based on technical conclusions of an analysis procedure. The tables show the impact depending on which type of ventilation system is selected and are divided into four categories as follows:

✋✋✋	Very high impact
✋✋	High impact
✋	Low impact
0	No impact

Basic Considerations for Table 6.1

Table 6.1 shows how the various architectural elements (e.g. walls, slabs, corridors and doors) are affected by the ventilation system and its components, plumbing and control. We consider its influence on both inner elements and the external envelope of a single family dwelling or apartment

- Extraction of ventilation air by one or several chimneys affects the roof design. The extraction can be located on the façade, depending on the chosen ventilation system.
- Air handling machinery, in the case of mechanical systems need technical rooms, these last need technical volumes to be foreseen during design. Spaces for access, maintenance, replacement may be necessary.
- The ductwork occupies vertical and horizontal volumes to deliver the ventilation air.

At first, we can imagine the building crossed by **flows** which are related to the vertical elements of the building such walls, windows, doors and to the horizontal such slabs. In addition, among the external elements we consider the envelope and the roof.

Basic Considerations for Table 6.2

In order to give the correct judgement or weight, we have to focus on the elements that have a higher percentage of the cost and divide it into three groups: Internal, Envelope, Building services excluding the ventilation. In each group further divisions are made. Thus more care must be made for the judgement when the system is influencing the element with the higher percentage of the cost within the group.

Consider for each of "internal", "envelope", and "building services excluding ventilation" the percentage of the total cost which is affected by the interaction with the ventilation system.
Since the indicated values are an average of a range of values which vary case by case, the final judgement might be undertaken increasing or decreasing the preliminary evaluation.
Rearranging the above table as per main components of the building we get the following table:

Table 6.1 Building Aspects. Ductwork and flow influence

System	Inner Elements		**Envelope**	
Window Airing	Wall	**0**	Wall	**0**
	Slab	**0**		
	Corridor	**0**	Window	✋✋✋
	Doors	✋✋	Roof	**0**
Passive Stack	Wall	✋	Wall	✋
	Slab	✋		
	Corridor	**0**	Window	✋
	Doors	✋✋	Roof	✋✋✋
Mechanical exhaust only	Wall	✋	Wall	✋
	Slab	✋		
	Corridor	**0**	Window	✋
	Doors	✋	Roof	✋
Mechanical supply and exhaust	Wall	✋✋	Wall	✋
	Slab	✋✋		
	Corridor	✋	Window	**0**
	Doors	✋	Roof	✋

Table 6.2 Impact weights of cost distribution

		%
Internal		
Walls		**21**
Slabs+corridor		**73**
doors		**6**
Sum		**100**
Envelope		
Walls		**51**
Windows		**36**
Roof		**13**
Sum		**100**
Building Services ventilation excluded		
Plumbing		**64**
Elect.(+lift+intercom)		**36**
Sum		**100**

Basic considerations for Table 6.3
When considering the architectural elements of a building the use of the **space** has to be considered too. All spaces require rational use and the architect must be aware of the space needed for each function including installation, operation, maintenance and replacement. Operation space is the space required for the normal running of the machine.

Maintenance space is the space required for the maintenance staff and the instruments and tools for carrying out a good work and is in addition to operation space. This space will have great influence on the maintenance cost and the possibility of carrying out servicing.

Replacement space has to be carefully evaluated, because ventilation systems have a shorter life-time than the building itself, so during the designed life-time of the building they have to be replaced several times. It is quite typical for it to be a large undertaking when machinery is replaced. The replacement space has to be foreseen at the design stage.

Two more sub-aspects have to be taken into consideration when looking at the **building** as a whole. **Layout** and **external appearance** are affected by the ventilation systems, because especially in the mechanical systems we have to plan during the design phase the location of the ducts, the location of the air handling units, grilles louvers and false ceilings. Furthermore positioning of the service rooms and vertical shafts and ducts influences the shape of rooms, corridors and rooms appearance.

Designers may decide to locate the machinery, if we are dealing with flats, in the basement or on the roof or, in case of using a heat pump for heat recovery, a split system. Local exhaust fans in kitchens and bathrooms may affect the façades, windows and walls. On the other hand, if we consider the case of an existing dwelling, a flat with only one external façade can suffer from the difficulty of achieving good ventilation when relying on natural ventilation and in particular window airing. The height of the flat also has an impact and is more important for natural ventilation systems.

The architect may have some design requirements on the air intake and extract outlet device which could affect the system. The architect might also influence the placement of the extract air outlet "chimneys". If the building has natural ventilation, the shape of the window the architect selects has impact on how the window airing is performed and the resulting air exchange rate. For mechanical systems this has little impact.

Table 6.3 Building aspects, architectural, building service

System	**Architectural**						**Building services**		
	Spatial		**Replacement**		**Building**		**Elect-ricity**	**Plumb-ing**	**Cont rol**
	Oper-ation	**Maint enance**	**Same sys-tem**	**Other sys-tem**	**Lay-out**	**External appear-ance**			**Sys-tem**
Window Airing, NWA	**0**	**0**	**0**	✋✋✋	**0**	**0**	**0**	**0**	**0**
Passive Stack, PSV	**0**	✋	✋✋	✋✋	✋✋✋	✋✋	✋	✋✋✋	**0**
Mechanical exhaust only, MEO	✋	✋	✋	✋	✋	✋	✋	✋	✋
Mechanical supply and exhaust, MSE	✋✋	✋✋	✋	✋	✋✋	✋	✋	✋✋	✋

Some further comments are given below for Tables 6.1 and 6.3.

Natural Window Airing (NWA)
The ventilation effectiveness is very dependent on whether the doors are opened or not. To replace a NWA with another system will cause great difficulties particularly in multi family buildings. Due to this the influence of doors are high.

Passive Stack Ventilation (PSV)
For this system, the ventilation effectiveness is also dependent on whether the doors are opened or not. The effectiveness is also affected by the roof pitch because of the stack effect. Old multi family buildings have a lot more faults than mechanical systems according to the evaluation of the compulsory ventilation inspection made in Sweden, see Månsson (1998).

Mechanical Exhaust Only (MEO)
All the elements show low impact. The impact on the envelope is because of the supply inlets that are installed in the windows and façades.

Mechanical Supply and Exhaust (MSE)
Similar considerations are required as ***PSV*** system. Furthermore we have to consider the higher impact on operation and maintenance and also on plumbing because of the need to discharge waste fluids. There is obviously a need for power and plumbing. This has an impact on all the inner building components. Façades and windows are typically not affected by this system. However, in some countries, MSE systems are allowed to be installed in apartments with an air intake and extract outlet on the external walls. But usually the air handling units are placed on the roofs or within service rooms.

Basic considerations for Table 6.4
The purpose of Table 6.4 is to focus on the practical phase when the building is constructed, used, furnished and renovated.
During the construction phase, people involved with ventilation have to have good communication with the **civil**, **mechanical, electrical** and **start-up** people, issuing the relevant approved shop-drawings before casting or placing the conduits to locate the necessary installations on slabs, walls, or roofs.
It is also very important to protect the equipment and devices when delivered on site prior to installation.
Commissioning has to be considered both for mechanical and natural ventilation systems. Technical specification based on test runs may be required before the final hand over. Rate of flows, temperatures and general conditions have to be approved on check lists and filed for future reference.

Impacts of the various ventilation systems have to be considered during the daily operations of the systems. Certificates are required for the materials used to show they offer good fire resistance.
Elements and circumstances which affect the buildings have consequences in the chance of a successful installation and operation of a ventilation system, e.g. **fire** prescriptions. In case of the refurbishment of old dwellings, to make openings or to install all the technical apparatus to achieve a complete mechanical ventilation system may represent a problem.

Table 6.4 Building Aspects, at building site and usage

Systems	**Construction – at site**				**Building in use**		**Others**	
	Constru-ction	**Bldg services**	**Decora-tion**	**Commis-sioning**	**Mainte-nance**	**Fire**	**Building Age**	**Furnish-ing**
Window Airing	0	0	0	✋	0	0	✋✋	✋✋
Stack	✋✋	✋	✋	✋✋	✋	✋	✋✋✋	✋
Mechanical exhaust	✋	✋	✋	✋	✋	✋	✋	✋
Mechanical supply and exhaust	✋✋	✋✋	✋✋	✋	✋	✋	✋	✋

When a designer has assessed the type of system to be installed in a dwelling and has evaluated each of the building aspects, the weighting of each aspect has to be done based on their judgement and requirements.

6.4 Further Information

The figures given in Table 6.2 were collected in Italy. The figures are for the direct material and labour costs. This does not include profit and tax and it will not affect the relationships provided in the table as they are usually calculated as an additional percentage.

6.5 References

Giorgiantoni G (1998). Background material. Building Aspects.

7 Indoor Air Quality

7.1 Introduction

This tool estimates the effect of the choice of ventilation system together with the air-tightness of the dwelling on the indoor air quality. The user selects values for basic input parameters related to the ventilation system, building envelope and climate. The user then refers to simple, easy-to-use matrices to obtain a rating of:

- The indoor air quality
- The level of condensation
- The energy required to heat the indoor air

Warning flags are also given if for long periods:

- The indoor air is dry
- The indoor air is humid (which can increase the level of house dust mites)
- The outdoor pressure is significantly greater than the indoor pressure (which can be a problem in high radon areas or during the use of combustion appliances).

The user selects the values for the basic input parameters from lists provided in the next section. The background report which accompanies this chapter provides more details than given here including statistical models to estimate all the indoor air qualities listed above with a wider range of input parameters. The results from this tool are based on computer simulations and the background material contains sufficient data to allow the user to perform their own computer simulations if required.

7.2 Input Parameters

7.2.1 Building parameters

3 climates are considered in this tool: Nice, London, and Ottawa which represent mild, moderate, and cold climates respectively.

3 types of dwellings are considered:

- An apartment with 4 main rooms (3 bedrooms) located on the ground floor of a four-storey building (denoted D4a ground).
- An apartment with 4 main rooms located on the top floor of a four-storey building (denoted D4a top).
- A detached single family house with 4 main rooms (denoted D4c)

Leakage values (n50) can have the following values :

- 1, 2.5, 5 ach for the apartments D4a
- 1, 2.5, 5 and 10 ach for the house D4c (for the 10 ach case there are two choices of leakage distribution). Generally in this tool the cracks are distributed approximately according to the room areas, which is an optimistic situation regarding indoor air quality. Only for house D4c with a leakage value of 10 ach is this different as there are two choices of leakage distribution. Distribution ‘10a’ is as above whilst in distribution ‘10b’ half of the cracks are located in the hall. There are no other differences between ‘10a’ and ‘10b’. This makes it possible to compare the sensitivity of crack distribution on the results.

A **4 person family** occupies all dwellings.

7.2.2 Ventilation system description

The ventilation systems are identified by one of the four base systems described in Chapter 3 (NWA, PSV, MEO, MSE). Those systems can then be combined with local fans in the bathroom/toilet and/or kitchen and window opening patterns (closed, or climate depending).

7.2.3 Windows opening (airing)

Bedroom windows can be opened during weekdays from 08:00 to 12:00, depending on the weather conditions.

Supply air

NWA: Two cases of air inlets:

- **No** : **0 cm^2**
- **Yes : 410 cm^2** (80 cm^2 in each habitable room and 30 cm^2 in each wet room)

PSV: Two cases of air inlets:

- **No : 0 cm^2**
- **Yes : 400 cm^2** (80 cm^2 in each bedroom and 160 cm^2 in the living-room)

MEO: Two cases of air inlets:

- **No : 0 cm^2**
- **Yes : 100 cm^2** (20 cm^2 in each bedroom and 40 cm^2 in the living-room)

MSE: Three cases of supply flow rates:

- **15 l/s** (3 l/s in each bedroom and 6 l/s in the living-room)
- **30 l/s** (6 l/s in each bedroom and 12 l/s in the living-room)
- **45 l/s** (9 l/s in each bedroom and 18 l/s in the living-room)

Exhaust flow rates and stacks

NWA: No vertical duct

PSV: A passive stack ducted system is installed in the kitchen, bathroom and toilet.

MEO and MSE: The mechanical exhaust flow rate is given for three levels.

- 15 l/s (7.5 l/s in the kitchen, 5 l/s in the bathroom and 2.5 l/s in the toilet)
- 30 l/s (15 l/s in the kitchen, 10 l/s in the bathroom and 5 l/s in the toilet)
- 45 l/s (22.5 l/s in the kitchen, 15 l/s in the bathroom and 7.5 l/s in the toilet)

Heat exchanger efficiency for MSE is η=50 %

7.2.4 Local additional exhaust fans

No (N): No local fan

Yes (Y): Local fans as follows:

- Kitchen hood: Running time 1 hr/day, at 17.00 - 18.00. Flow rate 100 l/s
- Bathroom fan: Running time 2 hr/day. **Weekdays** 06.00 - 08.00 and weekends at 09.00 - 11.00. Flow rate 25 l/s.

When not in use, a fan is considered as a hole of 40 cm^2. For the MEO system, this reduces the ventilation of habitable rooms and consequently the IAQ rating. This can be avoided either if additional flows are provided by a central system or the local fan is equipped with a device closing it when not in use. The affect of these possible improvements has not been determined and can not be estimated with the following tables.

7.2.5 Other situations

- The tool was produced on the basis of a 4 room dwelling and a 4 person family. For other cases, it is possible to use the results, if it is considered that one bedroom with one person is added or deleted (nevertheless, a one main room dwelling should not be taken into account). The results are then less precise, but the ranking would remain quite the same. The following rules should be applied: N 50: No change, as it is according to the dwelling volume
- Airing: No change
- Supply air devices: Bedroom(s) added or deleted are equipped as defined in 7.2.2

- Mechanical air flow: Add or subtract 3,6 or 9 l/s for each bedroom. Split the total air flow from kitchen, bathroom and toilet respectively using the proportions 3:2:1.
- Additional fan: If only one fan is added, the corresponding case of the added fan choice is as follows in Table 7.1

Table 7.1 Consequence for parameter if an extra fan is installed

Parameter	Bathroom fan only	Kitchen fan only
IAQ	N	Y
Condensation	N	N
Heat needs	N	Y
Dryness	Y	Y
Pressure	N	Y
Winter high humidity	N	N

7.3 Output parameters

For each climate, the output parameters are given in 3 matrices with rating from **"+ +"** to **"- -"** and 3 matrices with warning flags.

7.3.1 Matrix: IAQ

To study the effect of pollutants sources on IAQ, the most important parameter is the pattern of its production (level versus time and place), whichever pollutant is considered. For human feeling and health we choose to base the comparison on 3 main generic pollutants:

- CO_2: this pollutant is related to the human metabolism
- Cooking activities. It is proportional to the water evaporated during cooking and could be related to odour production or to CO or NO_x production in case of a combustion appliance.
- Passive smoking. It is based on a constant production of pollutants for the duration the person is smoking within the room they are located.

For each of these pollutants, we calculated the exposure of each occupant during the heating season for the 990 cases considered in the tables and defined 5 classes ranging from **"- -"** to **"+ +"**

(**"- -"** corresponds to the higher exposures, **"+ +"** to the lower ones). It must be noticed that these classes are only relative. The IAQ parameter was computed for each occupant. The IAQ final parameter displayed in the tables is the worst rating found for an occupant for each pollutant.

7.3.2 Matrix: condensation

This output is related to the hours of condensation in habitable rooms (single glazing is taken as reference) and in wet rooms (an internal wall is taken as reference).

7.3.3 Matrix: heat

In the matrix the heat needed is represented by the equivalent air change rate (i.e. heat loss by ventilation). Focusing on a single way to express the heat needs efficiency independently of the climate conditions, we choose to calculate heat needs equivalent air flow rate and air change rate which are the constant air flow (or air change rate) which would lead to the same heat needs as the ones calculated. This gives a first idea about the energy need. Nevertheless, many parameters are not taken into account in this table and the simplified energy tool must always be taken as a reference for the final check in this field.

7.3.4 Warning flags

They are shown as red boxes in the tables and are defined as follows:

- ***Dryness feeling***: A warning flag is given if the number of hours of dryness feeling (R.H. < 30 %) is more than 800 hours. In this case modifying the ventilation system may not be the best solution as it can lead to a reduction of the IAQ results. A better solution may be to install an additional humidification system with its control set to RH = 30 %.
- ***Pressure difference:*** A warning flag is given if the pressure difference (outdoors – indoors) is more than 20 Pa for 200 hours during the heating season. This parameter can be related to problems of the ingression of ground pollution (e.g. radon) or to the running of combustion appliances.
- ***Winter indoor high humidity:*** A warning flag is given if there is no 4-week-period with a water vapour content <7 g/kg during the heating season. This flag can be related, for example, to problems of house dust mites. It should be noted that it is difficult to have no warning flag both for dryness feeling and this parameter.

7.4 Evaluation Tools

The following 6 pages give the results according to the above assumptions and presentation.

climate : NICE

Indoor air quality

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a top	1	- -	- -	o	+	- -	- -	o	+	- -	-	+	++	-	-	+	-	+	o	o	o	+	+	+	++	o	o	+	++	+	++
	2.5	-	-	o	++	-	-	o	++	-	o	+	++	o	-	+	o	+	+	o	o	+	+	+	++	+	+	+	++	+	++
	5	-	o	o	++	-	o	o	++	+	+	+	++	o	+	+	+	+	++	+	++	+	++	+	++	+	++	+	++	+	++
D4a ground	1	- -	- -	o	+	- -	- -	o	+	-	-	+	++	-	-	+	-	+	o	o	o	+	+	+	+	o	o	+	++	+	++
	2.5	-	-	o	+	-	-	o	+	o	o	+	++	o	-	+	o	+	+	o	o	+	+	+	++	o	+	+	++	+	++
	5	-	o	o	++	-	o	o	++	+	+	+	++	o	+	+	+	+	++	+	+	+	++	+	++	+	++	+	++	+	++
D4c	1	- -	- -	o	o	- -	- -	o	o	- -	- -	+	++	-	-	o	-	+	-	o	-	+	o	+	+	o	o	+	++	+	++
	2.5	- -	-	o	+	- -	-	o	+	-	-	+	++	-	-	o	o	+	o	o	o	+	+	+	+	o	o	+	++	++	++
	5	-	-	+	+	-	-	+	+	o	o	+	++	o	o	+	+	+	+	o	o	+	+	+	++	+	+	+	++	++	++
	10 case a	o	+	+	++	o	+	+	++	+	++	++	++	+	+	+	+	+	++	+	+	+	++	+	++	+	++	+	++	++	++
	10 case b	-	-	+	++	-	-	+	++	o	o	++	++	o	o	o	o	o	o	o	o	+	+	+	+	+	+	+	++	++	++

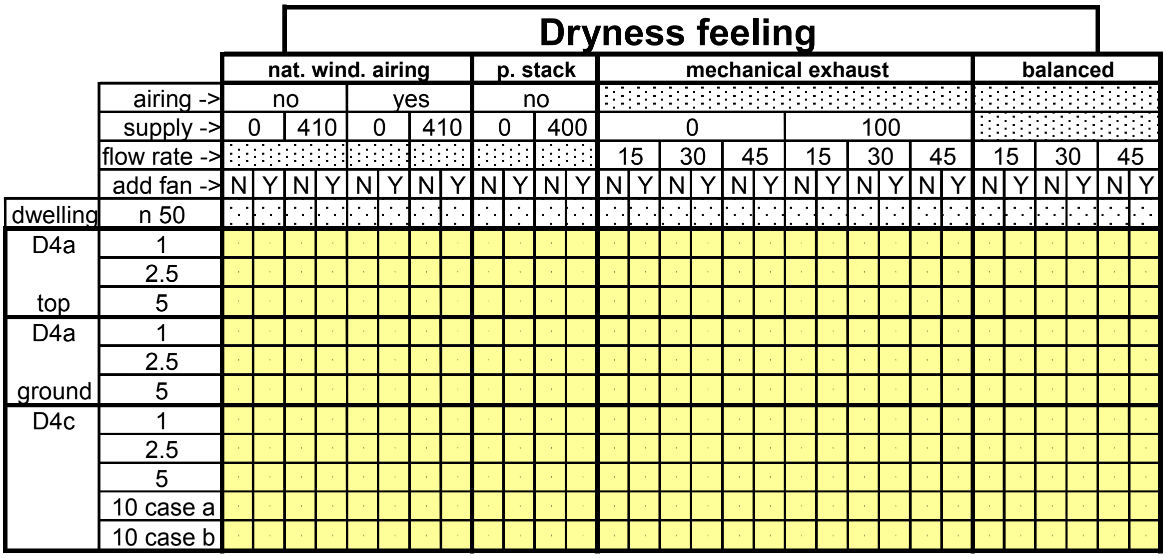
Condensation

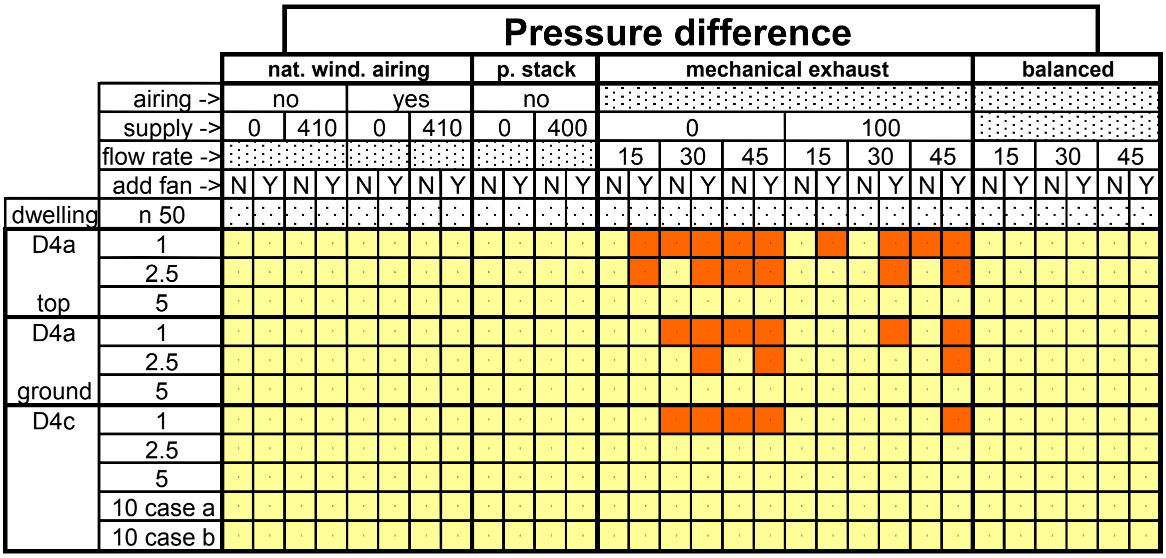
		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a top	1	- -	-	- -	++	- -	-	- -	++	-	-	o	++	-	+	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	2.5	- -	+	- -	++	- -	+	- -	++	-	++	o	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	5	- -	++	-	++	- -	++	-	++	-	++	o	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
D4a ground	1	- -	-	- -	++	- -	-	- -	++	-	-	o	++	-	+	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	2.5	- -	+	- -	++	- -	+	- -	++	-	++	o	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	5	- -	++	- -	++	- -	++	- -	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
D4c	1	- -	- -	-	++	- -	- -	-	++	-	-	+	++	-	o	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	2.5	- -	+	-	++	- -	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++	o	++	+	++	++	++
	5	- -	++	o	++	- -	++	o	++	+	++	+	++	o	++	o	++	+	++	o	++	+	++	++	++	o	++	+	++	++	++
	10 case a	-	++	o	++	-	++	o	++	+	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++	+	++	++	++	++	++
	10 case b	- -	++	-	++	- -	++	-	++	+	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++

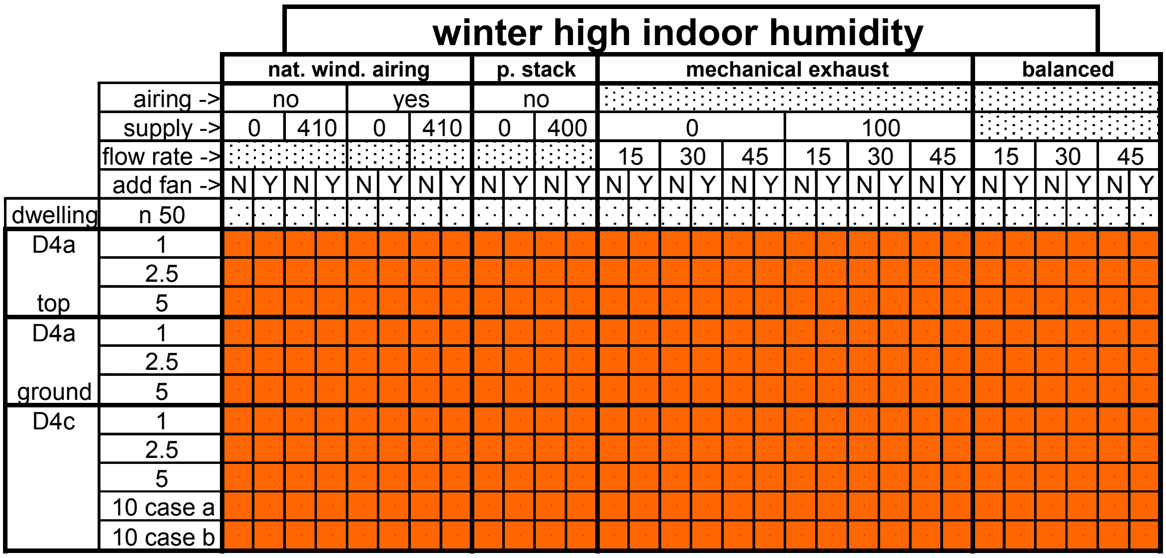
Heat needs

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a top	1	++	++	+	o	++	++	+	o	++	+	o	-	++	++	+	o	-	-	++	+	+	o	-	-	++	++	++	++	++	+
	2.5	++	++	+	o	++	++	o	o	+	o	-	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	+	+
	5	++	+	o	-	++	+	-	-	o	o	- -	- -	+	+	o	o	-	-	+	o	o	-	-	- -	++	+	+	o	+	o
D4a ground	1	++	++	+	+	++	++	+	o	++	+	-	- -	++	++	+	o	-	-	++	+	+	o	-	-	++	++	++	++	++	+
	2.5	++	++	+	o	++	++	o	o	+	o	- -	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	+	+
	5	++	+	o	-	++	+	-	-	-	-	- -	- -	+	+	o	o	-	-	+	o	o	-	-	- -	++	+	+	o	+	o
D4c	1	++	++	+	+	++	++	+	o	++	+	-	-	++	++	+	o	o	-	++	+	+	o	o	-	++	++	++	++	++	+
	2.5	++	++	+	o	++	++	+	o	+	o	-	- -	++	+	+	o	o	-	++	+	+	o	o	-	++	++	++	+	+	+
	5	++	++	o	o	++	+	o	-	o	o	- -	- -	++	+	+	o	o	-	+	o	o	o	-	-	++	+	+	+	+	o
	10 case a	+	o	-	- -	o	o	- -	- -	-	- -	- -	- -	o	-	-	-	-	- -	o	-	-	- -	- -	- -	o	o	o	-	-	-
	10 case b	+	+	-	-	+	o	-	- -	-	- -	- -	- -	+	o	o	-	-	- -	o	o	-	-	-	- -	+	o	o	o	o	-

climate : NICE







climate : LONDON

Indoor air quality

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	--	--	-	-	--	--	-	-	--	--	-	-	-	--	o	-	+	o	-	-	o	o	+	+	-	-	o	+	+	++
	2.5	--	--	-	-	--	--	-	-	--	--	-	o	-	--	o	-	+	o	-	-	o	o	+	+	-	o	o	+	+	++
top	5	--	-	-	o	--	-	-	o	-	-	o	o	-	-	o	o	+	+	-	-	o	o	+	+	o	o	o	+	+	++
D4a	1	--	--	-	-	--	--	-	-	--	--	o	o	-	--	o	-	+	o	-	-	o	o	+	+	-	-	o	+	+	++
	2.5	--	--	-	-	--	--	-	-	-	-	o	+	-	--	o	-	+	o	-	-	o	o	+	+	-	o	o	+	+	++
ground	5	--	-	-	o	--	-	-	o	o	o	+	+	-	-	o	o	+	+	-	-	o	o	+	+	o	o	o	+	+	++
D4c	1	--	--	-	o	--	--	-	o	--	--	o	o	--	--	o	-	+	-	-	--	o	-	+	o	-	-	o	+	+	++
	2.5	--	--	-	o	--	--	-	o	--	--	o	+	--	--	o	-	+	o	-	-	o	-	+	o	-	-	o	+	+	++
	5	--	--	o	o	--	-	o	o	-	-	o	+	--	-	-	-	+	o	-	-	-	-	+	o	o	o	o	+	+	++
	10 case a	o	o	o	+	o	o	o	+	o	o	+	++	o	o	-	-	-	-	o	+	o	o	o	o	o	+	o	++	+	++
	10 case b	-	-	o	o	-	-	o	o	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	o	o	+	+	+	++

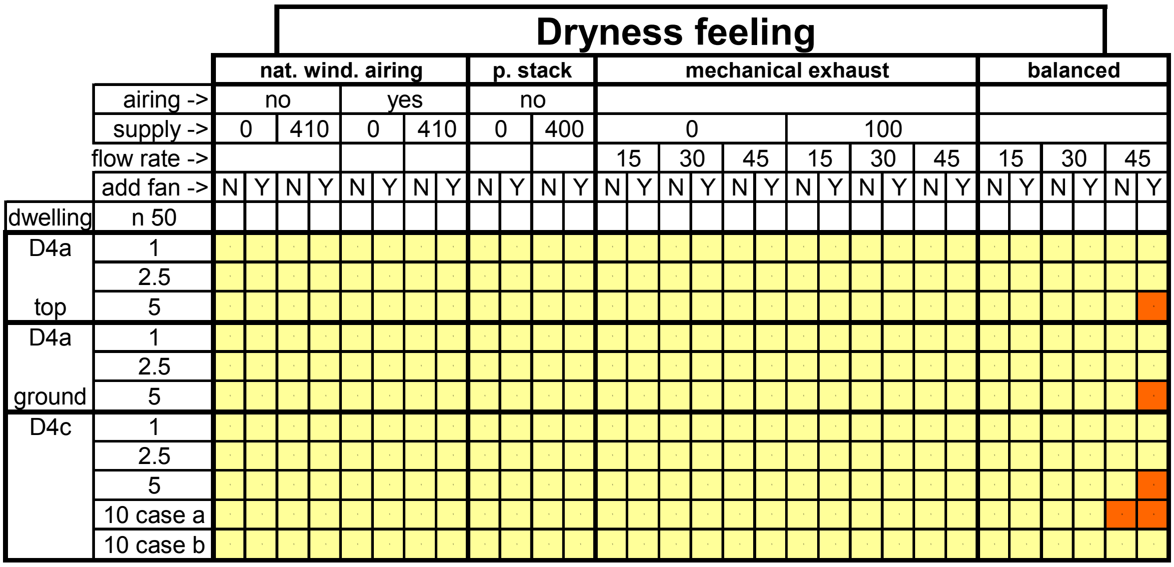
Condensation

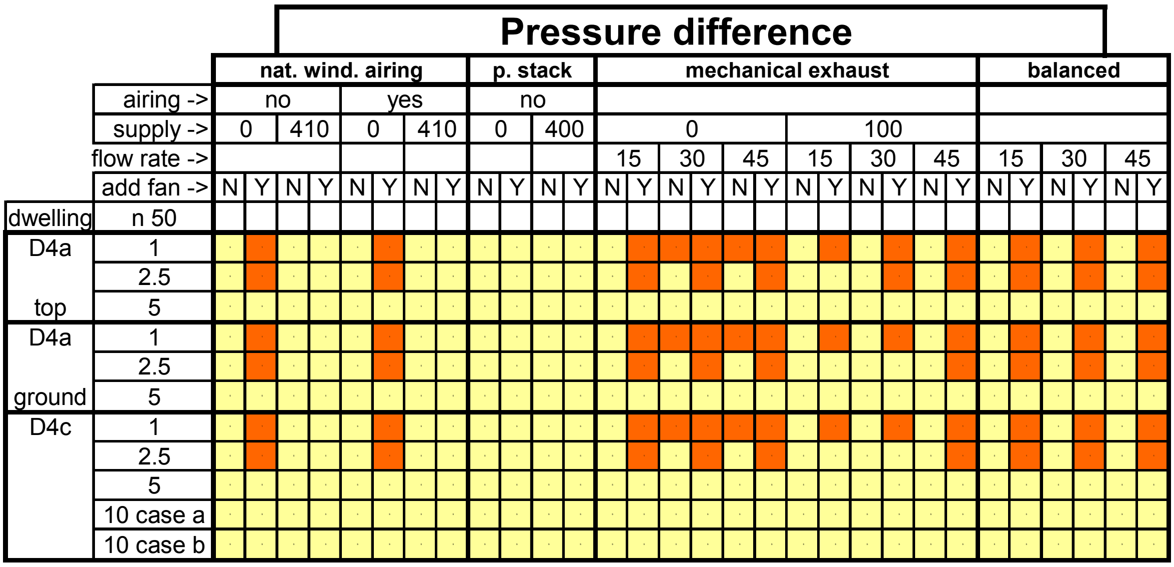
		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	--	--	--	-	--	--	--	-	--	--	-	++	--	-	-	++	o	++	--	+	-	++	o	++	--	++	-	++	o	++
	2.5	--	--	--	o	--	--	--	o	--	-	-	++	--	+	-	++	o	++	--	++	-	++	o	++	--	++	-	++	o	++
top	5	--	-	--	+	--	-	--	+	-	++	-	++	--	+	-	++	o	++	--	++	-	++	o	++	--	++	-	++	o	++
D4a	1	--	--	--	-	--	--	--	-	--	--	-	++	--	-	-	++	o	++	--	+	-	++	o	++	--	++	-	++	o	++
	2.5	--	--	--	o	--	--	--	o	-	+	o	++	--	+	-	++	o	++	--	+	-	++	o	++	--	++	-	++	o	++
ground	5	--	-	--	+	--	-	--	+	-	++	o	++	--	+	-	++	o	++	--	++	-	++	o	++	--	++	-	++	o	++
D4c	1	--	--	--	++	--	--	--	++	--	--	o	++	-	-	o	++	+	++	-	o	o	++	+	++	-	++	o	++	+	++
	2.5	--	--	--	++	--	-	--	++	--	--	o	++	-	-	o	++	+	++	-	o	o	++	+	++	-	++	o	++	+	++
	5	--	o	--	++	--	+	--	++	o	+	o	++	-	o	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	10 case a	-	++	-	++	-	++	-	++	+	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++	o	++	+	++	++	++
	10 case b	--	o	-	++	--	o	-	++	o	+	+	++	-	+	-	o	+	+	-	++	o	++	+	++	-	++	o	++	+	++

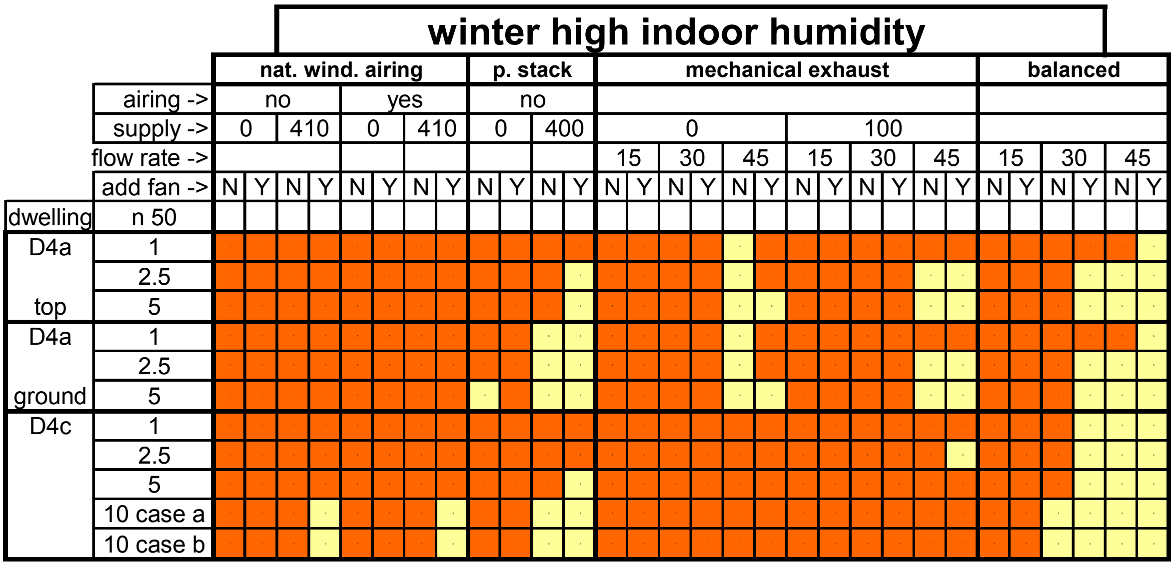
Heat needs

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	++	++	++	++	++	++	++	+	++	++	+	o	++	++	+	o	-	-	++	++	+	o	-	-	++	++	++	++	++	+
	2.5	++	++	++	++	++	++	++	+	++	+	+	o	++	++	+	o	-	-	++	+	+	o	-	-	++	++	++	++	++	+
top	5	++	++	++	+	++	++	+	+	+	+	o	o	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	+	+
D4a	1	++	++	++	++	++	++	++	+	++	+	-	-	++	++	+	o	-	-	++	++	+	o	-	-	++	++	++	++	++	+
	2.5	++	++	++	++	++	++	++	+	+	o	-	--	++	++	+	o	-	-	++	+	+	o	-	-	++	++	++	++	++	+
ground	5	++	++	++	+	++	++	+	+	o	-	--	--	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	+	+
D4c	1	++	++	++	+	++	++	+	+	++	+	o	o	++	++	+	o	o	-	++	++	+	o	o	-	++	++	++	++	++	+
	2.5	++	++	++	+	++	++	+	o	++	+	o	o	++	++	+	o	o	-	++	+	+	o	o	-	++	++	++	+	++	+
	5	++	++	+	+	++	+	+	o	+	+	o	-	++	+	+	o	o	-	++	+	+	o	o	-	++	++	++	+	+	+
	10 case a	+	+	o	-	+	o	-	-	o	-	--	--	+	o	o	-	-	--	o	o	o	-	-	--	+	o	o	o	o	-
	10 case b	++	+	o	-	+	o	-	-	o	-	--	--	+	o	o	-	-	-	+	o	o	-	-	--	+	+	+	o	o	o

climate : LONDON







climate : OTTAWA

Indoor air quality

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	- -	- -	-	o	- -	- -	-	o	- -	- -	o	o	-	- -	o	-	+	o	-	-	o	o	+	+	-	-	o	+	+	++
	2.5	- -	-	-	o	- -	-	-	o	-	-	o	+	-	-	o	-	+	o	-	-	o	o	+	+	o	o	o	+	+	++
top	5	-	-	-	+	-	-	-	+	o	o	o	++	o	o	o	o	+	+	o	o	o	+	+	+	o	+	o	++	+	++
D4a	1	- -	- -	-	o	- -	- -	-	o	- -	- -	o	+	-	- -	o	-	+	o	-	-	o	o	+	+	-	-	o	+	+	++
	2.5	- -	-	-	o	- -	-	-	o	-	-	+	++	-	-	o	-	+	o	-	-	o	o	+	+	o	o	o	+	+	++
ground	5	-	-	-	+	-	-	-	+	+	+	+	++	o	o	o	o	+	+	o	o	o	+	+	+	o	+	o	++	+	++
D4c	1	- -	- -	o	o	- -	- -	o	o	- -	- -	+	+	-	- -	o	- -	+	-	-	-	o	-	+	o	-	-	o	+	+	++
	2.5	- -	- -	o	+	- -	- -	o	+	-	-	+	++	-	-	o	-	+	o	-	-	o	-	+	o	o	o	o	+	+	++
	5	-	-	o	+	-	-	o	+	-	-	+	++	-	-	o	-	+	o	o	o	o	o	+	o	o	o	+	++	+	++
	10 case a	o	+	+	++	o	+	+	++	+	+	+	++	o	+	+	+	+	+	+	++	+	++	+	+	+	++	+	++	+	++
	10 case b	-	-	+	+	-	-	+	+	-	-	+	++	-	-	-	-	-	-	o	o	o	o	o	o	o	o	+	++	+	++

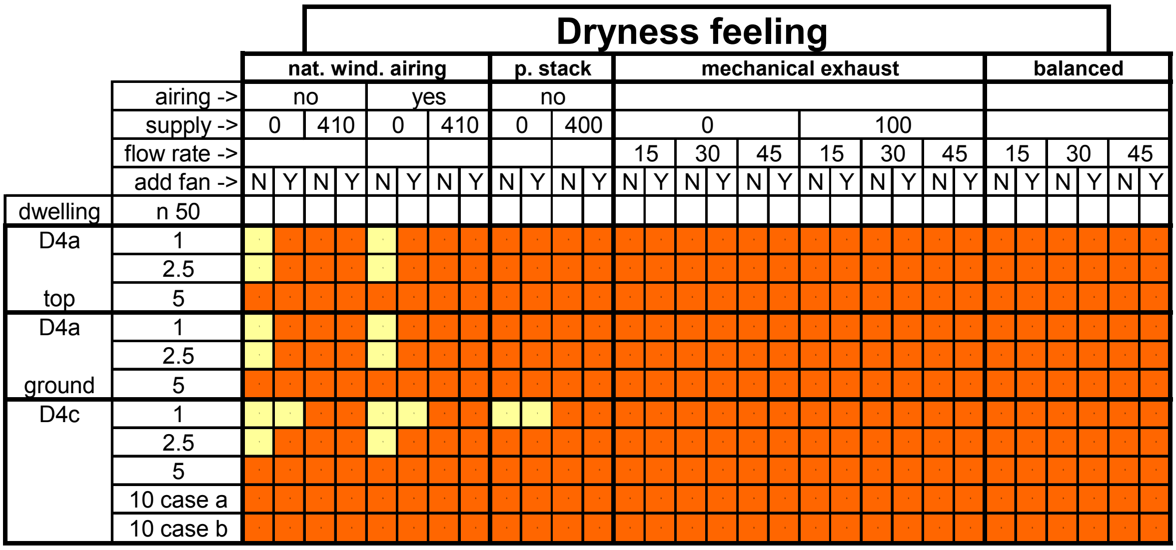
Condensation

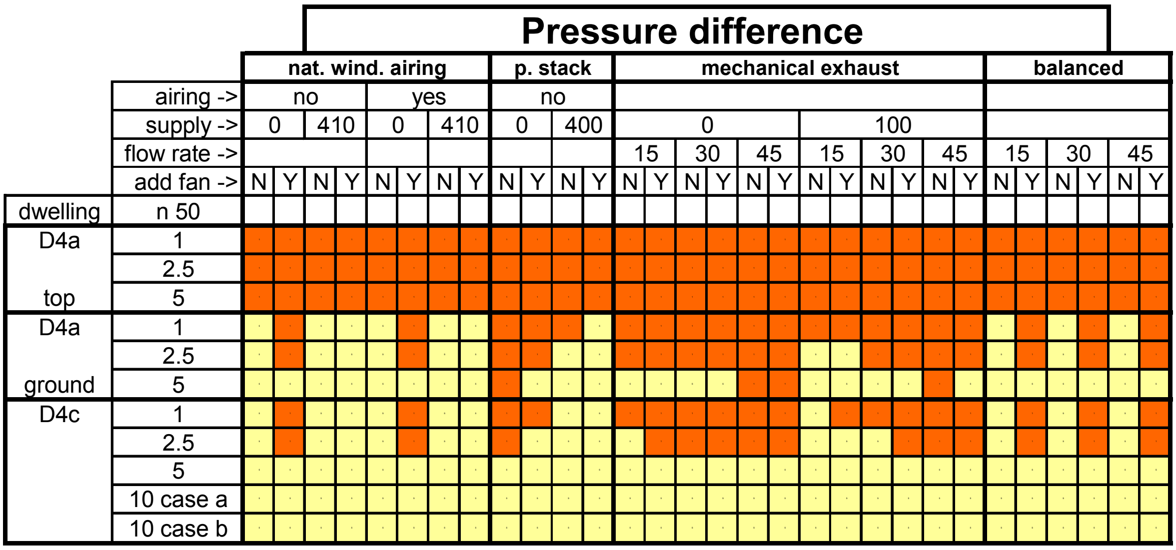
		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	- -	- -	- -	++	- -	- -	- -	++	- -	- -	o	++	-	-	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	2.5	- -	o	- -	++	- -	o	- -	++	-	+	o	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
top	5	- -	+	- -	++	- -	++	- -	++	o	++	o	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
D4a	1	- -	- -	- -	++	- -	- -	- -	++	-	-	+	++	-	-	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
	2.5	- -	-	- -	++	- -	o	- -	++	o	++	+	++	-	+	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
ground	5	- -	+	- -	++	- -	+	- -	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++	-	++	o	++	+	++
D4c	1	- -	- -	-	++	- -	- -	-	++	- -	- -	++	++	-	-	o	++	++	++	-	o	o	++	++	++	-	++	o	++	++	++
	2.5	- -	-	-	++	- -	o	-	++	o	o	++	++	-	o	o	++	++	++	-	++	o	++	++	++	o	++	+	++	++	++
	5	-	+	o	++	-	++	o	++	++	++	++	++	o	+	+	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++
	10 case a	o	++	+	++	o	++	+	++	++	++	++	++	+	++	++	++	++	++	+	++	++	++	++	++	+	++	++	++	++	++
	10 case b	-	++	o	++	-	++	o	++	++	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++	o	++	+	++	++	++

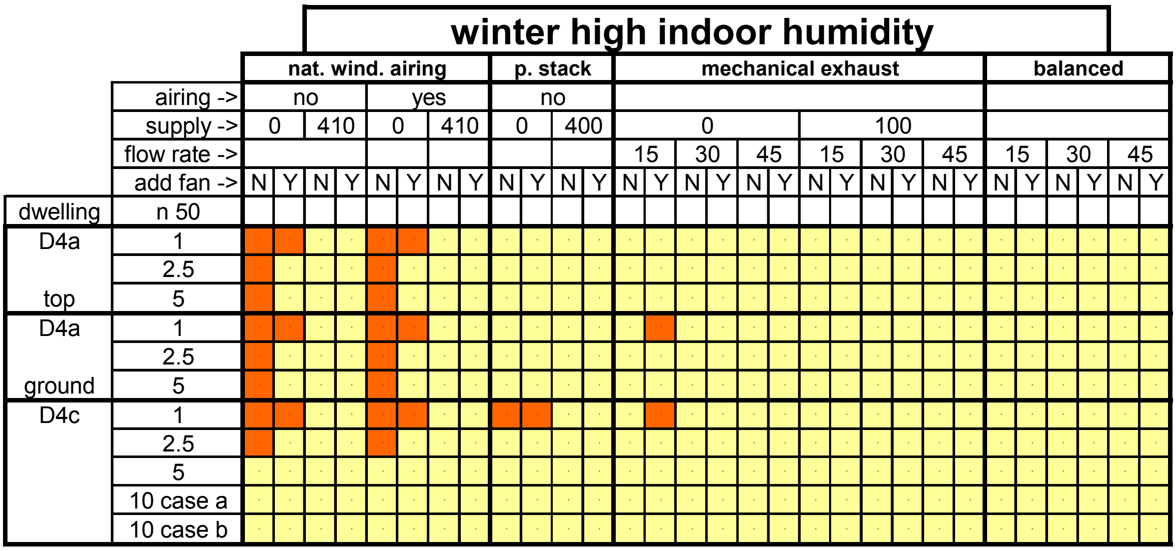
Heat needs

		nat. wind. airing								p. stack				mechanical exhaust												balanced					
	airing ->	no				yes				no																					
	supply ->	0		410		0		410		0		400		0						100											
	flow rate ->													15		30		45		15		30		45		15		30		45	
	add fan ->	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
dwelling	n 50																														
D4a	1	++	++	+	o	++	++	+	o	++	+	-	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	++	+
	2.5	++	++	+	o	++	++	+	o	+	o	-	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	+	++	+	+	o
top	5	++	+	o	-	++	+	o	-	o	-	- -	- -	+	o	o	o	-	- -	+	o	o	-	-	- -	++	+	+	o	o	o
D4a	1	++	++	+	o	++	++	+	o	+	-	- -	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	++	+
	2.5	++	++	+	o	++	++	+	o	o	- -	- -	- -	++	+	+	o	-	-	++	+	+	o	-	-	++	+	++	+	+	o
ground	5	++	+	o	-	++	+	o	-	- -	- -	- -	- -	+	+	o	o	-	-	+	o	o	-	-	- -	++	+	+	o	+	o
D4c	1	++	++	+	o	++	++	+	o	+	o	-	- -	++	++	+	o	o	-	++	+	+	o	o	-	++	++	++	+	++	+
	2.5	++	++	o	o	++	++	o	-	+	o	- -	- -	++	+	+	o	o	-	+	+	+	o	-	-	++	+	++	+	+	o
	5	++	+	o	-	++	+	-	-	-	-	- -	- -	+	o	o	-	-	-	+	o	o	-	-	- -	+	+	+	o	o	o
	10 case a	-	-	- -	- -	-	- -	- -	- -	- -	- -	- -	- -	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	-	- -	- -	- -	- -	- -
	10 case b	o	-	- -	- -	o	-	- -	- -	- -	- -	- -	- -	o	-	-	- -	- -	- -	-	- -	- -	- -	- -	- -	o	-	-	- -	-	- -

climate : OTTAWA







7.5 Additional Information

7.5.1 Simulations

The 990 simulations were done using the computer code SIREN95 ("SImulation du RENouvellement d'air") developed at CSTB. It is used to calculate the airflow throughout the entire heating season (about seven months) in a dwelling. The code uses hourly meteorological data (temperature, relative humidity, wind speed and direction). Occupancy and pollutant production (CO_2 and H_2O) are defined in 30 minute intervals.

Pollutant and humidity concentrations are assumed to be uniform (fully mixed) in each room. In SIREN95 internal pressures are assumed as a hydrostatic field; the inside temperature is considered to be constant in a horizontal plane (only vertical gradients (stack effect) are taken into account). The curves of parameters can be given by functions (not necessary smooth) or tables.

7.5.2 Input data

7.5.2.1 Climate

The simulations were performed for the heating season only with a preconditioning phase of 2 months to allow for the build-up of moisture within building and furniture. The definition of the heating season is as follows:

Cold climate: Ottawa heating season 2 Oct - 20 May
Moderate: London heating season 24 Sept - 20 May
Mild: Nice heating season 13 Nov - 27 April

The following charts give frequencies of outdoor temperature and wind speed and direction for the three climates (heating season only).

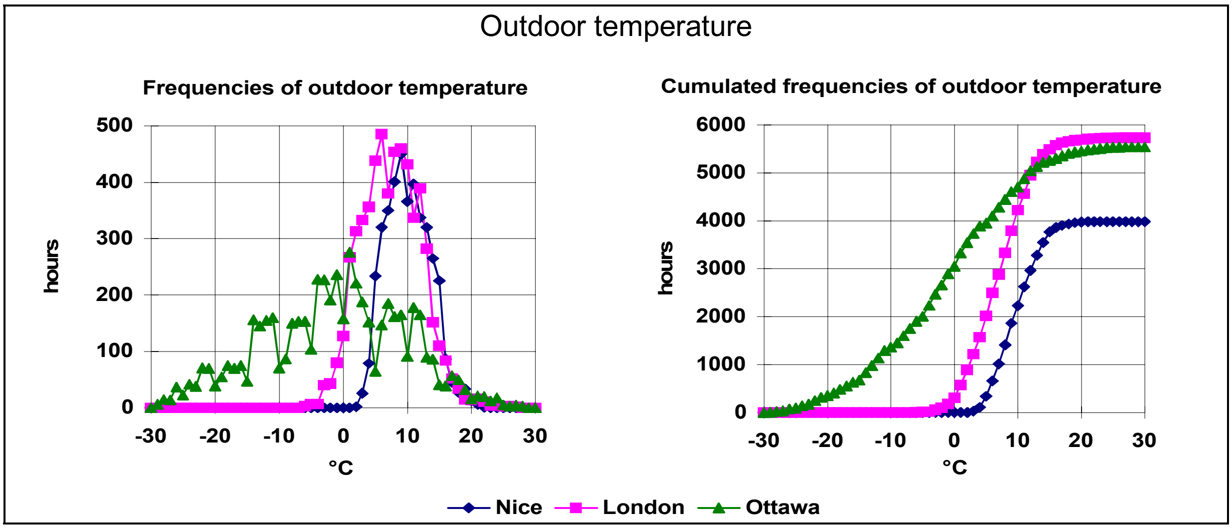


Figure 7.1 Outdoor temperatures for Nice, London, and Ottawa

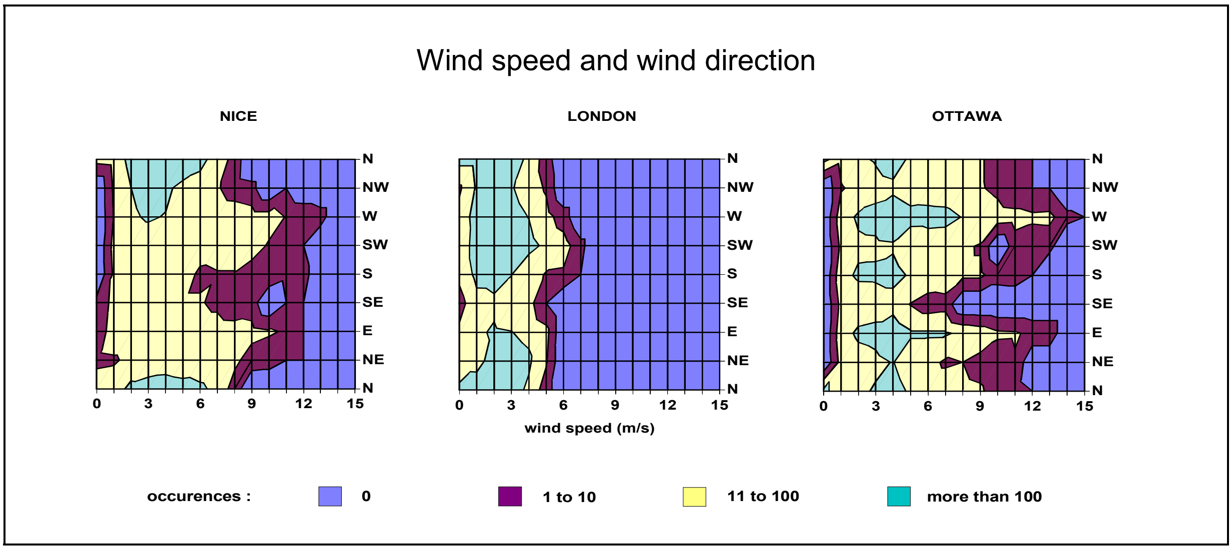


Figure 7.2 Wind speed and direction for Nice, London, and Ottawa

7.5.2.2 Dwellings

The D4a and D4c lay-outs are as follows (one square is $1m^2$):

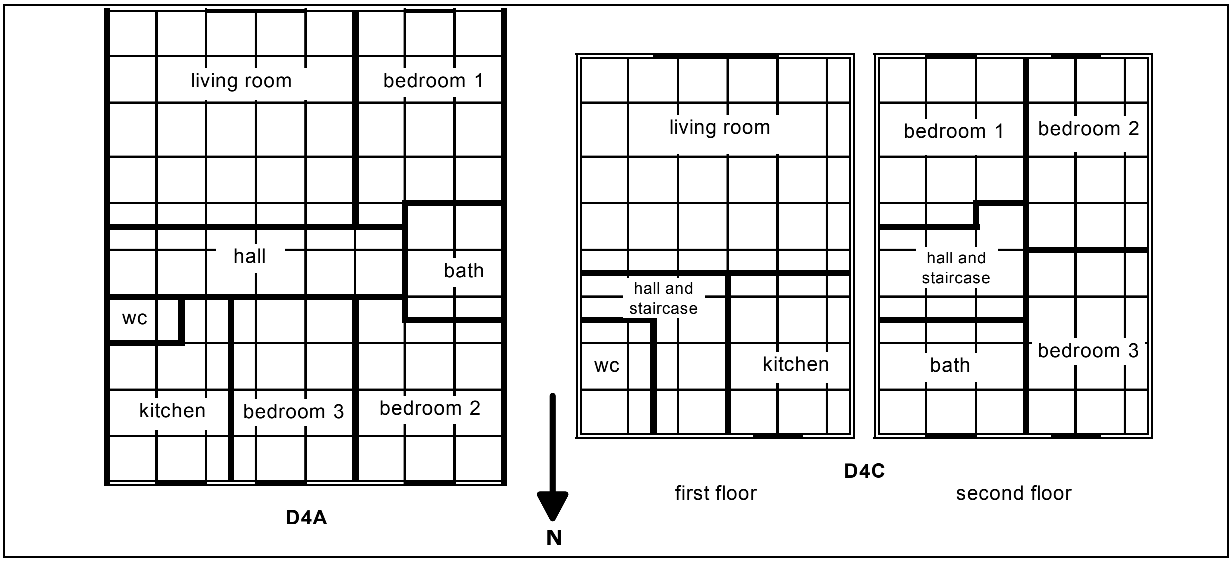


Figure 7.3 Dwelling lay-out

Half of the cracks are located at 0.625 m from the floor and the other half 1.875 m from the floor for leakageof 1, 2.5 and 5 ach. For a leakage of 10 ach the additional cracks are located at the floor and at the ceiling for the case '10a', and are concentrated in the hall for the case '10b'.

7.5.2.3 Window openings

Window airing is only assumed to occur by opening windows during the morning for cleaning and refreshing the bedrooms. Each bedroom is assumed to have a casement window with dimensions of 0.8 m*0.6 m (height*width).

The relationship between the ratio of opened area to the maximum area (0.48 m^2) depends on outdoor temperature and the wind conditions as follows:

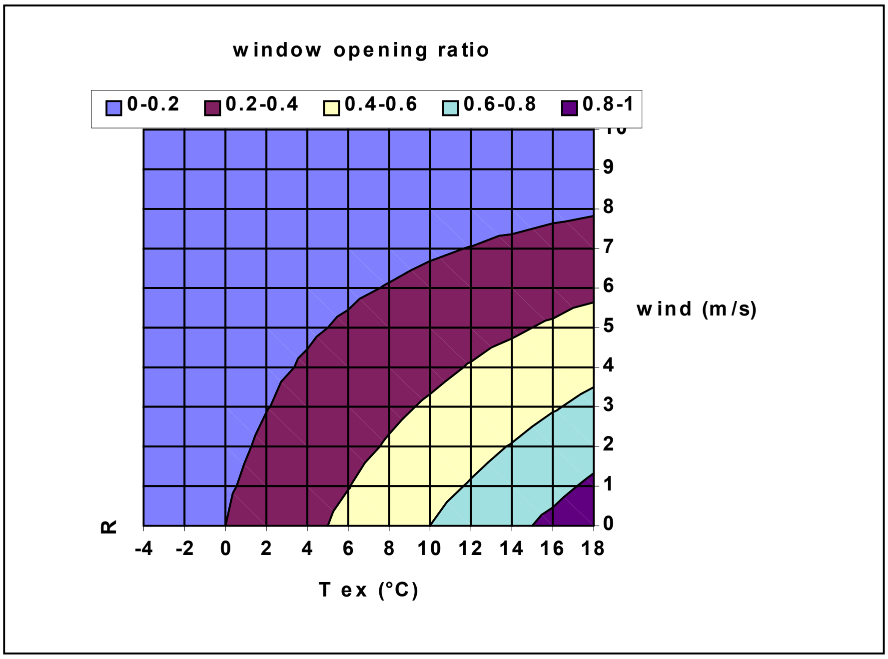


Figure 7.4. Relation between outdoor temperature and wind speed and window opening

7.5.2.4 Duct for passive ventilation system

The passive stack ducts are defined as follows:

- Length of the ducts:
  - ➢ Multifamily building. Building height to the top floor ceiling +1.5m.
  - ➢ Single family houses +2.5 m.
- Ducts are circular sheet metal with the sizes: Ø150 mm bath and toilet, Ø200 mm kitchen.
- The friction factor of the ducts is λ=0.05.
- The equivalent area of the exhaust device ("grilles"), (C_d=0.6), is 70 % of the cross-sectional area of the duct:
  - ➢ Kitchen: 200 cm^2
  - ➢ Bathroom and toilet: 125 cm^2

7.5.3 Output data

Pollutant description

- ***CO_2***: this pollutant is related to the human metabolism. It is based on the CO_2 production due to metabolism. CO_2 is not used here as an actual pollutant but is used, as commonly approved, as a tracer for the different pollutants produced by the human metabolism. The value taken into account is the exposure, in ppm.h above a level of 700 ppm (or 1050 if the outdoor level is assumed to be 350 ppm as an average). An exposure to 800 ppm above outdoor during 10 hr give therefore a value of (800-700)x10 = 1000 ppm h
- ***Cooking activities.*** It is proportional to the water evaporated during cooking and could be related to odour production or to CO or NO_x production in case of a combustion appliance. The unit is U3 with 1 U3/h ↔ 20 g/h of evaporated water
- ***Passive smoking.*** It is based on a constant production of pollutant for the duration the person is smoking within the room they are located. The unit is U4 with a production of 20 U4/h*smoker
- ***Indoor humidity:*** this is only used here to assess the feeling of dryness. It is not a generic pollutant as it can be expressed directly in terms of indoor relative humidity. The dryness feeling is assumed to occur when the relative humidity in the room air is less than 30 %.

The production of pollutants by occupants' metabolism is given in Table 7.2.

Table 7.2 Pollutant production due to metabolism, age and activity

		CO_2 (l/(h*p)	**H_2O (g/(h*p)**
Adult ≥ 15 years	Awake	18	55
	Sleeping	12	30
Children 10 and 13 years	Awake	12	45
	Sleeping	8	15
Child 2 years	Awake	8	30
	Sleeping	4	10

The production of pollutants by the residents' activities is given in Table 7.3.

Table 7.3 Pollutant production

Cooking g/h by person present at home			**Shower g/person**	**Smoking**
Breakfast	Lunch	Dinner		
50	150	300	300	20 U4/h in the living room when woman is present between 13.00 – 00.

7.5.3.1 Energy

The equivalent energy air change rate is simply calculated by:

$$Qave = \frac{\int 0.34 \times Q(t) \times (Ti - Te(t)) \times dt}{\int 0.34 \times (Ti - Te(t)) \times dt}$$

This parameter is the constant air change rate that would leads to the same heat demand as the actual one (this can vary with time).

7.5.4 Production of the "- -" "+ +" values and warning flags

As in most cases it is difficult to define what is right and what is wrong, we choose a relative way to classify the results. For a given parameter, the 990 results here presented were classified. Worst ones are quoted **"- -"** and best ones **"+ +".** More detailed information can be found in the background report.

For CO_2 we choose the exposure above 700 and 1400 ppm. The result is expressed in 10^3 ppm.h (kppm.h). For example, a value of 100 kppm.h for CO_2 over 1400 ppm can be due to an exposure of 1500 ppm during 1000 h ((1500-1400) * 1000) or to an exposure of 2400 ppm during 100 h.

For cooking and tobacco, we choose the total exposure to the pollutant.

Table 7.4 IAQ four pollutants, condensation two and energy are given the limits for the quality scores

Score	**IAQ**				**Condensation**		**Energy**
	CO2 700	CO2 1400	Cooking	Tobacco smoke	Wet rooms (cond WR)	Habitable rooms (cond HR)	
	[kppm.h]	[kppm.h]	[kU3.h]	[kU4.h]	[h]	[h]	[ach]
++ / +	500	100	600	400	100	5	0.4
+ / **0**	1000	200	1000	600	200	20	0.6
0 / -	2000	500	1500	1000	400	100	0.8
- / --	4000	1500	4000	1600	1000	500	1.0

7.6 References

Background reports:

1. Millet J-R, Villenave J G, Månsson L-G, De Gids W. *Assumptions for IAQ simulations and result presentations*.
2. Millet J-R, Villenave J G. *IAQ simplified tool*.
3. Millet J-R, Kronvall J, Villenave J G, Adalberth K. *Results for statistical analysis.*

Application

The IAQ tool was applied to the four ventilation systems and the three climates. The related input parameters were taken as follows:

IAQ input data	NWA	PSV	MEO	MSE
climate	Rome -> Nice			
	Amsterdam -> London			
	Stockolm -> Ottawa			
n50	5	5	5	2.5
airing	worst	no	no	no
supply	410	400	100	
airflow			30	30
add fan	Y for all except N for condensation and Winter low humidity			

Comments:
For Rome and Stockholm, the wind could be lower than Nice and Ottawa.
For n50 , supply air inlets, and airflows, we choose the nearest case available in the table.
For window airing is used a medium case, which is between standard and no window airing. We choose the worst rating for NWA and the only available case for the other systems. It can be noticed that when a ventilation system is installed, window airing does not modify in general the rating.
For the additional fan, we applied the rule given in 7.2.2
The results are as follows:

ROME / NICE

IAQ output results N	NWA	PSV	MEO	MSE
IAQ	+	+ +	+	+ +
condensation	o	+	+	+
heat needs	-	- -	o	+
dryness	noWF	noWF	noWF	noWF
pressure diff	noWF	noWF	noWF	WF
winter high indoor humidity	WF	WF	WF	WF

comments:

- IAQ results are always good, due to the fact that the heating season in short and that the wind is high which improves the results for NWA and PSV.
- Condensation ratings are quite good too. Even if the outdoor humidity is high, the temperatures are never low, which reduces the risks of condensation on outer walls.
- Heat needs equivalent air change are bad for NWA and PSV, due to the wind impact.
- Outdoor high humidity explains both dryness (no warning flag) and winter high indoor humidity (warning flag for all cases).
- For pressure difference, the warning for MSE is due to the good airtightness (n50=3 and no air inlets) and the running of the kitchen fan.

AMSTERDAM / LONDON

IAQ output results L	NWA	PSV	MEO	MSE
IAQ	o	+	-	+
condensation	- -	o	o	o
heat needs	o	-	o	+
dryness	noWF	noWF	noWF	noWF
pressure diff	noWF	noWF	noWF	WF
winter high indoor humidity	WF	WF	WF	WF

comments :

- IAQ results in the medium range. For MEO, the rating – can be due to the fact that hole due to the fan when it is not running reduces the ventilation in bedrooms (see comment in the last paragraph of 7.2.1).
- Condensation rating is bad for NWA. This is due to the fact that the wind is low and the heating season quite long.
- Heat needs equivalent air change is bad for NWA and PSV, due to the wind impact.
- For Warning flags, same comments as for Rome/Nice.

STOCKOLM / OTTAWA

IAQ output results O	NWA	PSV	MEO	MSE
IAQ	o	+ +	o	+
condensation	o	+ +	+ +	+
heat needs	-	- -	-	+
dryness	WF	WF	WF	WF
pressure diff	noWF	noWF	noWF	WF
winter high indoor humidity	noWF	noWF	noWF	noWF

comments :

- IAQ is good as the high wind and low outdoor temperature increase the air flows for NWA and PSV and improves the results for IAQ
- These high airflows also explain the good general rating for condensation and the bad rating o for heat needs.
- For Heat needs, only MSE has a good rating , due both to its better envelope airtightness and the heat recovery.
- Low outdoor humidity explains the Warning flag for dryness feeling, and its absence for Winter high indoor humidity. For pressure difference, see other climates comments.

8 Reliability

8.1 Introduction

This tool estimates the ventilation reliability for a dwelling. In general, the ventilation reliability means the probability that the chosen ventilation system performs in an acceptable way for a certain building, in a certain climate, between scheduled maintenance measures. Of real concern is the reliability of achieving good indoor air quality. For practical reasons two different reliability tools have been produced:

- reliability as indicated by air flow rate stability as a function of a number of factors (depending on the climate, home and ventilation system)
- reliability as indicated by performance over time i.e. systems and components reliability.

Furthermore, the reliability as indicated by perceived indoor air quality can be analysed using the IAQ tool (see Chapter 7).

The tool for airflow rate stability is based on the assumption that the ventilation flow rate in the bedrooms should exceed 4 l/s per person.

The tool for systems and components reliability is based on certain assumptions concerning their mean life times, standard deviation of mean life times and that which allows the user to see the effect of altering these assumed values.

8.2 Input Parameters

8.2.1 Building parameters

Three climates are taken into account: Nice, London, and Ottawa corresponding to mild, moderate and cold climates respectively.

Three types of dwellings are considered:

- An apartment with four main rooms (three bedrooms) located on the ground floor of a four-storey building, called D4a ground.
- An apartment with four main rooms (three bedrooms) located on the top floor of a four-storey building, called D4a top.
- A detached single family house with four main rooms (three bedrooms), called D4c

Two different leakage values. n_{50} can have the following values:

- or 5 air changes per hour at 50 Pa, for the apartments D4a
- or 10 air changes per hour at 50 Pa, for the house D4c

8.2.2 Ventilation system description

The ventilation systems are identified by the four base systems described in Chapter 3: Natural window airing (NWA), passive stack ventilation (PSV), mechanical exhaust only (MEO), mechanical exhaust and supply (MSE). Those systems can then be combined with local fans in bathroom/toilet and/or kitchen and window opening patterns (closed, or climate depending).

8.2.3 Windows opening (airing)

Bedroom windows can be opened during weekdays from 08:00 to 12:00, depending on the weather conditions.

Supply air

NWA 2 cases of purpose provided openings:

- **no** : **0 cm^2**
- **yes :** **410 cm^2** (80 cm^2 in each habitable room and 30 cm^2 in each of the toilet, bath, kitchen)

PSV 2 cases of purpose provided openings:

- **no :** **100 cm^2**
- **yes :** **400 cm^2** (80 cm^2 in each bedroom and 160 cm^2 in the living-room)

MEO 2 cases of purpose provided openings:

- **no :** **0 cm^2**
- **yes :** **100 cm^2** (20 cm^2 in each bedroom and 40 cm^2 in the living-room)

MSE 3 cases of supply flow rates:

- **15 l/s** (3 l/s in each bedroom and 6 l/s in the living-room)
- **30 l/s** (6 l/s in each bedroom and 12 l/s in the living-room)
- **45 l/s** (9 l/s in each bedroom and 18 l/s in the living-room)

8.2.4 Exhaust flow rates and stacks

NWA No vertical duct

PSV A passive stack ducted ventilation system is installed in the kitchen, bathroom and toilet.

MEO and MSE The mechanical exhaust flow rate is given for three levels.

- 15 l/s (7.5 l/s in the kitchen, 5 l/s in the bathroom and 2.5 l/s in the toilet)
- 30 l/s (15 l/s in the kitchen, 10 l/s in the bathroom and 5 l/s in the toilet)
- 45 l/s (22.5 l/s in the kitchen, 15 l/s in the bathroom and 7.5 l/s in the toilet)

Heat exchanger efficiency for MSE is 50 %

8.2.5 Local additional exhaust fans

No no local fan

Yes 2 local fans as follows:

- Kitchen hood: Running time 1 h/day, at 17.00 - 18.00. Flow rate 100 l/s
- Bathroom fan: Running time 2 h/day. **Weekdays** 06.00 - 08.00 and weekends from 9.00 - 11.00. Flow rate 25 l/s.

8.2.6 Technical quality of ventilation systems

Poor system: Low cost equipment is chosen in order to minimise the initial cost. Low attention to future maintenance and life cycle cost.

Average system: Relatively good quality standard equipment chosen according to good engineering practice. Some attention on minimising future maintenance and life cycle cost, but still rather high attention on minimising the investment cost.

Best Practice: The best available high quality equipment is carefully chosen. High attention on minimising future maintenance and life cycle cost. Less attention on reducing the investment cost.

Note: All the components of each system are assumed to be equally poor or good, i.e. there are no single especially weak (or strong) component. (To see the influence of an unevenly designed system we refer to the use of the advanced tool, which has been used when developing the simplified tool. See "Main background report".)

Maintenance levels

High: Maintenance is performed approximately 50-100 % more intense (often) than normal practice for the actual type of system.

Medium: Maintenance is performed with an intensity according to normal practice for the actual type of system.

Low: Maintenance is performed approximately 30-50 % less intense (often) than normal practice for the actual type of system.

Note: For each maintenance level, the maintenance interval of each component is assumed to be equally intense, i.e. there is no single maintenance interval for any component that is especially short or long. (To see the influence of an uneven maintenance scheme we refer to the use of the advanced tool. See "Main background report".) It should also be noted that if the chosen maintenance level does not correspond to the suggested level in the output of the LCC-tool, then the calculated LCC does not apply for the chosen level.

8.2.7 Other situations

The tool was produced based on a four room dwelling. For other cases, it is possible to use the tool if it is considered that one bedroom is added or deleted (nevertheless, a one main room dwelling should not be taken into account). The results are then less precise, but the ranking would remain quite the same. If these changes must be made, the following adjustments could be applied:

- n_{50} : no change, as n_{50} is related to the dwelling volume
- Airing : no change
- Supply air devices: the bedroom(s) added or deleted are equipped as defined in 2.2.2
- Mechanical airflow: add or subtract 3, 6 or 9 l/s for each bedroom. Split the total exhaust airflow in kitchen, bathroom and toilet using weights of 3:2:1.
- Additional fan : no change

8.3 Output Data

The output from the tool is given as qualitative ratings with the following interpretations:

+ +	**Excellent reliability**	**> 0.5 ach**
+	**Good reliability**	**0.25 – 0.5 ach**
0	**Fair reliability**	**0.12 – 0.25 ach**
-	**Poor reliability**	**0.06 – 0.12 ach**
- -	**Very poor reliability**	**< 0.12 ach**

8.4 Evaluation Tool

Tables 8.1, 8.2 and 8.3 give the reliability of air flow-rate stability as a function of a number of factors (depending on the climate, home and ventilation system).

Table 8.1 Reliability flow rate stability. Climate: **Nice**

System	**Airing**	**Inlet area**	**Exhaust fan flow rate**	**Extra fan**	**Dwelling**					
					Apartment				**House**	
					D4a top		**D4a ground**		**D4c**	
					n50		**n50**		**n50**	
					1	**5**	**1**	**5**	**2.5**	**10**
NWA	No	0		N	**- -**	**-**	**- -**	**-**	**- -**	**- -**
				Y	**- -**	**-**	**- -**	**-**	**- -**	**- -**
		410		N	**0**	**0**	**0**	**0**	**-**	**0**
				Y	**0**	+	**0**	**0**	**-**	**0**
	Yes	0		N	**-**	**0**	**-**	**0**	**-**	**-**
				Y	**-**	**0**	**-**	**0**	**- -**	**-**
		410		N	+	+	**0**	**0**	**0**	**0**
				Y	**0**	+	**0**	+	**0**	**0**
PSV	No	100		N	+	+	**0**	+	**0**	**0**
				Y	+	+	**0**	+	**0**	**0**
		400		N	+	+	+	+	+	+
				Y	+	+	+	+	+	+
MEO		0	15	N	**- -**	**0**	**- -**	**0**	**- -**	**0**
				Y	**- -**	**0**	**- -**	**0**	**- -**	**0**
			45	N	**0**	+	**0**	+	**-**	**0**
				Y	**0**	+	**0**	+	**-**	**0**
		100	15	N	**-**	**0**	**0**	**0**	**0**	**0**
				Y	**0**	+	**0**	**0**	**0**	**0**
			45	N	+	+	**0**	+	**0**	**0**
				Y	+	+	+	+	**0**	**0**
MSE			15	N	**0**	+	**0**	+	**0**	+
				Y	**0**	+	**0**	+	**0**	+
			30	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++
			45	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++

Table 8.2 Reliability flow rate stability. Climate: **London**

System	**Airing**	**Inlet area**	**Exhaust fan flow rate**	**Extra fan**	**Dwelling**					
					Apartment				**House**	
					D4a top		**D4a ground**		**D4c**	
					n50		**n50**		**n50**	
					1	**5**	**1**	**5**	**2.5**	**10**
NWA	No	0		N	**-**	**-**	**-**	**-**	**- -**	**-**
				Y	**- -**	**-**	**- -**	**-**	**- -**	**-**
		410		N	**0**	+	**0**	**0**	**0**	**0**
				Y	**0**	+	**0**	**0**	**0**	**0**
	Yes	0		N	**0**	**0**	**0**	**0**	**-**	**0**
				Y	**-**	**0**	**-**	**0**	**-**	**0**
		410		N	+	+	**0**	+	**0**	**0**
				Y	+	+	**0**	+	**0**	+
PSV	No	100		N	+	+	**0**	**0**	**-**	**0**
				Y	+	+	**0**	**0**	**-**	**0**
		400		N	+	+	+	+	**0**	**0**
				Y	+	+	+	+	**0**	**0**
MEO		0	15	N	**- -**	**0**	**- -**	**0**	**- -**	**0**
				Y	**- -**	**0**	**- -**	**0**	**-**	**0**
			45	N	**0**	+	**0**	+	**-**	**0**
				Y	**0**	+	**0**	+	**-**	**0**
		100	15	N	**0**	+	**0**	**0**	**0**	**0**
				Y	**0**	+	**0**	**0**	**0**	**0**
			45	N	+	+	+	+	**0**	**0**
				Y	+	+	+	+	**0**	**0**
MSE			15	N	**0**	+	**0**	+	**0**	+
				Y	**0**	+	**0**	+	**0**	+
			30	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++
			45	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++

Table 8.3 Reliability flow rate stability. Climate: **Ottawa**

System	Airing	Inlet area	Exhaust fan flow rate	Extra fan	Dwelling					
					Apartment				House	
					D4a top		D4a ground		D4c	
					n50		n50		n50	
					1	5	1	5	2.5	10
NWA	No	0		N	-	0	-	0	-	0
				Y	-	0	-	0	-	0
		410		N	0	+	0	+	0	0
				Y	0	+	0	+	0	0
	Yes	0		N	0	0	0	0	0	0
				Y	0	0	0	0	0	0
		410		N	+	+	+	+	0	+
				Y	+	+	+	+	0	+
PSV	No	100		N	0	0	0	0	-	0
				Y	0	0	0	0	-	0
		400		N	+	+	0	0	0	0
				Y	+	+	0	0	0	0
MEO		0	15	N	- -	0	- -	0	-	0
				Y	- -	+	-	0	-	0
			45	N	0	+	0	+	-	0
				Y	+	+	0	+	0	0
		100	15	N	0	+	0	0	0	0
				Y	0	+	0	+	0	0
			45	N	+	+	+	+	0	0
				Y	+	++	+	+	0	0
MSE			15	N	0	+	0	+	0	+
				Y	0	+	0	+	0	+
			30	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++
			45	N	++	++	++	++	++	++
				Y	++	++	++	++	++	++

Table 8.4 Reliability as indicated by performance over time is shown in the set of tables on this page

8.4.1 Apartments

Passive stack ventilation system			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	++	++	-
Average system	++	++	+
Best practice	++	++	++

Central exhaust ventilation			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	++	-	--
Average system	++	++	-
Best practice	++	++	+

Central supply and exhaust ventilation			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	+	--	--
Average system	++	+	--
Best practice	++	++	0

For natural window airing ventilation strategy, only openable windows, and sometimes natural supply air devices in the facades, constitute the ventilation system. For this
case, the score "++" could be used.

8.4.2 Single family houses

Passive stack ventilation system			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	++	+	-
Average system	++	++	+
Best practice	++	++	+

Central exhaust ventilation			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	++	-	--
Average system	++	++	-
Best practice	++	++	+

Central supply and exhaust ventilation			
Technical quality of system	Maintenance level		
	High	Medium	Low
Poor system	+	--	--
Average system	++	0	-
Best practice	++	++	-

For natural window airing ventilation strategy, only openable windows, and sometimes natural supply air devices in the facades, constitute the ventilation system. For this
case, the score "++" could be used.

8.5 Further Information

8.5.1 Reliability as indicated by situational factors

Computer simulations of the supply rate of outdoor air to individual rooms have been performed using a multi-zone air flow model.

The reliability as indicated by situational factors study is focused on the fraction of the total heating season when the **ventilation airflow rate is at or above a certain ventilation requirement.** The target value chosen for outdoor air ventilation flow rate is 4 litres per second per person in the bedrooms. This target value is commonly used by a number of countries.

In order to establish quantitative relationships between building characteristics, ventilation strategies, climates etc. and the air flow rates to the bedrooms, a procedure using fractional factorial design (174 combinations) and statistical analysis was used.

In the simplified tool a qualitative value is given depending on the fraction of time when the air flow rates at or above the target value. This is 4 litres per second per person in the bedrooms, as an average for the bedrooms in the house/dwelling.

In order to assess the performance of different ventilation strategies etc., from a flow rate stability point of view, it is necessary to set up intervals for different levels of stability, see Table 8.5.

Table 8.5 Interpretation from fraction of time the flow rate is kept to a quality guide

Fraction of time with acceptable flow rates	**0.50-1.00**	**0.25-0.50**	**0.12-0.25**	**0.06-0.12**	**0.00-0.06**
Assessment	++	+	**0**	**-**	**--**
Reliability Quality	**Excellent**	**Good**	**Fair**	**Poor**	**Very poor**

8.5.2 Reliability as indicated by performance over time

Mechanical ventilation systems are built up of a number of mechanical and electrical components, such as fans, electrical motors, dampers, silencers, air terminal devices, systems for automatic control etc. The way that these components influence the performance of the system can be described in a fault-tree analysis. There are principally three different kinds of probabilities to estimate individual events.

Fixed probabilities These probabilities, in principle, are independent of time. The probability of power failure, for example, can be estimated if you can acquire data from the electricity company on how many hours each year power failure occurs.

Time-depending probabilities These probabilities are dependant on time. As an example, the failure rate for mechanical components will increase with time as the components get older. Another example is duct fouling which will gradually lower the flow rate over time.

Poorly-defined probabilities In the context of ventilation performance, typical examples are events based on user influence. There is little knowledge of the values of these probabilities both because each person is different and that the design of the ventilation system influences user behaviour.

By connecting component models in a fault-tree scheme, the analysis can be extended to a system level. An example of a fault-tree for a mechanical exhaust ventilation system is given in Figure 8.1.

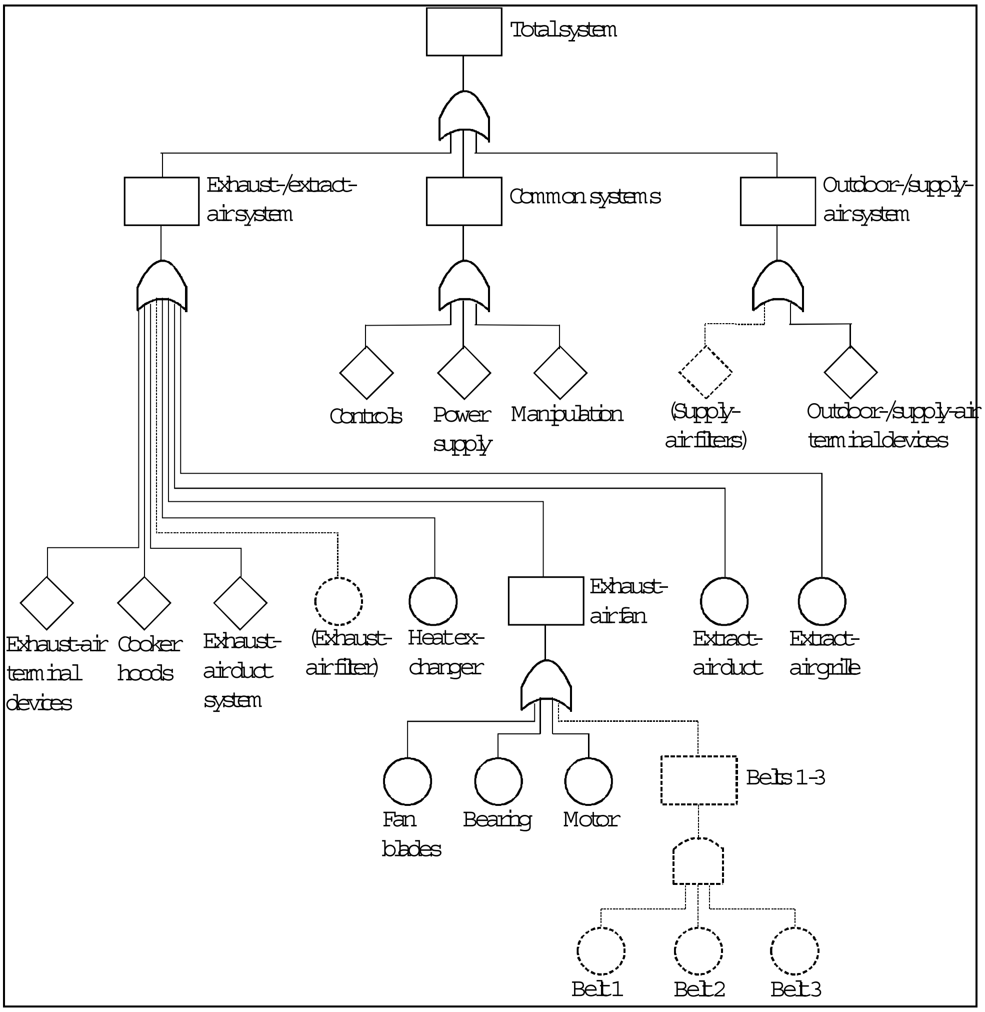


Figure 8.1 Fault tree for a central mechanical exhaust ventilation system

A simplified model for describing the influence of maintenance has also been incorporated into each component model. It assumes that after each maintenance occasion, the component is "as good as new".

For each type of system, three different quality standards have been defined and combined with three different levels of maintenance. This results in a matrix with a total of nine different combinations for each ventilation system. Relevant data has been collected from published work of and personal communication with maintenance people and other researchers working with reliability or related matters.

The result of each combination in the matrixes with life time and maintenance intervals can be presented in figures showing the estimated reliability for the system as a function of time. The result is further evaluated by calculating the mean and minimum value of the reliability for a time span of 30 years. An example is shown in Figure 8.2. The result for each system applied to both single-family houses and multi family buildings can be summarised in a set of matrixes.

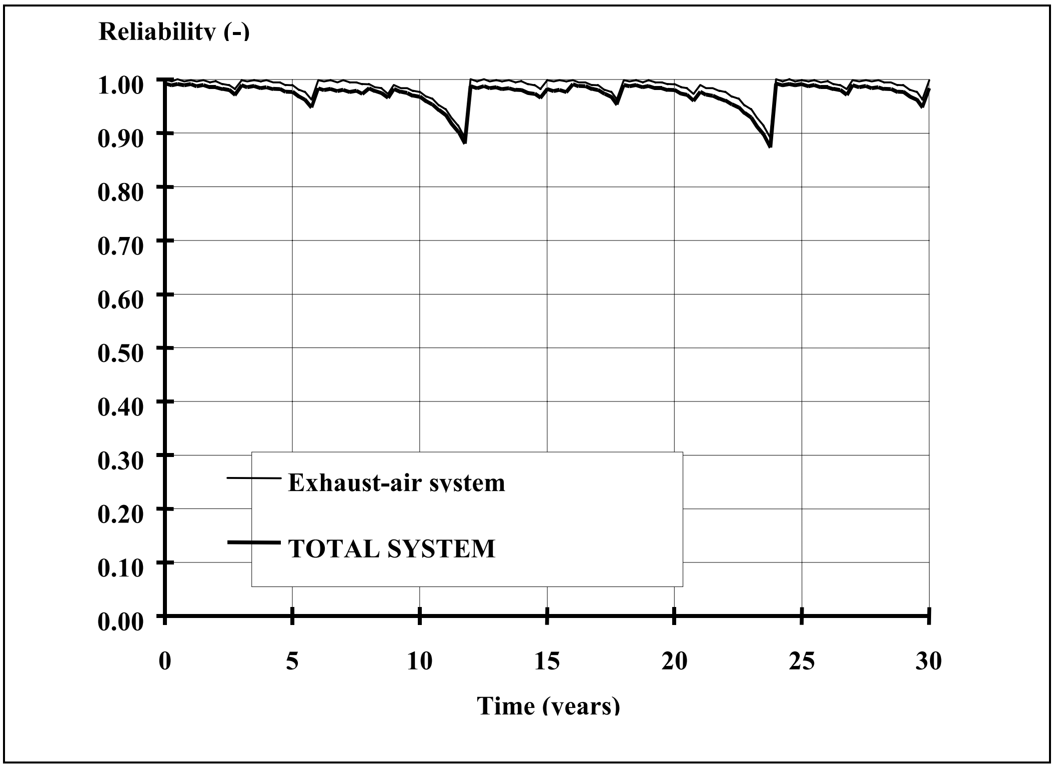


Figure 8.2 The variation of reliability over a 30 year period for a multi-family building with exhaust ventilation at an average system performance with medium maintenance

The resulting mean and minimum values (of the reliability for a time span of thirty years) given in the matrixes is then finally evaluated and transferred into a single classification system, the qualitative tool. The interpretation from mean and minimum values to qualitative values are given in Table 8.6.

Table 8.6 Interpretation from quantitative values to qualitative values

	Minimum reliability									
Mean reliability	**0.90-1.00**	**0.80-0.89**	**0.70-0.79**	**0.60-0.69**	**0.50-0.59**	**0.40-0.49**	**0.30-0.39**	**0.20-0.29**	**0.10-0.19**	**0.00-0.09**
0.90-1.00	++	++	+	+	0	0	-	-	- -	- -
0.80-0.89		+	+	0	0	-	-	- -	- -	- -
0.70-0.79			0	0	-	-	- -	- -	- -	- -
0.60-0.69				-	-	- -	- -	- -	- -	- -
0.50-0.59					- -	- -	- -	- -	- -	- -
0.40-0.49						- -	- -	- -	- -	- -
0.30-0.39							- -	- -	- -	- -
0.20-0.29								- -	- -	- -
0.10-0.19									- -	- -
0.00-0.09										- -

The use of the advanced tool for systems and components factors involves the use of a computerised tool (spreadsheet) for MS-Excel, Version 5.0 or 7.0. The tool is available electronically (by e-mail with attached *.XLS files, or on diskette) from:

Mr. Svein Ruud, Swedish National Testing and Research Institute,
Mail: Box 857, S-501 15 BORAAS, Sweden,
E-mail: svein.ruud@sp.se

Or

Dr. Johnny Kronvall, J&W
Mail: Slagthuset, S-211 20 MALMOE, Sweden,
E-mail: johnny.kronvall@jw.se

In this advanced tool, it is possible to change the figures and use your own figures.

8.6 References

8.6.1 Main background report

1. Kronvall, J., Ruud, S. et al., (1998) *Reliability of Domestic Ventilation Systems*, AB J&W, Malmö, Sweden.

Other related literature

2. Feustel, H. & Raynor-Hoosen, A., (1990) *COMIS Fundamentals*, Energy Performance of Buildings Group, Applied Science Division, Lawrence Berkeley Laboratories, Berkeley, USA.
3. Gröninger, B.P. and van Paasen, A.H.C. (1997) *Characteristics Values of Natural Ventilation and Air Conditioning,* Proceedings from the 18th AIVC Conference in Greece, AIVC, Coventry, UK, 1997.
4. Kronvall, J., (1996). *System Safety Analysis on the Performance of Mechanical Ventilation Systems,* Proceedings from the 17th AIVC Conference in Sweden, AIVC, Coventry, UK.
5. Kronvall, J. & Ruud, S., (1997). *System Safety Analysis on the Performance of Mechanical Ventilation Systems – the quantitative approach*, Proceedings from the 18th AIVC Conference in Greece, AIVC, Coventry, UK, 1997.
6. Myrefelt, S., (1996). *A Model for Feed-back of Experience on Operational Reliability in Indoor-climate and Ventilation systems* (In Swedish) Div. of Building Services Engineering, Royal Institute of Technology, Sweden.

9 Energy

9.1 Introduction

9.1.1 General

The first idea for the energy tool was to develop nomograms to evaluate the energy consumption in dwellings due to ventilation. The energy use due to ventilation and infiltration can be divided into two parts:

- The energy to heat the infiltration and ventilation air
- The energy used for the transport of air through the ventilation system

On the basis of some ideas in Dutch Standard and some draft CEN standards we started of with nomograms on printed paper to evaluate energy consumption for mechanical exhaust systems.
Important parameters for energy calculations are:

- Flow rate
- Heat recovery yes or no and if yes the efficiency of it
- The dwelling leakage
- The use of the ventilation provisions
- The climate.

Since there is an interaction between infiltration and ventilation, it was almost impossible to use nomograms for the ventilation systems with natural supply. The decision was taken to run a single zone ventilation model behind the nomogram calculating the lines of the nomogram instantaneously. This approach was successful. The tool now consists of an interactive computer program which calculates the nomogram. The user has to provide input data to define the dwelling, the ventilation system and the climate. The tool is called Enervent 2, and is available on disk which is included with this report. Full installation instructions are found on the disk.

More detailed information of the tool can be found in the background report [1].

The complete screen of the nomogram is given in Figure 9.1.

9.1.2 Limitations

The energy tool can be applied for almost all type of dwellings and ventilation systems. The dwelling to be considered has to be defined in a brief way, the number of stories, volume, number and size of windows and air inlets, air leakage, etc. The user has a choice of the following ventilation systems ;

Natural Window Airing (NWA),
Passive Stack Ventilation (PSV),
Mechanical Exhaust Only (MEO),
Mechanical Supply and Exhaust (MSE).

For the definitions of these ventilation systems see Chapter 3

With this flexibility, the energy tool can be applied to almost all dwellings throughout the world.

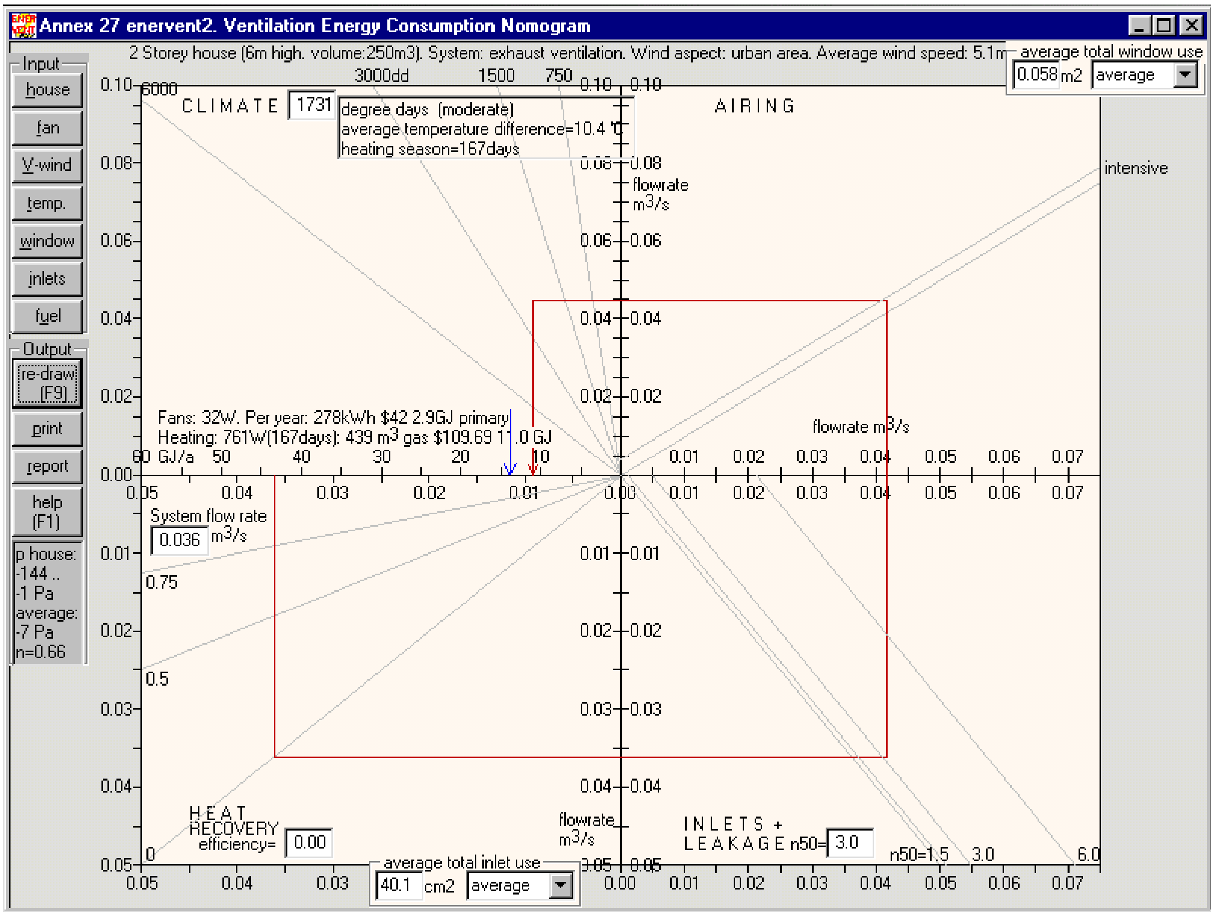
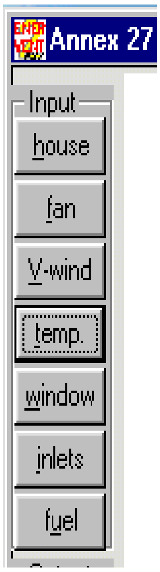


Figure 9.1 The screen from the program of the nomogram



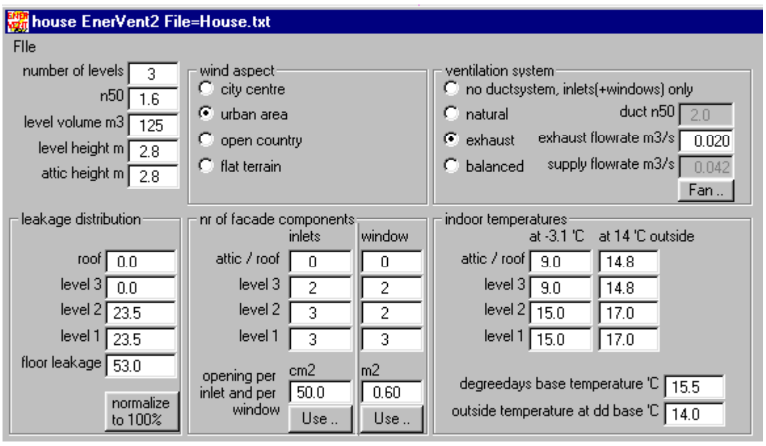


Figure 9.3 Input field under the button

Figure 9.2 Input bar of the nomogram

9.2 Input Data

The nomogram for energy necessary to heat the infiltration and ventilation air consists of the following parts:

- Air flow rate and heat recovery efficiency
- Air leakage of the dwelling
- The use of windows for airing
- The climate indoor/outdoor.

The nomogram input bar is given in Figure 9.2.
Each of the 7 buttons can be clicked to open an input data sheet for the user to complete. The input data associated with each of these buttons is described in more detail below.

9.2.1 System flow rates

For the calculation of the energy used by ventilation one need to start from a designed system flow rate. For mechanical systems (MEO, MSE) this is quite clear. Values from building codes or standards may be taken. But further information must be given on the time the fans are running and if applicable the fan switch position. For the ventilation systems with natural supply it is more difficult. Some building codes or standards require windows or other inlets with a certain defined opening size. The single zone model behind the nomogram calculates the flow rate with that information on the basis of the inlets and outlets you have defined yourself. The number, position, inlet area and the wind shielding as well as other items which will be explained later are entered under the button "house", see Figure 9.3.

The use of the inlets by the residents is defined under the button "inlets", see Figure 9.4.

Default data is also available.
The data on the use of the inlets by the inhabitants is based on earlier work in IEA Annex 8 - Inhabitants behaviour with regard to ventilation [3].
Energy from the airflow through the system can be recovered with a heat exchanger. The efficiency of the heat exchanger must be known and can be chosen in the first part of the nomogram, which will be found in the lower left part of the nomogram.

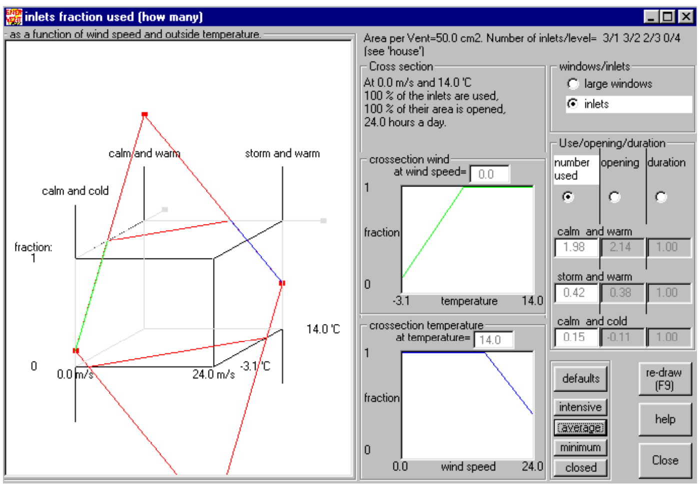


Figure 9.4 Input field for the use of inlets by the habitants

Specific information on fan(s) may be defined under the button "fan", see Figure 9.5. All flow rates are given in m^3/s.

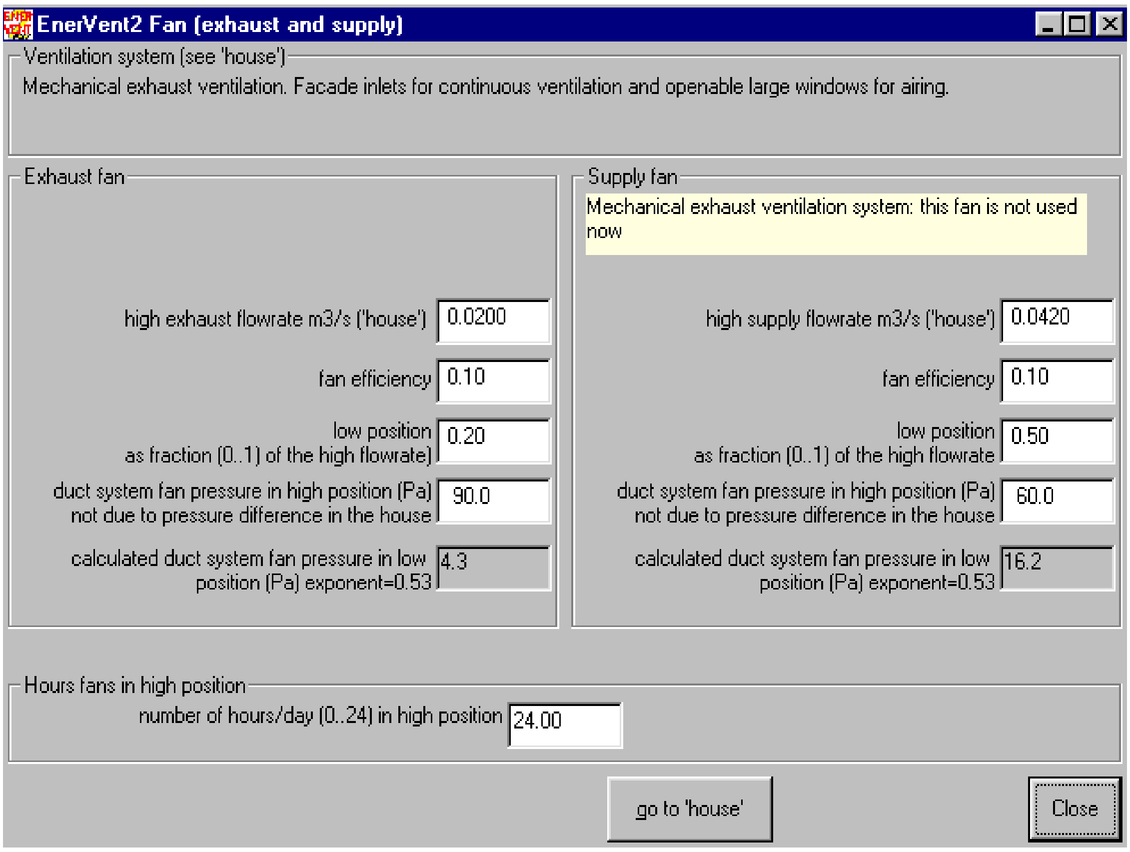


Figure 9.5 Input field for fans in the program.

9.2.2 Infiltration

Added to the system flow will be an infiltration flow due to the air leakage of the dwelling. Not only the air leakage of the whole dwelling but also the distribution of this over the dwelling envelope is important. This input must be given under the button "house" in the tool. The overall leakage data of the dwelling as an N_{50}-value is necessary. For the leakage distribution, default values are taken in case no data will be supplied. This air leakage effect will be found in the lower right part of the nomogram.

9.2.3 Airing

In addition to the system flow and the infiltration flow, the airflow due to window airing must be added.

As defaults we distinguish between minimum use, average use and extensive use. The relation between the outside weather and the use of the windows is based on the results of IEA Annex 8 [3] and on reference [2]

The user defines the number and size of the windows under the button "house". The use of the windows is defined under the button "window", see Figure 9.6.

The effect of window airing can be found in the upper right part of the nomogram.

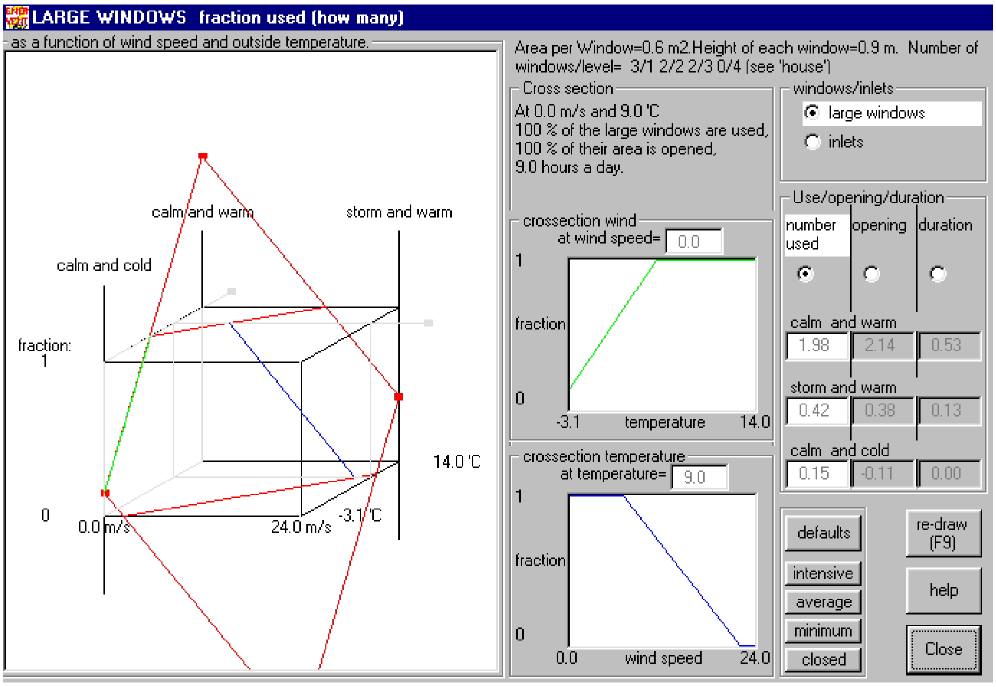


Figure 9.6 Input field under the button “window”

9.2.4 Climate

General
For the calculation of the energy consumption due to ventilation and infiltration one need to take into account the temperature difference between inside and outside and the wind velocity distribution.

Indoor Climate
Indoor room temperatures are not calculated by the program. The user has to estimate the indoor temperature for two levels of outside air temperature. The indoor temperatures for each level or storey must be specified under the button “house”.

Outdoor Climate
From the total flow one may find the energy consumption due to ventilation and infiltration. This needs information on the average temperature difference. This average temperature difference is calculated from the outdoor climate you can define yourself. Default data on climate is available for three climates, mild, moderate and cold. This can be found in the upper left part of the nomogram.
This input can be given under the button “V-wind” and the button “temp.”, see Figure 9.7.

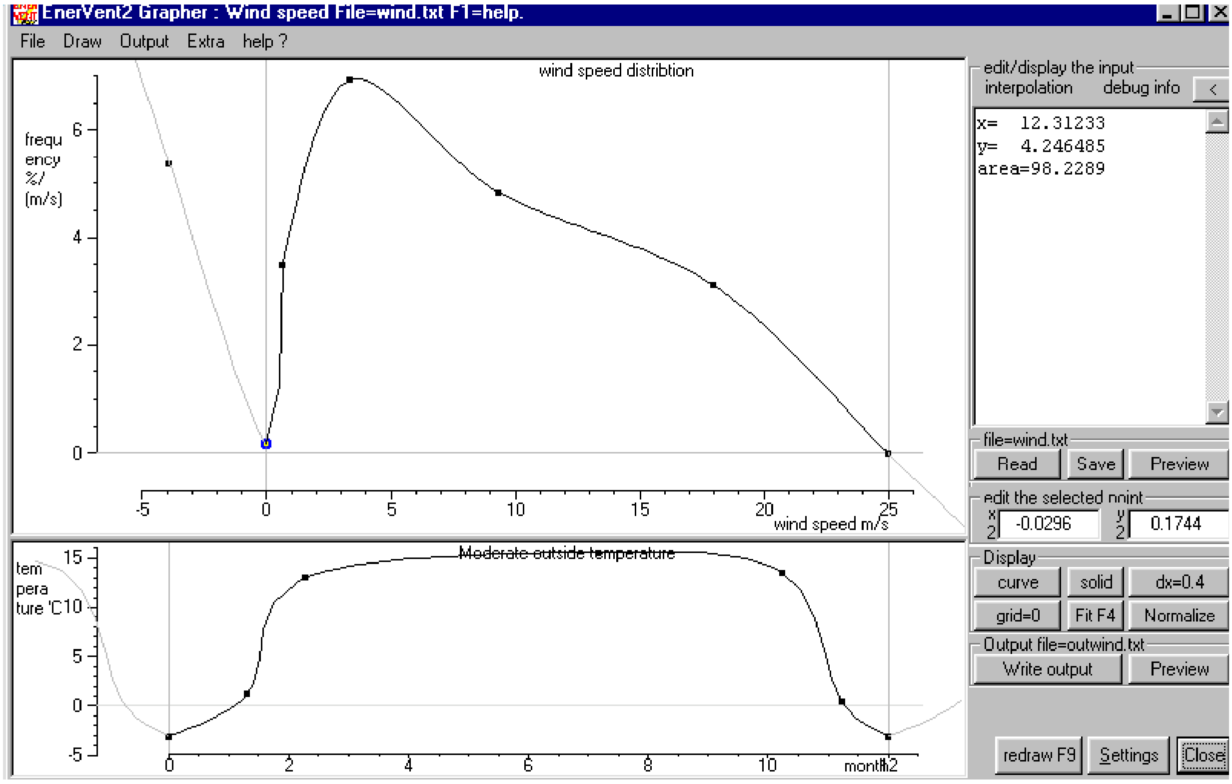


Figure 9.7 Input fields for wind and outside temperature

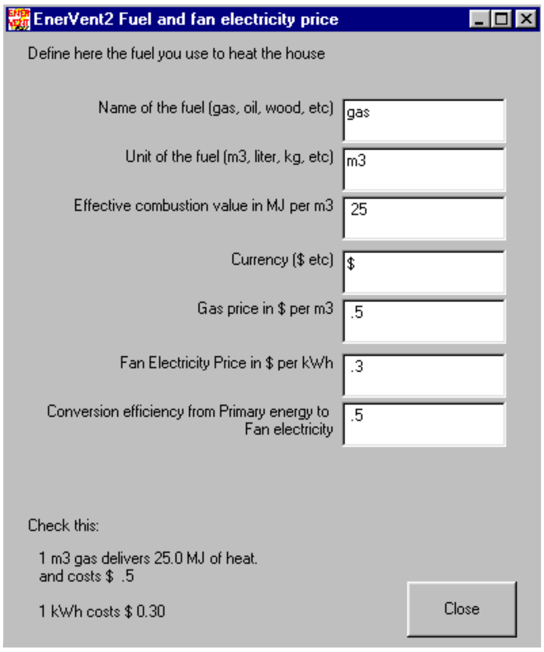


Figure 9.8 The input field for fuel

Figure 9.9 The output bar *of the nomogram*

9.2.5 Fuel

Under the button "fuel" the user can define their one fuel to be used to heat the ventilation and infiltration air. The fuel input field is given in Figure 9.8.

9.3 Output

9.3.1 General

- The nomogram for energy, will after sufficient input data, finally draw a red line passing the four fields of the nomogram and ending with a red and blue arrow.
- The blue arrow give the result of the calculations for the total annual energy consumption in GJ.
- The red arrow is the result to heat the infiltration and ventilation air in GJ.
- The nomogram output bar is given in Figure 9.9.

In addition, the following buttons will be found under output:

- Redraw - redraws the final result and erases the previous green ones,
- Print - prints the nomogram on a default printer
- Report - open a text file with explanation about current input and output data, including some warnings,
- Help - open the help file,
- "p" house - which gives information about the weighted average pressure.

An example of the report is presented on the next page.

IEA Annex 27. EnerVent2. Calculation of the energy used to warm up the ventilation air for a house during the heating season.

======I n p u t======

The example house is a 3 Storey house (11m high. volume: 438m^3). System: Exhaust Ventilation (MEO). Wind aspect: urban area. Average wind speed: 9.8m/s n=0.71

Files used:

House	House.txt		
Wind	wind.txt		
Temperature	temp.txt		

Fan: exhaust high=	0.020m^3/s		
efficiency=	0.10 -	System pressure=	90.0 Pa.
Fan: time high=	24:00hours		

Average system flow rate = 0.020 m^3/s
Air leakage value, n50 =1.6 Air Changes per Hour at 50 Pa giving:
0.1944 m^3/s at 50 Pa; 0.0615 m^3/s at 10 Pa; 0.0320 m^3/s at 4 Pa; 0.0119 m^3/s at 1 Pa.
The estimated envelope area is 288.2 m^2 .
The flow rate per m^2 is: 6.75-4m/s at 50 Pa; 2.14-4 at 10 Pa; 1.11-4 at 4 Pa; 4.12-5m/s at 1 Pa.
The total opened area of large windows (averaged over the heating season)= 0.446 m^2
The total opened area of inlets (averaged over the heating season)= 142 cm^2
The number of degree-days is: 1488 dd

======C a l c u l a t i o n======

This run considers heating during the heating season and fan energy during the whole year.
The heating season is the period with outdoor temperatures below 14.0 °C which occurs at the degree-days base temperature inside (15.5 °C).
The pressure in the house ranges from =-4.3 to -1.2 Pa
The weighted average pressure in the house is -2.8 Pa .
The weighted average system flow rate = 0.020 m^3/s
There is no heat recovery.
The air leakage of the house (n50=1.6) results in an extra ventilation flow rate of 0.018 m^3/s
The ventilation inlets that have an average area of 141.6 cm^2 result in an extra ventilation flow rate of 0.018 m^3/s
The average use of 0.446m2 windows results in an extra flow rate of 0.017 m^3/s
The total air flow rate is 0.074 m3/s
The average temperature difference is 10.0 K and the duration of the heating season is 150 days.
The energy used for Heating: 836W (150days): 432 m^3 gas, $216.01, 10.8 GJ
The energy for the whole year for Fans: power = 13W. Per year: 114 kWh, $34, 0.8GJ primary.

9.3.2 Energy to heat ventilation and infiltration air

In a given or specified case where the flow rate due to the ventilation system, infiltration and window airing is known, then the length of the heating season and the temperature difference determine the energy consumption. Of course the efficiency of the plants delivering the energy must be taken into account. This information is defined under the button "fuel".
The final output is given as:

- The average heating power needed in W,
- The amount of fuel used expressed in a unit the user has defined,
- The annual cost in units the user has defined,
- The annual energy consumption in GJ.

9.3.3 Fan energy

The energy consumption for the fan or fans may be divided in three parts:

1. Flow rate and fan pressure
2. Fan efficiency
3. Time of the day the system is in use.

From the flow rate and the pressure difference over the ventilation system one can calculate the power (W) which is needed to transport the air. Together with the fan efficiency, one may be able to calculate the electrical power. Multiplying this electrical power with the time the system is in use, gives the energy consumption in kWh or MJ per year.

The difference between the red arrow and the blue arrows is the energy used by the fan(s).
The final output for the fan(s) is given as:

- The average fan power used in W
- The electric energy used in kWh
- The annual cost in the unit you have defined
- The annual primary energy consumption in GJ

9.4 Tool

The tool is a nomogram as described earlier. It is based on a single zone computer model, which uses the input data specified by the user to provide the necessary data to construct the nomogram, including a red line with a red and blue arrow, showing the annual energy consumption.
The basis of the single zone ventilation model is the conservation of mass.
The flow through each opening in a building is calculated by the model using:

$$q_m = C \cdot \Delta p^n$$

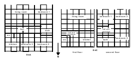
in which

q_m is the mass flow rate through an opening

C is the flow coefficient depending on the effective open area

Δp is the pressure difference across the opening concerned

Since the model is a single zone model, for the zone the total mass flow must be zero.



This means that the same amount of air both enters and leaves the zone.

For more information about ventilation calculations models see references [4] and [5]

Using the calculated total air flow together with the length of the heating season and the average temperature difference, one can calculate the total energy consumption for ventilation and infiltration.

$Q_{annual} = q_{total} \cdot C_{air} \cdot \Delta T_{average} \cdot t_{heatingseason}$ in which

Q_{annual} is the annual energy consumption

q_{total} is the total air flow rate due to system flow, infiltration and airing

C_{air} is the specific heat of air

$\Delta T_{average}$ is the average temperature difference between inside and outside

$t_{heatingseason}$ is the length of the heating season

9.5 Additional Information

More information on the energy tool can be obtained in the background report [1] and in the user guide to the tool.

9.6 References

1. Gids, W. F. de, Phaff J.C. (1998). *Background report on the IEA annex 27 Energy tool*
2. TNO Building and Construction Research, Report BBI 98/0gsw, Delft. The Netherlands.
3. Dubrul, C (1988). *Inhabitants behaviour with regard to ventilation*. AIVC, TN 23, Bracknell, UK
4. Liddament, M; Allen C. (1983). *The validation and comparison of mathematical models for air infiltration.* AIVC, TN 11. Bracknell, UK
5. Feustel, H.E. et al (1990). *Fundamentals of the multizone air flow model – COMIS.* AIVC,TN29. Coventry, UK.

10 Life Cycle Cost (LCC)

This chapter discusses the Life Cycle Cost for installation (initial) and maintenance of a ventilation system. It does not include costs for energy, which are discussed separately in Chapter 9.

10.1 Introduction

The cost is one of the main decision factors for the selection of a domestic ventilation system. This often leads to a ventilation system that just meets the requirements of building regulations at the lowest initial costs. Decision makers are often not aware of the impact of the quality of the ventilation system on life cycle costs (LCC), not only for the ventilation system itself but also for the building, as a result of complaints or even damage due to a poor functioning ventilation system. The objective of a tool for LCC is to compare the total costs of ventilation systems and to make selections based on a cost comparison. The costs include:

- initial costs (investments);
- costs for maintenance of the system;
- costs for maintenance of the building as a result of the ventilation system and its use.

As a fourth component, costs for energy consumption can be included. This tool however, focuses on the first three aspects as the cost for energy is an output of the energy-tool of Annex 27 (see Chapter 9).

One of the ideas behind developing this tool was that by investing more in the quality of the installation and selecting the right kind of ventilation system in relation to building properties and user characteristics it could result in lower maintenance costs, especially for complaint related maintenance. This simplified tool can be used for estimating the expected maintenance and maintenance activity cycles as well as the total life cycle costs for the system, based on the initial costs and costs for maintenance of the system, the expected complaints and the ventilation-related maintenance of the building.

With the developed tool the maintenance costs by different maintenance activities can be found for a ventilation system with mechanical exhaust and a ventilation system with mechanical exhaust and supply with heat-recovery for a considered period of 30 years. The design of the tool is as follows: The basic quality of system and building as well as the system loading need to be determined by qualitative descriptions. Then the maintenance class and the accompanying cost ranges are read from a graph. Then the expected maintenance costs and the planned maintenance activities can be determined from a series of tables. Finally the total life cycle cost is calculated by summating the initial costs and the maintenance costs.

All estimated costs are averages from several EU countries (the Netherlands, France, Sweden, Germany, Denmark) and Canada. Material costs as well as labour costs have a limited spread for most western and northern European countries. Costs are expressed in ECU and include material and labour and exclude costs for location, company management risk and profit and national and/or regional taxes. These extra costs can vary from country to country and can be added as a specific percentage per country. (Example: in the Netherlands additional costs are ~ 20%, national taxes (VAT) are 17.5%).

In this tool we first discuss the initial costs for the ventilation systems. Then we discuss various activities which can have an impact on the maintenance of the system and building. Then finally the simplified tools are provided to give an estimation of the LCC of the system.

10.2 Initial Costs

For the initial costs the following systems are discriminated:
- NWA: natural window airing (using purposed provided openings)
- PSV: natural supply/passive stack
- MEO: natural supply/mechanical extract
- MSE-X: mechanical supply and extract with heat recovery

Costs are given, in steps of 25 ECU, for single family dwellings, houses, and multi family dwellings (an apartment in a four storey residential building).

Three levels of basic installation and construction qualities are discriminated: poor, average and best practice, except for system NWA. The description of the installation and construction properties are given in the tools applied on PSV, MEO, MSE-X in houses and apartments.

Table 10.1. Initial costs (EURO)

Ventilation system		**Single family house Basic quality**			**Apartment Basic quality**		
		Poor	**Average**	**Best practice**	**Poor**	**Average**	**Best practice**
NWA	**natural supply**		350			275	
PSV	natural supply	300	350	500 1)	225	275	400 1)
	passive stack	450	450	450	350	350	350
	total	750	800	950	575	625	750
MEO	natural supply	300	350	500 1)	225	275	400 1)
	mechanical exhaust	500	550	700	400	425 2)	800
	total	800	900	1200	625	700	1200
MSE	MSE-X	1500	1625	2100 4)	1250	1375 3)	1825 4)
	total	1500	1625	2100	1250	1375	1825

1) including self regulating inlets
2) central mechanical extract
3) individual mechanical ventilation heat recovery
4) including cross flow heat exchanger 90%

Note that all these costs include:
- material
- labour

and exclude:
- additional costs for location, company management, risk and profit etc.
- taxes

10.3 Maintenance

10.3.1 Definitions in relation to maintenance

The following aspects related to maintenance are considered:

Type of maintenance,
in relation to its overall organisation.
The type of maintenance is defined by the way the maintenance is organised and managed. It can be split into two types; systematic maintenance and non-systematic maintenance. Systematic maintenance is planned maintenance to achieve a desired quality. Non-systematic maintenance is in response to a signal such as a complaint or change in occupancy etc.

Maintenance activity,
in relation to a technical property of a building or construction part.
Maintenance activities are the activities that are necessary during the life span of a building to maintain a certain level of quality. Each activity has its own cycle: maintaining, partial repairing, replacing.

System loading.
Building and construction parts are loaded by the environment and by daily use. This is an important factor to determine the need for maintenance. The design of the ventilation system in relation to the building must provide a best practice “load bearing” by a good selection of materials, construction and capacity. The degree of maintenance is also dependant on the demands placed on the ventilation system. This includes:

- The frequency of use by the user
- The degree of load placed on the system compared to the load it was designed for
- The correct use of the system by the user

The system loading is the load, in relation to the extent of use. This includes operating the ventilation provisions and cleaning.

Basic quality.
The basic quality of the building includes air tightness of the building envelope, location and type of supply devices in façade, ventilation windows etc. For the ventilation system it includes the type of ventilation unit, fans, supply and exhaust air grilles and lay out and design of ducts.

Maintenance classification.
The level of maintenance indicates the necessary intensity of the maintenance activity, as a result of the load by use and the design and construction. The sensitivity of a building or construction part can vary. The maintenance is classified in three categories:

- Low level
- Medium level (this should be according to common and accepted standards)
- High level

10.3.2 User frequency and maintenance activity

To determine the user frequency some indicators are used. These indicators give information about the way a user (occupant) operates and maintains ventilation provisions.

Table 10.2 System loading

Maintenance activities			**System loading**		
			Low[1)]	**Medium**[1)]	**High**[1)]
Use	Ventilation system	Cleaning	Regularly (monthly)	Cleaning 4 times a year	Not
		Control and use	Meet always requirements	Meet mostly requirements	Deranged
	Building	Ventilation	Devices/grilles always open	Alternating devices/grilles open	Never
		Cleaning devices/grilles	Cleaning regularly	Cleaning not regularly	Never

[1)] This means: low, medium or high negative impact on the ventilation system

The maintenance activities must guarantee the original quality during the life span of the building. In other words: the maintenance activities must guarantee a certain level of reliability. The parameters are:

- Cycle
- Costs (the quantity of the expected activities)
- Life cycle of construction parts (the moment of replacement)
- The chance of complaints or failures between planned maintenance activities (non-systematic maintenance).
-

Table 10.3 Maintenance activities

Maintenance activities				**System loading**		
				Low	**Medium**	**High**
Mainte-nance	Ventilation system	Taking care of	Measure-ments	Lower costs/ Lower cycle	Standard costs/ Standard cycle	Standard costs/ Standard cycle
			Inspection	Lower costs/ Lower cycle	Standard costs/ Standard cycle	Standard costs/ Standard cycle
			Cleaning	Lower costs	Reference costs	Higher costs
		Replace parts		Longer life cycle	Reference life cycle	Shorter life cycle
	Building	Cleaning devices/grilles		Lower costs	Reference costs	Reference costs
		Repair devices/grilles		Longer life cycle	Reference life cycle	Shorter life cycle
Complaints. (design and construction meet requirements)				No extra maintenance	Chance 1 to 30	Chance 1 to 20

10.4 Simplified Tool for Estimating Initial Complaints and Maintenance Costs

In the simplified tools seven situations are discriminated:

- Single family dwellings with passive stacks and natural supply (PSV)
- Single family dwellings with mechanical exhaust and natural supply (MEO)
- Single family dwellings with mechanical exhaust and supply with heat-recovery (MSE-X)
- Multifamily dwellings with passive stacks and natural supply (PSV)
- Multifamily dwellings with central mechanical exhaust and natural supply (MEO)
- Multifamily dwellings with individual mechanical exhaust and natural supply (MEO-local)
- Multifamily dwellings with mechanical exhaust and supply with heat-recovery (MSE-X)

The maintenance costs, expressed as net present value, are estimated in 5 steps which are further explained in Table 10.4. For NWA no data are available for maintenance costs.

The basic boundary condition is that every level of maintenance is tuned to the basic quality of the building and the ventilation system and the user specification. The building and ventilation system qualities, initial and maintenance costs and maintenance cycles lead to equal *reliability* of the different situations.

Table 10.4 Steps to estimate the maintenance costs

Step 1	Estimate the basic quality and initial costs. The basic quality is determined by some qualitative descriptions of the installation and building qualities and properties.
Step 2	Estimate system loading. The users influence or system loading is determined by qualitative descriptions.
Step 3	Estimate for the situation, most suitable maintenance class. The maintenance class is estimated in a graph as a function of the basic quality and system loading. Also some cost ranges for maintenance (planned and complaints/failures) are given.
Step 4	Estimate the expected maintenance costs and the planned maintenance activities. The expected costs, expressed as NPV for planned maintenance and for complaints and failures, can be estimated by using tables D and E from the tool. Also the recommended maintenance activities and cycles are given. Special attention is needed for level “low”. Some of the maintenance activities are carried out by the users (as a result of a conscious behaviour, resulting in a “low system loading”) and some maintenance activities don’t have to be carried out at all as a result of the basic quality of installation components. (Note: The costs are given in steps of 25 EURO)
Step 5	Estimate the total LCC by summarising initial costs from step 1 and costs for maintenance from step 4.

10.5 Simplified Tools for LCC. Initial Costs and Maintenance Costs. Maintenance Activities and Cycles

In the below frame is indicated which of the 7 combinations, ◎, and ventilation system the LCC is calculated on by showing the case on top of the pages as follows:

Each of the seven combinations starts with:

◎ Type of building:
Type of ventilation system:

And follows by

◎ Type of building:
Type of ventilation system:

Each combination is presented on 4 pages:
Page 1: Description: Specific qualities of concern
Page 2: Step 1
Page 3: Step 2 and Step 3
Page 4: Step 4 and Step 5 in which the total cost is summed up.

① Type of building:	Single family house
Type of ventilation system:	Passive stack, natural supply (PSV)

Specific qualities that are of concern for assessment:

Ventilation system, installation:
Not applicable

Building:
Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

➀ **Type of building:**	Single family house
Type of ventilation system: Passive stack, natural supply (PSV)	

STEP 1: Estimate the basic quality by Table A

Table A. Basic Quality

	Best practice	**Average**	**Poor**
		Building:	
Grilles/devices	• Cleaning possibilities without disorder the adjustment (marking or securing) • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality devices (control possibilities, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No special requirements
Air tightness	• n50 = 5...6	• n50 = 5...6	• No requirements
Initial costs (ECU)	• 950	• 800	• 750

Explanation:
Classification in category "best practice" or "poor" if most of the aspects are applicable for that specific category, otherwise category "average"

① **Type of building:**	Single family house
Type of ventilation system: Passive stack, natural supply (PSV)	

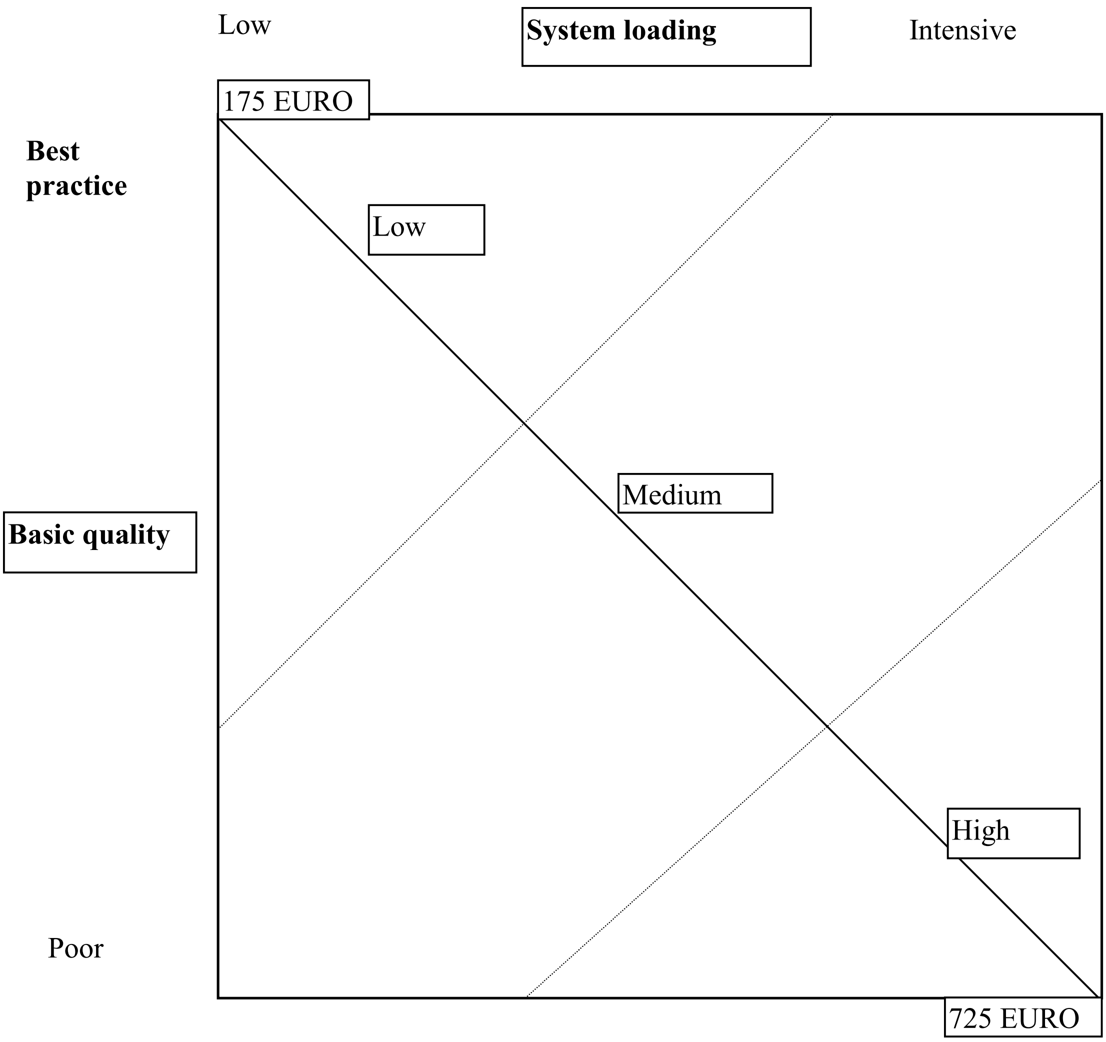
STEP 2: Estimate system loading by Table B

Table B. System loading

	Low	Average	Intensive
	Use of installation:		
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
	Building:		
Ventilating, airing	Conscious use of provisions	Alternating use of provisions	Incidental, very alternating or no use at all
Cleaning vents	Regularly	Occasionally	No cleaning

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



① **Type of building:**	Single family house
Type of ventilation system: Passive stack, natural supply (PSV)	

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)

Maintenance costs	**Planned maintenance**	**10.5.1.1.1 Complaints**	**Total**
Low	100	75	175
Medium	250	150	500
High	500	225	725

Table E. Planned maintenance activities

Activities	**10.5.1.1.2 Maintenance class. Cycle**		
	Low	**Medium**	**High**
Installation			
• **Cleaning grilles**	*	6	6
• **Replacing grilles**	--	18	18
Building			
• **Cleaning vents/grilles**	*	6	6
• **Repairing vents/grilles**	--	12	12
• **Repairing ventilation windows**	6	6	6

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

② Type of building:	Single family house
Type of ventilation system: Mechanical extract, natural supply (MEO)	

Specific qualities that are of concern for assessment:

Ventilation system, installation

Unit:
- Location
- Accessibility
- Devices

Duct and duct work:
- Lay out of the system
- Devices
- Quality of design
- Quality of execution

Grilles, devices:
- Control possibilities
- Cleaning possibilities

Building

Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

② **Type of building:** Single family house
Type of ventilation system: Mechanical extract, natural supply (MEO)

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality

	Best practice	Average	Poor
Installation			
Unit	• Easily accessible Mounted on construction with special sound proofing provisions	• Accessible • Flexible mounting on construction	• Difficult to access • No sound proofing provisions for mounting
Ducts	• Straight duct lay-out • Short duct lengths • No sharp bends, flexible tubes • Air tight sealing of ducts and connections • Sound proofing provisions as silencers and flexible mounting on unit	• Limited flexible bends • No special sealing of ducts; connections sealed with tape	• Excessive duct lengths • Many bends • Flexible tubes • Leaky ducts • No sound proofing provisions
Commissioning and adjustment	• Adjustment and commissioning in every dwelling • Completion reports of commissioning required	• Adjustment in limited number of test dwellings • Completion report of test dwellings required	• No measurements and/or completion reports required
Grilles, devices	• Cleaning possibilities without disorder the adjustment (marking or securing) • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality grilles (regulable, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No special requirements
Building			
Air tightness	• n50 = 3.. 5	• n50 = 5...6	• No requirements
Initial costs	• 1200	• 900	• 800

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”

② Type of building:	Single family house
Type of ventilation system:	Mechanical extract, natural supply (MEO)

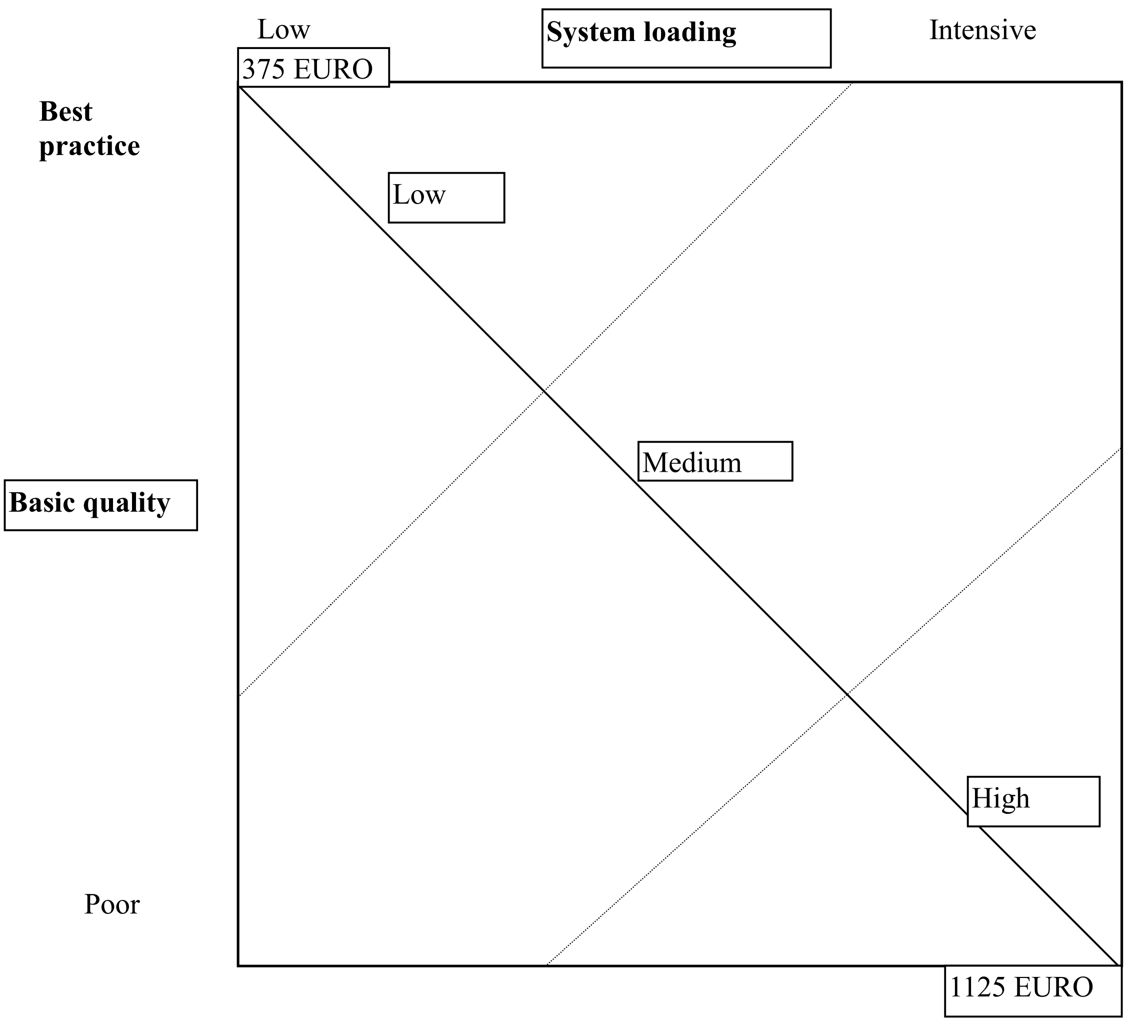
STEP 2: Estimate system loading by Table B

Table B. System loading

	Low	**Average**	**Intensive**
Use of installation			
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
Building			
Ventilating, airing	Conscious use of provisions	Alternating use of provisions	Incidental, very alternating or no use at all
Cleaning vents	Regularly	Occasionally	No cleaning

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



② Type of building:	Single family house
Type of ventilation system: Mechanical extract, natural supply (MEO)	

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)

Maintenance costs	Planned maintenance	Complaints	Total
Low	300	75	375
Medium	550	150	700
High	900	225	1125

Table E. Planned maintenance activities

Activities	Maintenance class. Cycle		
	Low	**Medium**	**High**
Installation			
• **Measuring flow capacity**	9	6	6
• **Cleaning grilles/devices**	*	6	6
• **Inspecting ducts**	9	9	6
• **Cleaning ducts**	9	9	6
• **Cleaning extraction fan unit**	3	3	3
• **Replacing grilles/devices**	--	18	18
• **Cleaning kitchen hood**	*	6	6
• **Replacing kitchen hood**	--	18	15
• **Replacing extract fan unit**	18	15	12
• **Checking control system**	9	6	6
Building			
• **Cleaning vents/grilles/devices**	*	6	6
• **Repairing vents/grilles/devices**	--	12	12
• **Repairing ventilation windows**	6	6	6

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

③ **Type of building**	Single family house
Type of ventilation system	Mechanical ventilation with heat recovery (MSE-X)

Specific qualities that are of concern for assessment:

Ventilation system, installation:

Unit:
- Location
- Accessibility
- Devices

Duct and duct work:
- Lay out of the system
- Devices
- Quality of design
- Quality of execution

Grilles, devices:
- Control possibilities
- Cleaning possibilities

Building:

Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

③ **Type of building:**	Single family house
Type of ventilation system:	Mechanical ventilation with heat recovery (MSE-X)

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality

	Best practice	**Average**	**Poor**
	Installation:		
Unit	• Easily accessible • Mounted on construction with special sound proofing provisions • No internal leakage • Heat recovery efficiency 90% • DC fans	• Accessible • Flexible mounting on construction • Re-heater • If no re-heater high induction grilles • Internal leakage <5 % • Heat recovery efficiency 60 - 65 %	• Difficult to access • No sound proofing provisions for mounting • No special attention for thermal comfort • Internal leakage >5% • No requirements on heat recovery efficiency
Ducts	• Straight duct lay-out • Short duct lengths • No sharp bends, flexible tubes • Air tight sealing of ducts and connections • Sound proofing provisions as silencers and flexible mounting on unit	• Limited flexible bends • No special sealing of ducts; connections sealed with tape	• Excessive duct lengths • Many bends • Flexible tubes • Leaky ducts • No sound proofing provisions
Control	• At least three positions	• Two positions	• No control possibilities
Commissioning and adjustment	• Commissioning in every dwelling • Completion reports of commissioning required	• Adjustment in limited number of test dwellings • Completion report of test dwellings required	• No measurements and/or completion reports required
Grilles	• Cleaning possibilities without disorder the adjustment (marking or securing) • Special attention for selection of grilles in relation to living zone and supply temperature • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality grilles (regulable, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No attention for selection of grilles • No special requirements
	Building:		
Air tightness	• n50 = 1.0...1.5	• n50 = 1.5...3	• > 3 or no requirements
Initial costs	• 2100	• 1625	• 1500

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”.

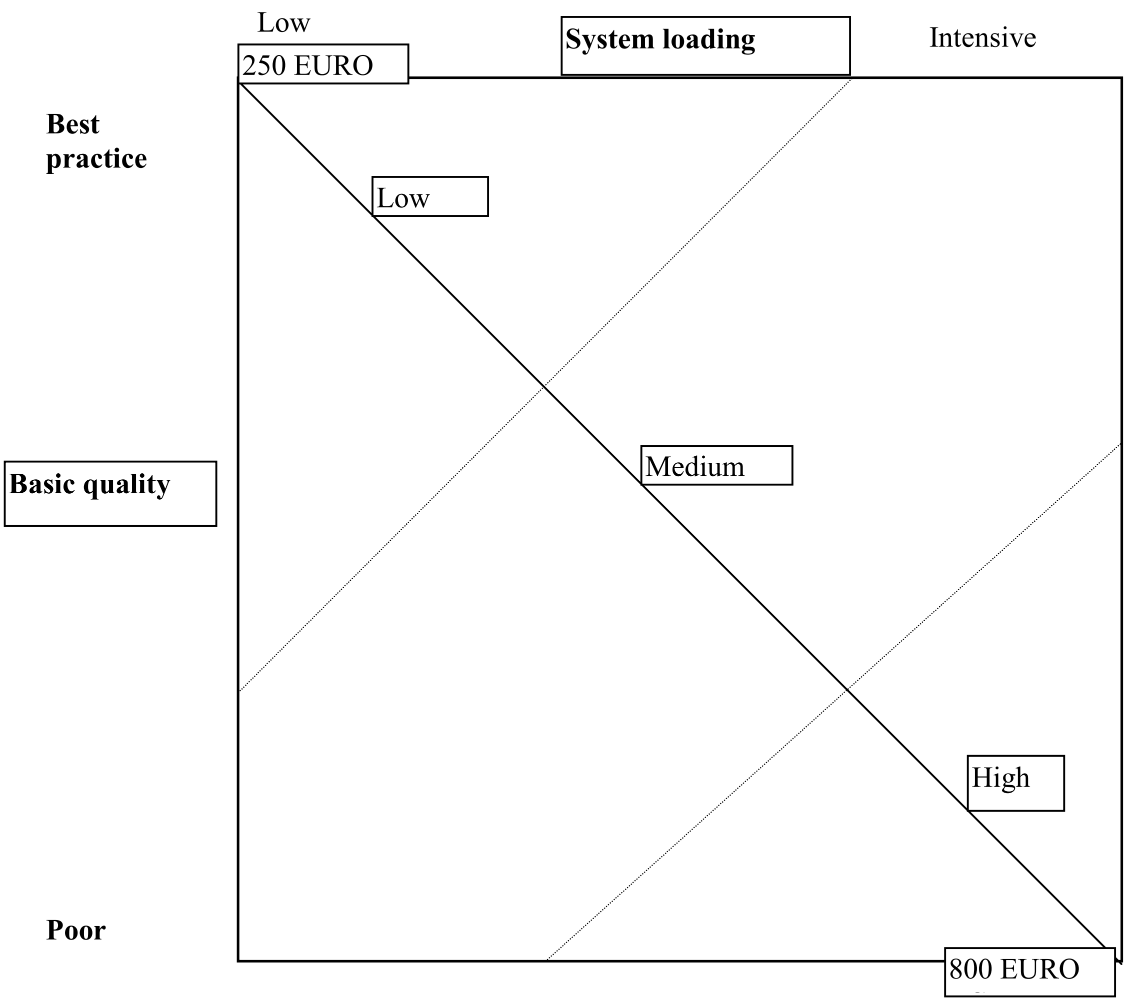
③ Type of building:	Single family house
Type of ventilation system:	Mechanical ventilation with heat recovery (MSE-X)

STEP 2: Estimate system loading by Table B

Table B. System loading			
	Low	**Average**	**Intensive**
Use of installation:			
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
Building:			
Ventilating, airing	Conscious use of control possibilities and airing	Alternating use of control possibilities and airing	Incidental, very alternating or no use at all

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



③ **Type of building:**	Single family house
Type of ventilation system:	Mechanical ventilation with heat recovery (MSE-X)

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)

Maintenance costs	Planned maintenance	Complaints	Total
Low	225	25	250
Medium	500	25	525
High	750	50	800

Table E. Planned maintenance activities

Activities	Maintenance class. Cycle		
	Low	**Medium**	**High**
Installation:			
• **Measuring flow capacity**	9	6	6
• **Cleaning extract grilles/devices**	*	6	6
• **Measuring flow kitchen hood**	9	6	6
• **Inspecting ducts**	9	9	6
• **Cleaning ducts**	9	9	6
• **Cleaning fan**	6	3	3
• **Replacing grilles/devices**	--	18	18
• **Checking control system**	9	6	6
• **Checking re-heater, defrost, condensation drainage**	--	--	6
• **Replacing filters**	*	*	6
• **Cleaning supply grilles/devices**	*	6	6
• **Cleaning heat exchanger**	6	6	6
• **Replacing kitchen hood**	--	18	15
• **Replacing fan motor**	18	15	12
Building: (not applicable)			

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

④ **Type of building:**	Multifamily building. Apartment
Type of ventilation system: Passive stack, natural supply (PSV)	

Specific qualities that are of concern for assessment:

Ventilation system, installation:

10.5.1.1.3 Not applicable

Building:

10.5.1.1.4 Building height

- Number of floors

Purpose provided openings:

- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:

- Air tightness

④ **Type of building:**	Multifamily building. Apartment
Type of ventilation system: Passive stack, natural supply (PSV)	

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality			
	Best practice	**Average**	**Poor**
Installation:			
Grilles	• Cleaning possibilities without disorder the adjustment (marking or securing) • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality grilles (control possibilities, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No special requirements
Building:			
Number of floors	• < 5	• <5	• No limitations
Air tightness	• n50 = 5...6	• n50 = 5...6	• No requirements
Initial costs	• 750	• 625	• 575

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”

④ Type of building:	Multifamily building. Apartment
Type of ventilation system: Passive stack, natural supply (PSV)	

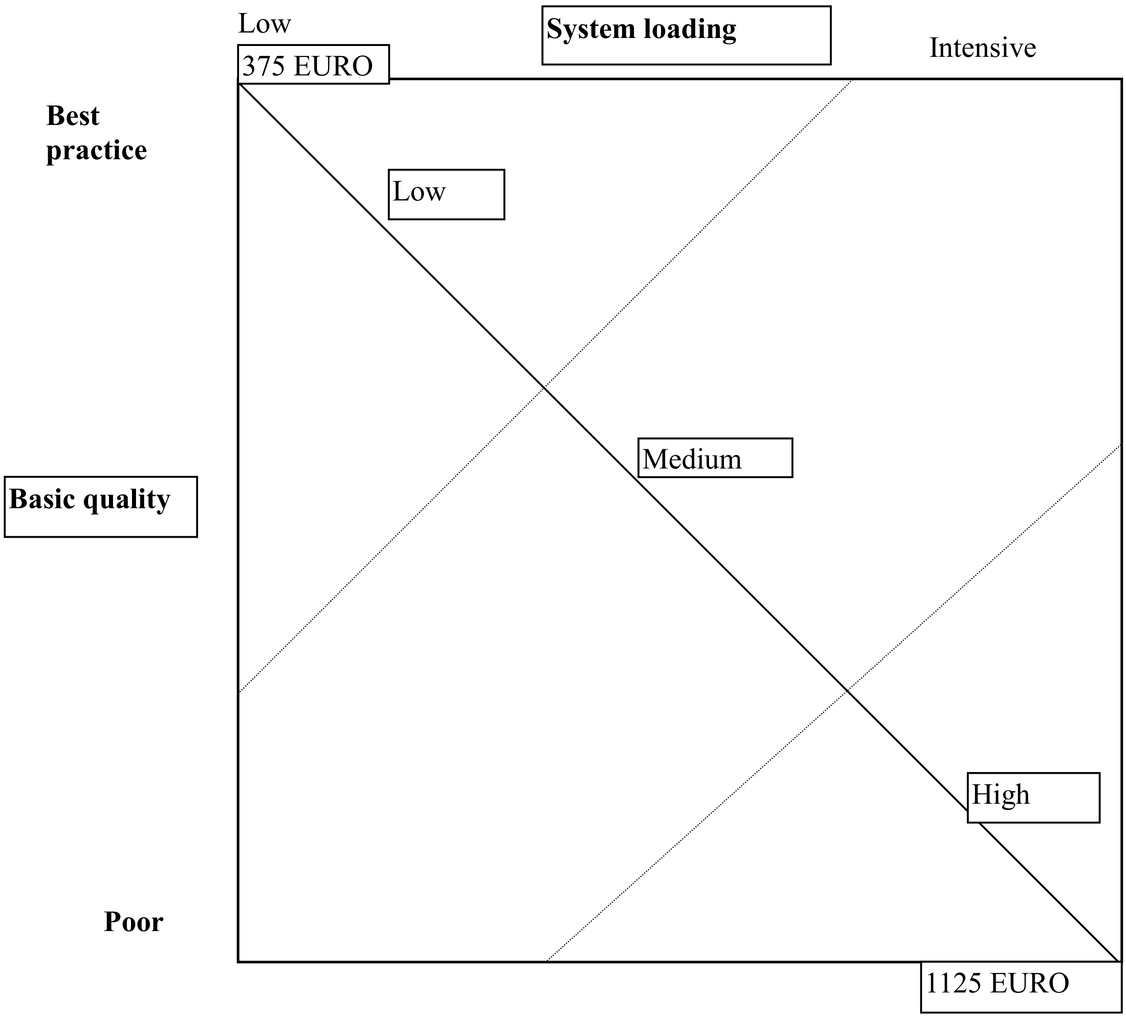
STEP 2: Estimate system loading by Table B

Table B. System loading

	Low	**Average**	**Intensive**
	Use of installation:		
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
	Building:		
Ventilating, airing	Conscious use of provisions	Alternating use of provisions	Incidental, very alternating or no use at all
Cleaning vents	Regularly	Occasionally	No cleaning

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C Maintenance classes



④ **Type of building:** Multifamily
Type of ventilation system: Passive stack, natural supply

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)

Maintenance costs	Planned maintenance	Complaints	Total
Low	100	75	175
Medium	250	150	500
High	500	225	725

Table E. Planned maintenance activities

Activities	Maintenance class. Cycle		
	Low	**Medium**	**High**
Installation:			
• **Cleaning grilles/devices**	*	6	6
• **Replacing grilles/devices**	--	18	18
Building:			
• **Cleaning vents/grilles/devices**	*	6	6
• **Repairing vents/grilles/devices**	--	12	12
• **Repairing ventilation windows**	6	6	6

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

⑤ **Type of building:**	Multifamily building. Apartment
Type of ventilation system:	Central mechanical extract, natural supply (MEO)

Specific qualities that are of concern for assessment:

Ventilation system, installation:

Unit:
- Location
- Accessibility
- Devices, control possibilities

Duct and duct work:
- Lay out of the system
- Devices
- Quality of design
- Quality of execution

Grille/devicess:
- Control possibilities
- Cleaning possibilities

Building:

Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

⑤ **Type of building:**	Multifamily building. Apartment
Type of ventilation system: Central mechanical extract, natural supply (MEO)	

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality

	Best practice	**Average**	**Poor**
		Installation:	
Unit	• Easily accessible • Mounted on construction with special sound proofing provisions • Frequency controlled fan speed	• Accessible • Flexible mounting on construction • Central controlled program day/night or high during cooking/bathing hours etc.	• Difficult to access • No sound proofing provisions for mounting • No control possibilities
Ducts	• Straight duct lay-out • Short duct lengths • No sharp bends, flexible tubes • Air tight sealing of ducts and connections • Sound proofing provisions as silencers and flexible mounting on unit	• Limited flexible bends • No special sealing of ducts; connections sealed with tape	• Excessive duct lengths • Many bends • Flexible tubes • Leaky ducts • No sound proofing provisions
Commissioning and adjustment	• Adjustment and commissioning in every dwelling • Completion reports of commissioning required	• Adjustment in limited number of test dwellings • Completion report of test dwellings required	• No measurements and/or completion reports required
Grilles/devices	• Cleaning possibilities without disorder the adjustment (marking or securing) • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality grilles (regulable, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No special requirements
		Building:	
Air tightness	• n50 = 3.. 5 but not < 3 !	• n50 = 5...6	• No requirements • or n50 < 3
Initial costs	• 1200	• 825	• 625

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”

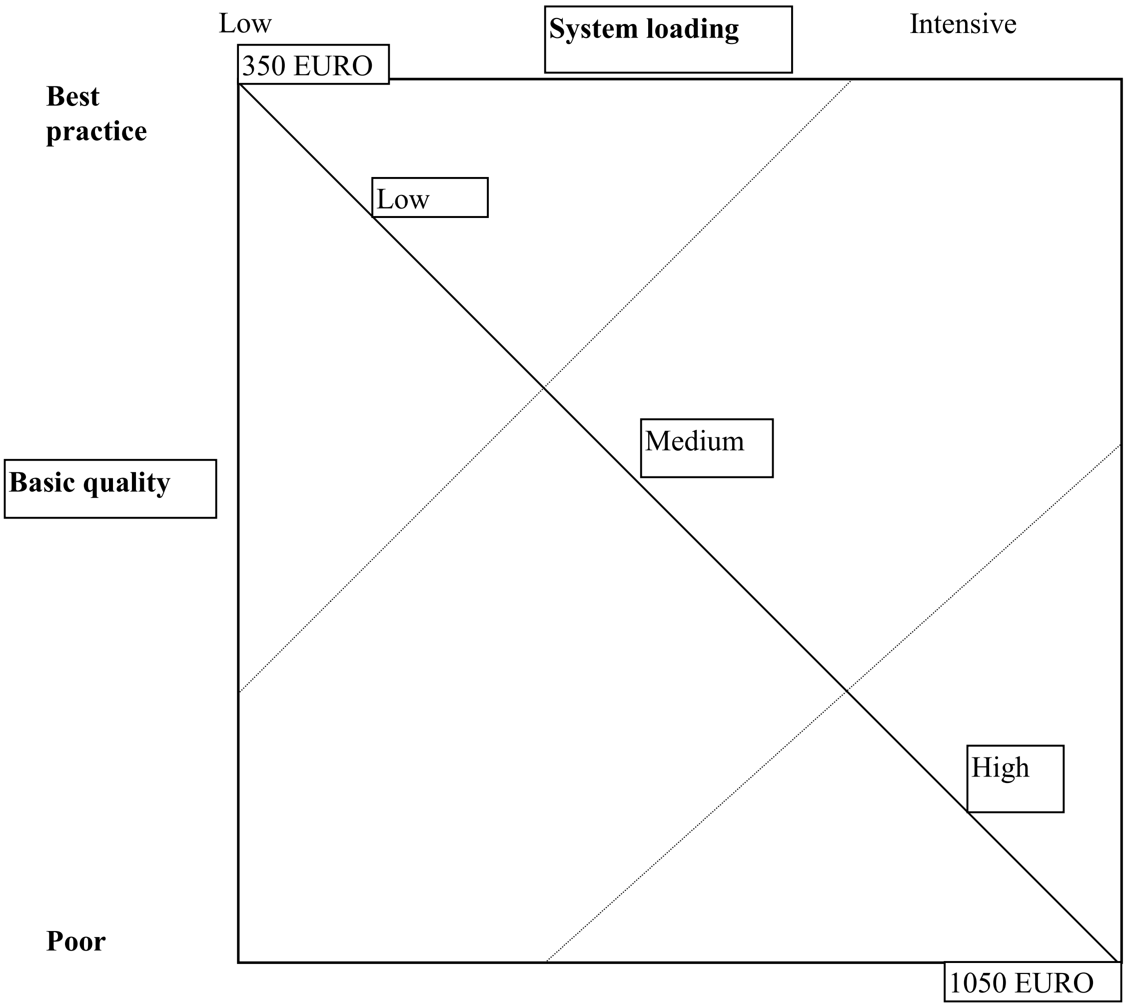
⑤ Type of building:	Multifamily building. Apartment
Type of ventilation system: Central mechanical extract, natural supply (MEO)	

STEP 2: Estimate system loading by Table B

Table B. System loading			
	Low	**Average**	**Intensive**
Use of installation:			
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
Building:			
Ventilating, airing	Conscious use of provisions	Alternating use of provisions	Incidental, very alternating or no use at all
Cleaning vents	Regularly	Occasionally	No cleaning

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



⑤ **Type of building:** Multifamily building. Apartment
Type of ventilation system: Central mechanical extract, natural supply (MEO)

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)

Maintenance costs	**Planned maintenance**	**Complaints**	**Total**
Low	300	50	350
Medium	550	100	650
High	900	150	1050

Table D. Planned maintenance activities

Activities	**Maintenance class. Cycle**		
	Low	**Medium**	**High**
Installation:			
• **Measuring flow capacity**	9	6	6
• **Cleaning grilles/devices**	*	6	6
• **Inspecting ducts**	9	9	6
• **Cleaning ducts**	9	9	6
• **Cleaning extraction fan unit**	3	3	3
• **Replacing grilles/devices**	--	18	18
• **Cleaning kitchen hood**	*	6	6
• **Replacing kitchen hood**	--	18	15
• **Replacing extraction fan unit**	18	15	12
• **Checking control system**	9	6	6
Building:			
• **Cleaning vents/grilles/devices**	*	6	6
• **Repairing vents/grilles/devices**	--	12	12
• **Repairing ventilation windows**	6	6	6

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

⑥ **Type of building:** Multifamily building. Apartment
Type of ventilation system: Individual mechanical extract for each apartment, natural supply (MEO-local)

Specific qualities that are of concern for assessment:

Ventilation system, installation:
Unit:
- Location
- Accessibility
- Devices, control possibilities

Duct and duct work:
- Lay out of the system
- Devices
- Quality of design
- Quality of execution

Grilles/devices:
- Control possibilities
- Cleaning possibilities

Building:
Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

⑥ Type of building:	Multifamily building. Apartment
Type of ventilation system:	Individual mechanical extract, natural supply (MEO local)

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality			
	Best practice	**Average**	**Poor**
	Installation:		
Unit	• Easily accessible • Mounted on construction with special sound proofing provisions	• Accessible • Flexible mounting on construction	• Difficult to access • No sound proofing provisions for mounting
Ducts	• Straight duct lay-out • Short duct lengths • No sharp bends, flexible tubes • Air tight sealing of ducts and connections • Sound proofing provisions as silencers and flexible mounting on unit	• Limited flexible bends • No special sealing of ducts; connections sealed with tape	• Excessive duct lengths • Many bends • Flexible tubes • Leaky ducts • No sound proofing provisions
Commissioning and adjustment	• Adjustment and commissioning in every dwelling • Completion reports of commissioning required	• Adjustment in limited number of test dwellings • Completion report of test dwellings required	• No measurements and/or completion reports required
Grilles/devices	• Cleaning possibilities without disorder the adjustment (marking or securing) • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality (regulable, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No special requirements
	Building:		
Air tightness	• n50 = 3.. 5	• n50 = 5...6	• No requirements
Initial costs	• 975	• 700	• 600

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”

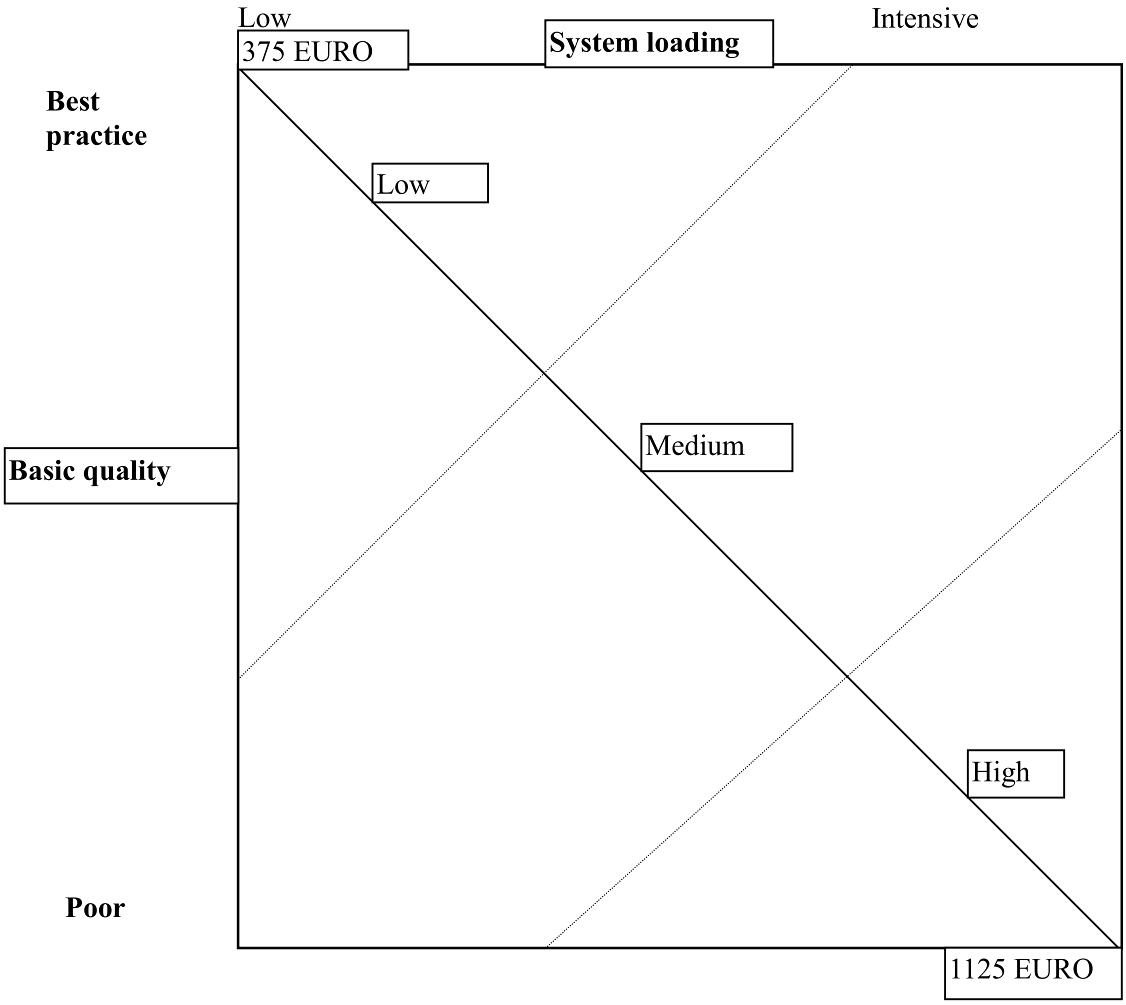
⑥ **Type of building:**	Multifamily building. Apartment
Type of ventilation system:	Individual mechanical extract, natural supply (MEO local)

STEP 2: Estimate system loading by Table B

Table B. System loading			
	Low	**Average**	**Intensive**
Use of installation:			
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
Building:			
Ventilating, airing	Conscious use of provisions	Alternating use of provisions	Incidental, very alternating or no use at all
Cleaning vents	Regularly	Occasionally	No cleaning

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



© **Type of building:** Multifamily
Type of ventilation system: Individual mechanical extract, natural supply

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over 30 years (EURO)			
Maintenance costs	**Planned maintenance**	**Complaints**	**Total**
Low	300	75	375
Medium	550	150	700
High	900	225	1125

Table E. Planned maintenance activities			
Activities	**Maintenance class. CYCLE**		
	Low	**Medium**	**High**
Installation:			
• **Measuring flow capacity**	9	6	6
• **Cleaning grilles/devices**	*	6	6
• **Inspecting ducts**	9	9	6
• **Cleaning ducts**	9	9	6
• **Cleaning extraction fan unit**	3	3	3
• **Replacing grilles/devices**	--	18	18
• **Cleaning kitchen hood**	*	6	6
• **Replacing kitchen hood**	--	18	15
• **Replacing extraction fan unit**	18	15	12
• **Checking control system**	9	6	6
Building:			
• **Cleaning vents/grilles/devices**	*	6	6
• **Repairing vents/grilles/devices**	--	12	12
• **Repairing ventilation windows**	6	6	6

* activity carried out by occupant

STEP 5: Estimate the total LCC by summarising initial from step 1and maintenance costs from step 4

⑦ **Type of building:**	Multifamily building. Apartment
Type of ventilation system:	Mechanical ventilation with heat recovery (MSE-X)

Specific qualities that are of concern for assessment:

Ventilation system, installation:

Unit:
- Location
- Accessibility
- Devices

Duct and duct work:
- Lay out of the system
- Devices
- Quality of design
- Quality of execution

Grilles/devices:
- Control possibilities
- Cleaning possibilities

Building:

Purpose provided openings:
- Presence
- Design, according to building regulations
- Accessibility
- Control possibilities
- Cleaning possibilities

Building envelope:
- Air tightness

⑦ **Type of building:** Multifamily building. Apartment
Type of ventilation system: Mechanical ventilation with heat recovery (MSE-X)

STEP 1: Estimate the basic quality by Table A

Table A. Basic quality

	Best practice	**Average**	**Poor**
		Installation:	
Unit	• Easily accessible • Mounted on construction with special sound proofing provisions • No internal leakage • Heat recovery efficiency 90% • DC fans	• Accessible • Flexible mounting on construction • Re-heater • If no re-heater high induction grilles • Internal leakage <5 % • Heat recovery efficiency 60 - 65 %	• Difficult to access • No sound proofing provisions for mounting • No special attention for thermal comfort • Internal leakage >5% • No requirements on heat recovery efficiency
Ducts	• Straight duct lay-out • Short duct lengths • No sharp bends, flexible tubes • Air tight sealing of ducts and connections • Sound proofing provisions as silencers and flexible mounting on unit	• Limited flexible bends • No special sealing of ducts; connections sealed with tape	• Excessive duct lengths • Many bends • Flexible tubes • Leaky ducts • No sound proofing provisions
Control	• At least three positions	• Two positions	• No control possibilities
Commissioning and adjustment	• Commissioning in every dwelling • Completion reports of commissioning required	• Adjustment in limited number of test dwellings • Completion report of test dwellings required	• No measurements and/or completion reports required
Grilles/devices	• Cleaning possibilities without disorder the adjustment (marking or securing) • Special attention for selection of grilles in relation to living zone and supply temperature • Self regulating inlets (pressure and temperature)	• Cleaning possibilities with limited chance of disorder the adjustment • Good quality grilles/devices (regulable, airtight when closed)	• No cleaning possibilities or cleaning possibilities with chance of disorder adjustment • No attention for selection of grilles • No special requirements
		Building:	
Air tightness	• n50 = 1.0...1.5	• n50 = 1.5...3	• > 3 or no requirements
Initial costs	• 1625	• 1375	• 1250

Explanation:
Classification in category “best practice” or “poor” if most of the aspects are applicable for that specific category, otherwise category “average”

⑦ Type of building:	Multifamily
Type of ventilation system: Mechanical ventilation with heat recovery (MSE-X)	

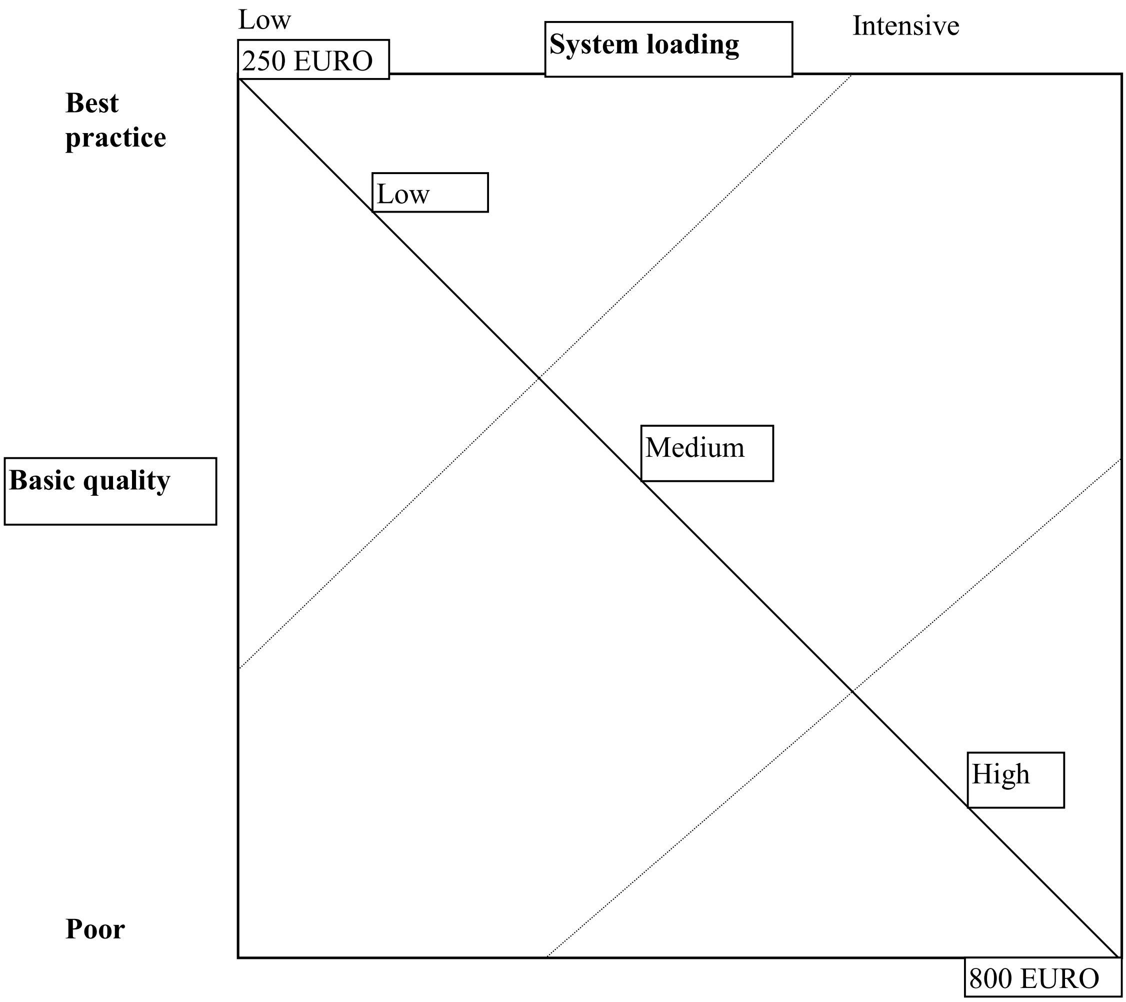
STEP 2: Estimate system loading by Table B

Table B. System loading

	Low	Average	Intensive
Use of installation:			
Instructions for use, control, maintenance etc.	Personally addressed	Written instructions are present	No instructions
Cleaning grilles, unit	Monthly cleaning	Cleaning 4 times/year	No cleaning
Use	In accordance with manual and instructions	Mostly in accordance with manual and instructions	Disordering system
Building:			
Ventilating, airing	Conscious use of control possibilities and airing	Alternating use of control possibilities and airing	Incidental, very alternating or no use at all

STEP 3: After estimating the basic quality and expected system loading the most suitable maintenance class can be established by Figure C

Figure C. Maintenance classes



⑦ **Type of building:**	Multifamily
Type of ventilation system:	Mechanical ventilation with heat recovery (MSE-X)

STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by Table D and the planned maintenance activities by Table E

Table D. Expected costs of maintenance expressed as LCC over ***30 years (EURO)***

Maintenance costs	**Planned maintenance**	**Complaints**	**Total**
Low	225	25	250
Medium	500	25	525
High	750	50	800

Table E. Planned maintenance activities

Activities	**10.5.1.1.5 Maintenance class. Cycle**		
	Low	**Medium**	**High**
Installation:			
• **Measuring flow capacity**	9	6	6
• **Cleaning extract grilles**	*	6	6
• **Measuring flow cookerhood**	9	6	6
• **Inspecting ducts**	9	9	6
• **Cleaning ducts**	9	9	6
• **Cleaning fan**	6	3	3
• **Replacing grilles**	--	18	18
• **Checking control system**	9	6	6
• **Checking re-heater, defrost, condensation outlet**	--	--	6
• **Replacing filters**	*	1)	6
• **Cleaning supply grilles**	*	6	6
• **Cleaning heat exchanger**	6	6	6
• **Replacing cookerhood**	--	18	15
• **Replacing fan motor**	18	15	12
Building: (not applicable)			

* activity carried out by residents

STEP 5: Estimate the total LCC by summarising initial from step 1 and maintenance costs from step 4

11 Application

This chapter gives an example of the use of the simplified tools presented in the previous chapters. They are applied on a specific house, with its underlying assumption, for all three climates. The results are presented in a table. They are also illustrated in the executive summary as figures

11.1 Conditions for this Case study

Table 11.1 shows the values used in this case study for the parameters that are used in more than one tool. Those parameters that affect only one tool are described in the following pages under the sub-heading for that tool. As the actual (real) value of a parameter does not often match the values used in the simplified tools, the possible alternative values used in the tools are given and the one that best meets the actual value is highlighted in bold. When reading this chapter, please refer in parallel to the relevant chapter for each tool.

Table 11.1 Case conditions - alternative in each tool that fits best to case selected marked in **bold**.

Parameter	**Present case**	**Alternative**			
		1	**2**	**3**	**4**
Dwelling type	2 storey 4 room detached house	**Detached**	Apartment ground floor	Apartment top floor	
Location/Climate	Amsterdam, NL	Cold	**Moderate**	Mild	
Ventilation system	All to be investigated	**NWA**	**PSV**	**MEO**	**MSE**
Leakage Detached n50 (ach) Apartment	6 for NWA, PSV, MEO. And 3 for MSE	1 1	**2.5 MSE** 2.5	**5 NWA, PSV, MEO** 5	10
Mechanical exhaust flow rate [l/s]	35 l/s	15	**30**	45	
Natural supply - NWA inlet area [cm²] - PSV - MEO	70 cm²/inlet for NWA and PSV 20 cm²/inlet for MEO	0 100 0	**410** **400** **100**		
Supply flow rate per inlet [l/s]. 1/bedroom, 2 in living room. Only MSE	7 l/s per inlet	3 l/s,inlet (15 l/s, per dwelling)	**6 l/s,inlet** (30 l/s, per dwelling)	9 l/s,inlet (45 l/s, per dwelling)	
Outer wall characteristic	Brickwork	Light	**Heavy**		
Local extra exhaust fans in kitchen and/or bathroom	Kitchen fan No bathroom fan	No (No local fan)	**Yes** Given pattern		
Window airing	Average	No (windows closed)	**Yes** Given pattern		
Technical quality of ventilation system	Average	Poor	**Average**	Best practice	
Maintenance level	Medium	High	**Medium**	Low	

The ventilation systems are:	NWA	= Natural Window Airing
	PSV	= Passive Stack Ventilation
	MEO	= Mechanical Exhaust Only
	MSE	= Mechanical Supply and Exhaust

11.2 Case Application on Thermal Comfort

The building is located in Amsterdam, which has a moderate climate, with a lowest outdoor temperature of about –3 °C during wintertime. The design outdoor temperature is defined such that 90% of the time the temperature is above this value during the heating season. Chapter 4 discusses how the tool should be used for each of the 4 ventilation systems.

Some general remarks to achieve good thermal comfort are:
- The location of the inlets should be higher than 1.6 m above the floor to avoid serious thermal impact.
- Self regulating function of air flow is recommended to avoid excess cold air supply.
- When the devices are located in a low position a **"- -"** score is given. To avoid poor thermal comfort, heating devices can be placed to preheat the supply air before reaching the occupant.

NWA
Ground floor (living room).
Leakage area is 500 cm².
Opening area of the inlets is 350 cm².
Air change rate (ach) is 0.5 ach giving 150 m³/h (42 l/s) giving
Background air flow (through cracks) 150•{500/(500+350)}=90 m³/h (25 l/s)
Air flow through inlets 150•{350/(500+350)}=60 m³/h (17 l/s)
From Table 4.1 the thermal comfort is "- -" for leakage
For inlets "-" if the inlets are high positioned and "- -" for other positions

First floor (Upstairs)
The 2 storey house works as a PSV within the dwelling with the exhaust flow through the inlet devices on the leeward side upstairs.
If there is self regulating inlet devices against exhaust flow the thermal comfort is judged to be "+ +" on the leeward side. Without this function and if the supply rate due to the wind is assumed to be 15 m³/h (4 l/s) the score is "- -".

PSV
By using the Table 4.1 the score is **"- -"** with the supply rate 35 m³/h (10 l/s)

MEO
Leakage area is 500 cm²
Opening area of the inlets is 100 cm².
Air flow through background leakage is dominant and this gives the score **"- -"**
However, if the airtightness can be increased to reduce n50 by a factor of 4 to 1.5, the score can go up to **"0"** by using upward directed high induction inlets. But it must be noted that the underpressure (pressure difference between inside and outside) is increased.

MSE
This type of system gives the score **"+ +"**

11.3 Case Application on Noise

The tool given in Chapter 5 can be applied to give the results for noise. The results are independent of climate.

Outdoor Noise
First is assumed for this case study that the outdoor noise level is L_o = 61 dB(A).
With the construction and house design, we require the indoor noise level to be L_i = 35 dB(A)

Therefore, the required noise reduction of the façade G_a = 26 dB(A)

Table 11.1 Values to be used in the tables

Room	$S_{façade}$	S_{window}	**% soundproofed construction**	A_{net}
Living room	12.5	8	64	140
Bedroom 1	7.5	1.5	20	70
Bedroom 2	5.0	1.5	30	70

Living room (ground floor):
NWA: $R_{a,vent}$ = –5 dB(A) the tables in Chapter 5 give a rating of "-" and the system is not possible
PSV and MEO: With $R_{a,vent}$ = 0 dB(A), the tables give a rating of "0" and the system is possible only with excellent sound proofing.
If the soundproofing of the ventilation opening is $R_{a,vent}$ = 10 dB(A), then the tables give a rating "+ +" and no other measure is necessary
MSE: The tables give a rating of "+ +" and is a very good solution and no other measure is needed

Bedroom (upstairs)
NWA: The score is "-" and the system is not possible
PSV and MEO: With $R_{a,vent}$ = 0 dB(A) the rating is "+" and the system is "good" if the window is 6mm glass – 20mm air - 10mm glass and has a good single weather stripping.
or with $R_{a,vent}$ = 10 dB(A), the rating is "+ +" and the system is "very good" with a window of 4mm glass – 12mm air – 6mm glass and is assumed to have a good single weather stripping.
MSE: Have "+ +" and is a very good solution and no other measure is needed

System Noise
Scores are only given for the mechanical systems (MEO, MSE).

MEO:
In this case study Δp system = 70 Pa the flow rate q_v = 35 l/s and L_{ws} = 2
This gives L_w = 54 dB(A) and the nearest value for this tool is 55 dB(A). At this sound power level the duct length does not need to be considered for this tool.
In the kitchen there are 2 branches and2 outlets
With no silencer the noise level is 33 – 38 dB(A) with the score "0"
With a silencer of 1000 mm the score is "+ +" and noise level of 25 dB(A)

MSE:
In this case study Δp system = 120 Pa, the flow rate q_v = 35 l/s and L_{ws} = 3
This gives L_w = 59 dB(A) and the nearest value for the tool is 60 dB(A). At this sound power level the duct length does not need to be considered for this tool.

Living room, one branch and two inlets:
With no silencer the noise level is > 40 dB(A) with a score of "- -"
With a silencer, the noise level is 33 – 38 dB(A) with a score of "0"
With a silencer and cross talk absorber, the noise level is 25 dB(A) with a score of "+ +"
Bedroom with 2 branches and 1 inlet
With no silencer the noise level is 40 dB(A) giving a score of "- -"
With a silencer the noise level is 25 – 30 dB(A) and the score is "0"
With a silencer and cross talk absorber, the noise level is 25 dB(A) and the score is "+ +"

It is recommended to install a 500 mm cross talk damper in this MSE system.

11.4 Case Application on Building Aspects

The tool for Building Aspects is given in Chapter 6. It has been used to give the ratings for this case and they are shown in Table 11.2. The table provides warnings signals shown by ✌. The final output from whole tool would include those parameters of most concern (most warning signals).

Table 11.2 Scores and warning signals for the case

NWA									
Doors	Windows	Replacement with other systems			Building age		Furnish		
✌✌	✌✌✌	✌✌✌			✌✌		✌✌		
PSV									
Wall	Slab	Doors	Roof	Replacement with other systems			Lay out	Plumbing	
✌	✌	✌✌	✌✌✌	✌✌			✌✌	✌✌✌	
MEO									
Wall	Slab	Doors	Operation	Maintenance	Replace	Lay out		Building service	
✌	✌	✌	✌	✌	✌	✌		✌	
MSE									
Wall	Slab	Operation		Maintenance		Lay out	Construction	Building Services	
✌✌	✌✌	✌✌		✌✌		✌✌	✌✌	✌✌	

11.5 Case Application on IAQ

Details of the tool can be found in Chapter 7 - Indoor Air Quality (IAQ).

Table 11.3 shows the input data used in the tool. It shows the input data allowed in the tool that most closely represents the input data supplied for this case. Table 11.4 provides the results in the form of ratings and warning flags.
The location for this building is Amsterdam and is represented by a moderate climate (London).
Some comments to the Table 11.4 are needed:

- IAQ result is in the medium range. For MEO the score **"-"** can be due to the fact that when the extra fan is not running, the ventilation in bedrooms is reduced, see also comments in 7.2.1.
- Condensation score is bad for NWA. This is due to the fact that the wind is low and the heating season quite long.
- Heat need is equivalent to the air change and is bad for NWA and PSV due to the wind impact.
- Due to high outdoor humidity it results in high indoor humidity giving warning flags for all systems.

Table 11.3 Input data for the case. IAQ tool

	System			
	NWA	**PSV**	**MEO**	**MSE**
Climate	London	London	London	London
Air tightness n50	5	5	5	2,5
Window airing	no	no	no	no
Supply area, cm²	410	400	100	
Air flow rate, l/s			30	30
Extra fan	Worst case chosen			

Table 11.4 Results. Output data for the case. IAQ tool

	System			
	NWA	PSV	MEO	MSE
IAQ	0	+ +	0	0
Condensation	0	+ +	+ +	+
Heat needs	-	- -	-	+
Dryness	No problem			
Pressure difference	No problem			⚐
Winter. High indoor humidity	⚐	⚐	⚐	⚐

11.6 Case Application on Reliability

Details of the tool can be found in Chapter 8. Table 8.2 is used for air flow stability and Table 8.4 for performance over time. In these tables we have selected the London climate data, the D4c dwelling and n50 of 2.5. The results are given in Table 11.5.

Table 11.5 Reliability for systems in moderate climate

	System			
	NWA	**PSV**	**MEO**	**MSE**
Air flow stability, Table 8.2	**0**	**0**	**0**	+ +
Performance over time, Table 8.4	+ +	+ +	+ +	**0**

11.7 Case Application on Energy

The energy tool Enervent2 as described in Chapter 9 is applied with the general input data for the case for the main ventilation systems: NWA, PSV, MEO, MSE and MSE-X and with “moderate climate”

General input:
The house is chosen to be a 2 storey house with height 6 m volume 250 m³. Wind as for urban areas with the average wind speed of 5.1 m/s; n = 0.6. For other input data see 11.1

11.7.1 NWA application

Remark: System choice in the tool was MEO because of the extra fan in the kitchen. The results can be interpreted as natural window only because the purpose provided openings are just the windows. Figure 11.1 is shown the screen from the computer tool.

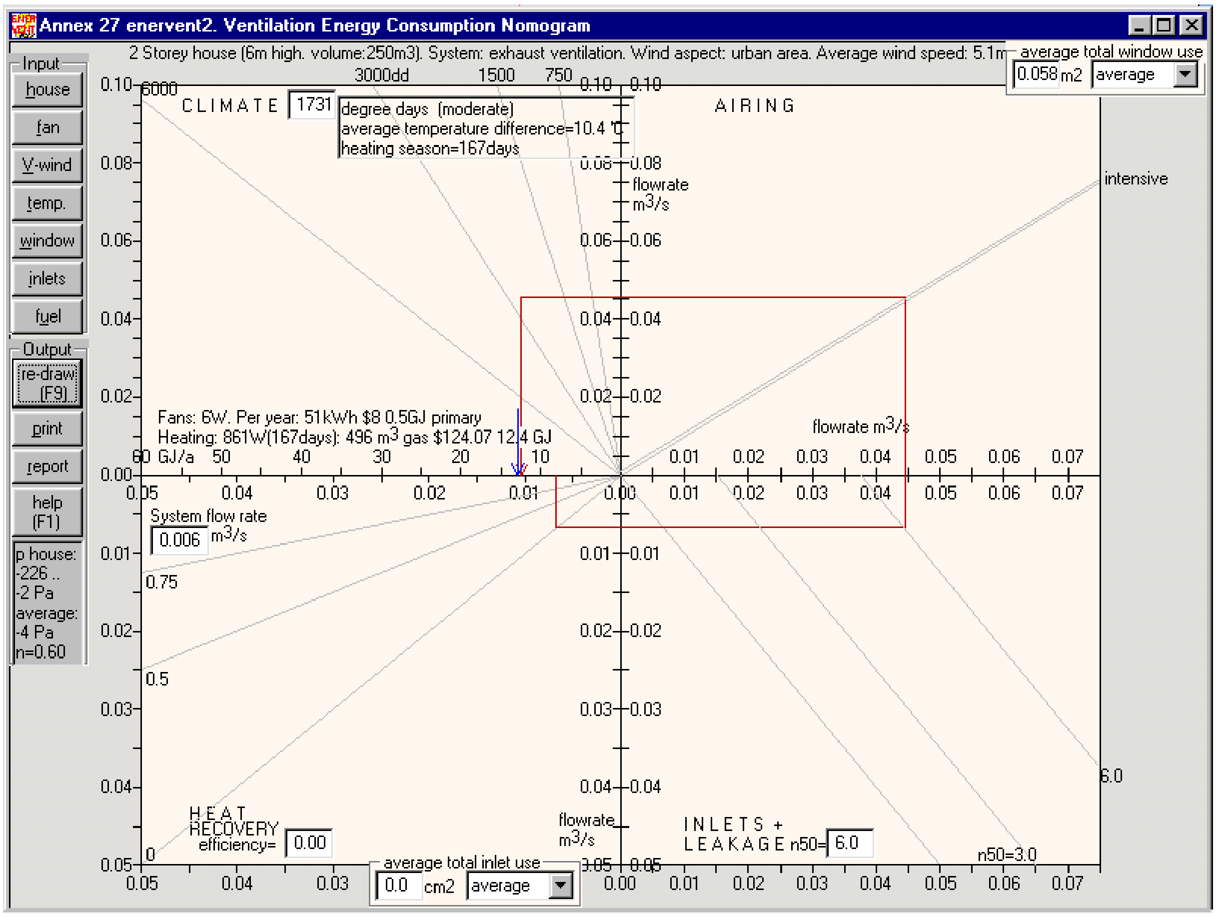


Figure 11.1 Energy tool applied on NWA. Energy for heating the supply air

Input

Files used: House: House.txt
Wind: C:\Program Files\Enervent2\WindModerate.txt
Temperature: C:\Program Files\Enervent2\TempModerate.txt

Fan: Exhaust; high = 0.040 m^3/s; low = 0.002 m^3/s
Fan efficiency: 0.10. System pressure 90.0 Pa
Fan running time: High = 3 h. Low = 21 h
Average system flow rate: 0.007 m^3/s
Air leakage value, n50= 6.0 ach at 50 Pa. This gives 0.4167 m^3/s at 50 Pa; 0.1594 m^3/s at 10 Pa; 0.0922 m^3/s at 4 Pa; 0.0403 m^3/s at 1 Pa.
The estimated envelope area is 198.4 m^2
The flow rate per m^2 is 0.0021 m/s at 50 Pa; $8.03*10^{-4}$ m/s at 10 Pa; $4.65*10^{-4}$ m/s at 4 Pa; $2.03*10^{-4}$ m/s at 1 Pa.
The total opened area of large windows (average over the heating season) = 0.065 m^2
Inlets are not used
The number of degree-days are: 1731 dd

Calculation
This run considers heating during the heating season and fan energy during the whole year. The heating season is the period with outdoor temperatures below 14.0 °C which occurs at the degree-day base temperature inside at 15.5 °C.
The pressure in the house ranges from – 29.6 Pa to – 1.7 Pa.
The weighted average pressure in the house is – 4.0 Pa.
The weighted average flow rate is: 0.007 m^3/s
No heat recovery
The air leakage, n50 = 6.0 ach, results in an extra ventilation flow rate of 0.038 m^3/s
The average use of windows (0.065 m^2) results in an extra ventilation flow rate of 0.002 m^3/s
The total flow rate is 0.046 m^3/s.
The average temperature difference is 10.4 K. The duration of the heating season is 167 days
The energy for heating: 874 W (167 days); 504 m^3 gas for $125.91. Energy 12.6 GJ

The electric energy for the whole year for the fan (power = 6 W): 50 kWh $8.0. Primary energy 0.5 GJ

11.7.2 PSV application

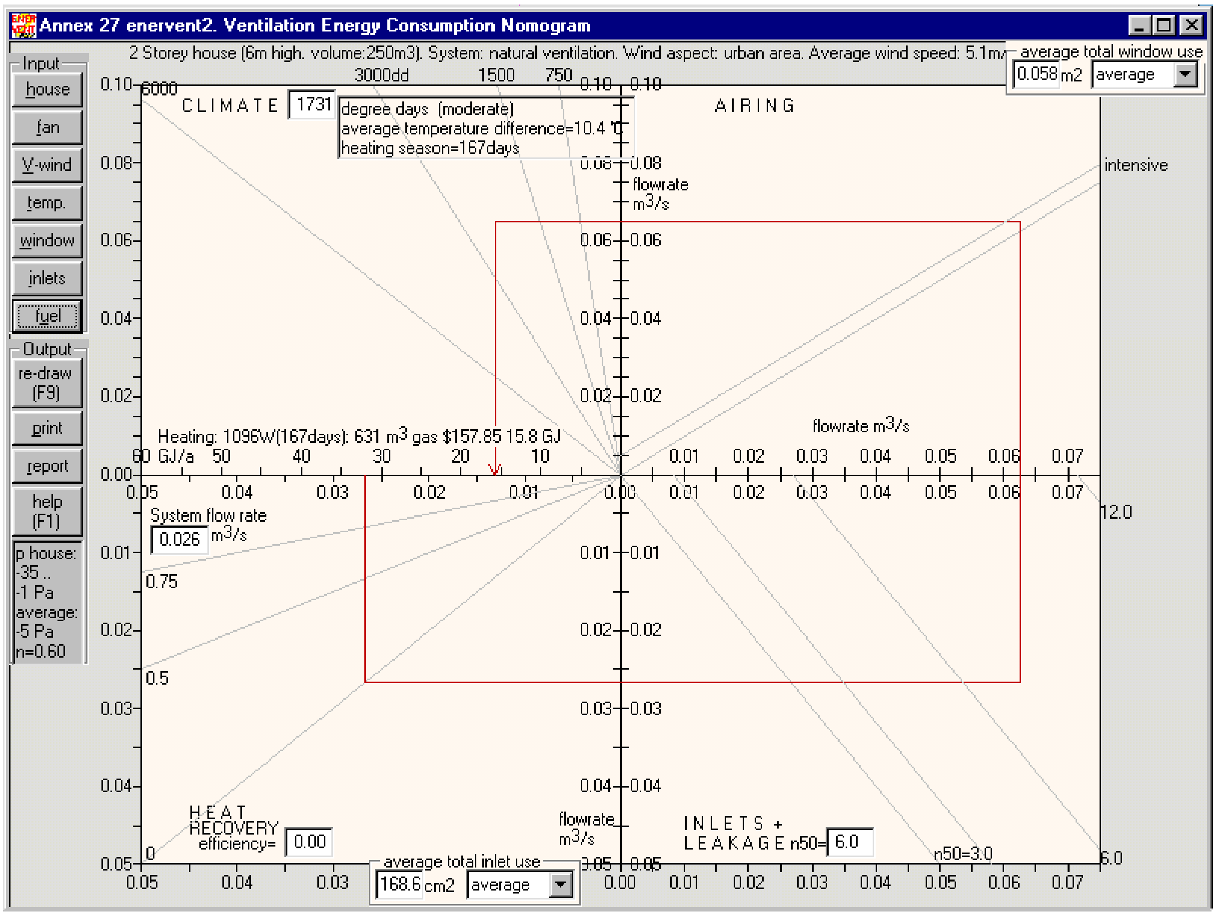


Figure 11.2 Energy tool applied on PSV. Energy for heating the supply air

Input
Files used: House: House.txt
Wind: C:\Program Files\Enervent2\WindModerate.txt
Temperature: C:\Program Files\Enervent2\TempModerate.txt

Average system flow rate: 0.0027 m³/s
Air leakage value, n50= 6.0 ach at 50 Pa. This gives 0.4167 m³/s at 50 Pa; 0.1594 m³/s at 10 Pa; 0.0922 m³/s at 4 Pa; 0.0403 m³/s at 1 Pa.
The estimated envelope area is 198.4 m²
The flow rate per m² is 0.0021 m/s at 50 Pa; $8.03*10^{-4}$ m/s at 10 Pa; $4.65*10^{-4}$ m/s at 4 Pa; $2.03*10^{-4}$ m/s at 1 Pa.
The total opened area of large windows (average over the heating season) = 0.058 m²
The total opened area of inlets (average over the heating season) = 169 cm²
The number of degree-days are: 1731 dd

Calculation
This run considers heating during the heating season and fan energy during the whole year. The heating season is the period with outdoor temperatures below 14.0 °C which occurs at the degree-day base temperature inside at 15.5 °C.
The pressure in the house ranges from – 35.2 Pa to – 1.5 Pa.
The weighted average pressure in the house is – 4.8 Pa.
The weighted average flow rate is: 0.027 m³/s
No heat recovery

The air leakage, n50 = 6.0 ach, results in an extra ventilation flow rate of 0.027 m³/s
The ventilation inlets with the average area of 168.6 cm² result in an extra ventilation flow rate of 0.009 m³/s.
The average use of windows (0.058 m²) results in an extra ventilation flow rate of 0.003 m³/s
The total flow rate is 0.065 m³/s.
The average temperature difference is 10.4 K. The duration of the heating season is 167 days
The energy for heating: 1096 W (167 days); 631 m³ gas for $157.85. Energy 15.8 GJ

11.7.3 MEO application

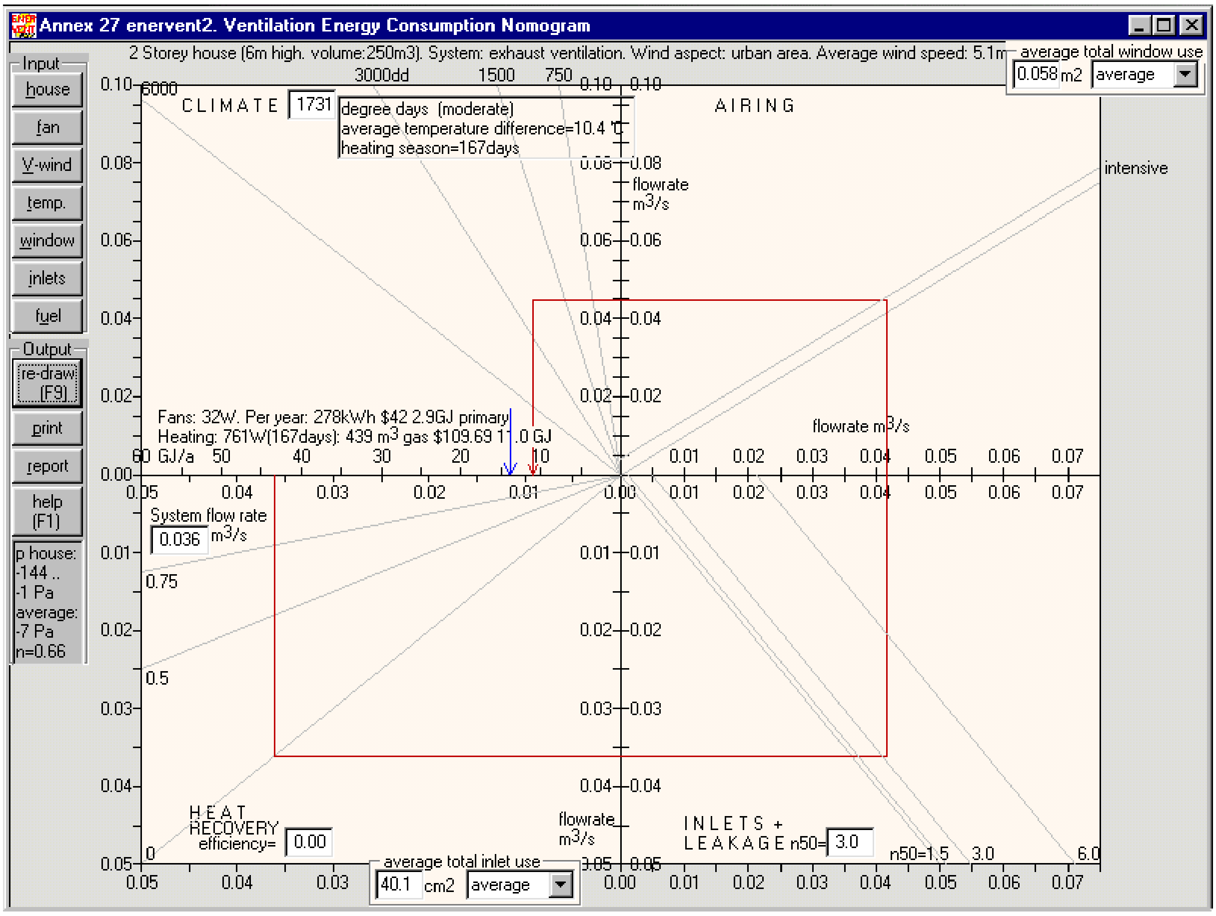


Figure 11.3 Energy tool applied on MEO. Energy for heating the supply air

Input
Files used: House: House.txt
Wind: C:\Program Files\Enervent2\WindModerate.txt
Temperature: C:\Program Files\Enervent2\TempModerate.txt

Fan: Exhaust; high = 0.041 m³/s; low = 0.002 m³/s
Fan efficiency: 0.10. System pressure 90.0 Pa
Fan running time: High = 21 h. Low = 3 h
Average system flow rate: 0.036 m³/s
Air leakage value, n50= 6.0 ach at 50 Pa. This gives 0.4167 m³/s at 50 Pa; 0.1594 m³/s at 10 Pa; 0.0922 m³/s at 4 Pa; 0.0403 m³/s at 1 Pa.
The estimated envelope area is 198.4 m²
The flow rate per m² is 0.0021 m/s at 50 Pa; $8.03*10^{-4}$ m/s at 10 Pa; $4.65*10^{-4}$ m/s at 4 Pa; $2.03*10^{-4}$ m/s at 1 Pa.

The total opened area of large windows (average over the heating season) = 0.058 m²
The total opened area of inlets (average over the heating season) = 169 cm²
The number of degree-days are: 1731 dd

Calculation
This run considers heating during the heating season and fan energy during the whole year. The heating season is the period with outdoor temperatures below 14.0 °C which occurs at the degree-day base temperature inside at 15.5 °C.
The pressure in the house ranges from – 234.5 Pa to – 1.5 Pa.
The weighted average pressure in the house is – 5.3 Pa.
The weighted average flow rate is: 0.036 m³/s
No heat recovery
The air leakage, n50 = 6.0 ach, results in an extra ventilation flow rate of 0.022 m³/s
The ventilation inlets with the average area of 168.6 cm² result in an extra ventilation flow rate of 0.008 m³/s.
The average use of windows (0.058 m²) results in an extra ventilation flow rate of 0.002 m³/s
The total flow rate is 0.068 m³/s.
The average temperature difference is 10.4 K. The duration of the heating season is 167 days
The energy for heating: 1173 W (167 days); 676 m³ gas for $169.05. Energy 16.9 GJ

The electric energy for the whole year for the fan (power = 31 W): 272 kWh $41. Primary energy 2.8 GJ

11.7.4 MSE, MSE-X application

Input
Files used: House: House.txt
Wind: C:\Program Files\Enervent2\WindModerate.txt
Temperature: C:\Program Files\Enervent2\TempModerate.txt

Fan: Exhaust; high = 0.041 m³/s; low = 0.002 m³/s
Fan efficiency: 0.10. System pressure 90.0 Pa
Supply; high = 0.035 m³/s; low = 0.018 m³/s
Fan efficiency: 0.10. System pressure 60 Pa
Fans running time: High = 21 h. Low = 3 h
Average system flow rate: 0.038 m³/s
Air leakage value, n50= 3.0 ach at 50 Pa. This gives 0.2083 m³/s at 50 Pa; 0.0723 m³/s at 10 Pa; 0.0396 m³/s at 4 Pa; 0.0159 m³/s at 1 Pa.
The estimated envelope area is 198.4 m²
The flow rate per m² is 0.0010 m/s at 50 Pa; $3.64 \cdot 10^{-4}$ m/s at 10 Pa; $1.99 \cdot 10^{-4}$ m/s at 4 Pa; $0.801 \cdot 10^{-4}$ m/s at 1 Pa.
The total opened area of large windows (average over the heating season) = 0.058 m²
Inlets in the façade are not used
The number of degree-days are: 1731 dd

Calculation
This run considers heating during the heating season and fan energy during the whole year. The heating season is the period with outdoor temperatures below 14.0 °C which occurs at the degree-day base temperature inside at 15.5 °C.
The pressure in the house ranges from – 25.1 Pa to 33.0 Pa.
The weighted average pressure in the house is – 3.9 Pa.
The weighted average flow rate is: 0.038 m³/s
Heat recovery efficiency 0.60. Reduces the heat need to a ventilation flow rate of 0.015 m³/s

The air leakage, n50 = 3.0 ach, results in an extra ventilation flow rate of 0.014 m³/s
The average use of windows (0.058 m²) results in an extra ventilation flow rate of 0.003 m³/s
The total flow rate is 0.055 m³/s.
The average temperature difference is 10.4 K. The duration of the heating season is 167 days
The energy for heating: 672 W (167 days); 387 m³ gas for $96.87. Energy 9.7 GJ

The electric energy for the whole year for the fan (power = 52 W): 457 kWh $68. Primary energy 4.7 GJ

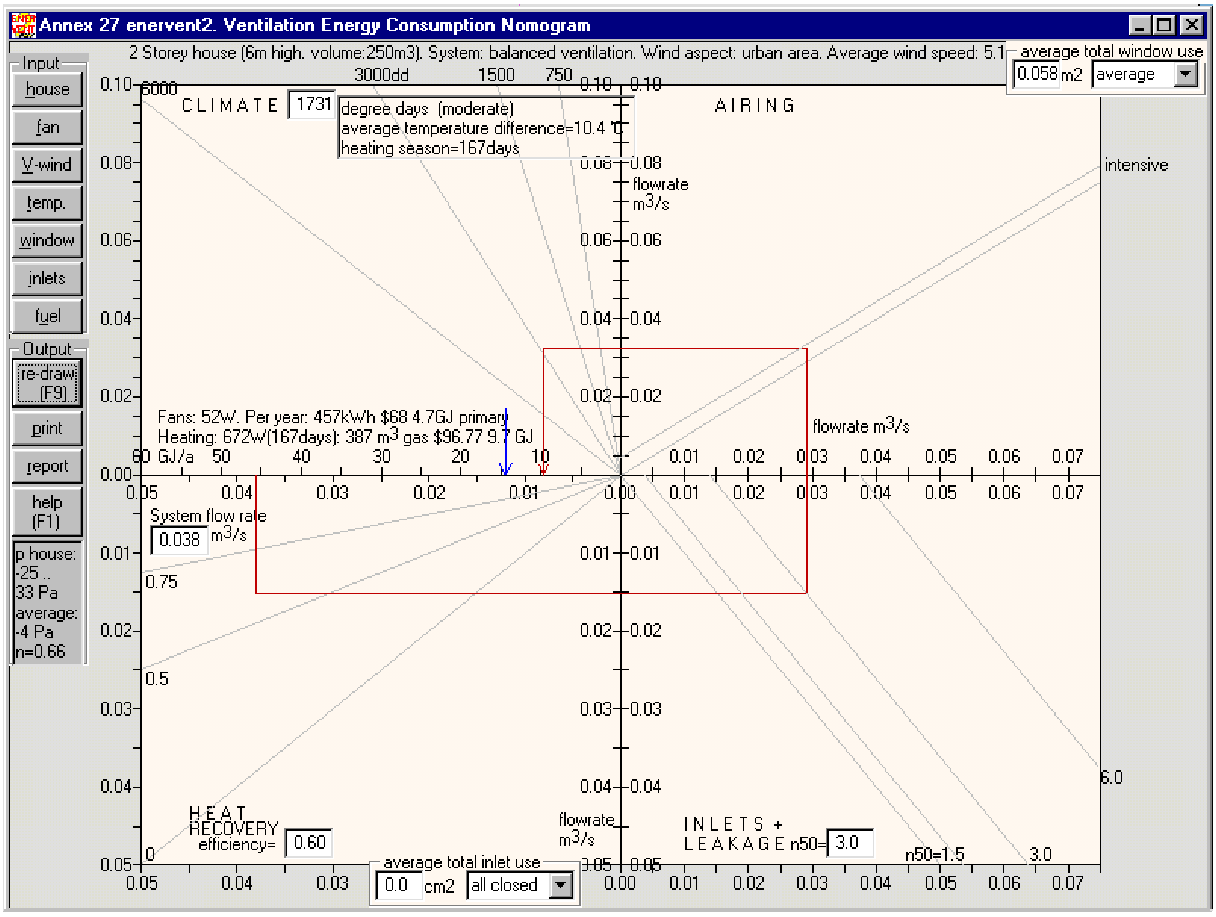


Figure 11.4 Energy tool applied on MSE, MSE-X. Energy for heating the supply air

For comparison, Table 11.6 shows the results for the case for all three climates: mild, moderate, and cold. It includes the cost and energy.

Table 11.6 Energy use and cost for heating the air and the fan energy

Ventilation system	Fan energy		Heating for ventilation and infiltration air	
	GJ	$	GJ	$
Mild climate				
NWA	0.5	8	3.9	39
PSV	0.5	8	4.2	42
MEO	2.9	42	4.6	46
MSE, MSE-X	4.7	69	3.4	34
Moderate climate				
NWA	0.5	8	12.6	126
PSV	0.5	8	15.8	158
MEO	2.9	42	11.0	110
MSE, MSE-X	4.7	69	9.7	97
Cold climate				
NWA	0.5	8	48.4	484
PSV	0.5	8	55.9	559
MEO	2.9	42	53.2	532
MSE, MSE-X	4.7	69	31.5	315

11.8 Case Application on LCC

The LCC tool is described in Chapter 10.The LCC is independent of the climate as the energy cost is not included here. The results were derived from the tables and figures in Chapter 10.

The assumptions made are that the system has an “average” ***basic quality*** and the ***system loading*** is “medium”.

General for all systems are:
The maintenance includes cleaning of devices by the residents 4 times/year; service cleaning every 6 years; replacement of outlets every 10 years; repairing windows every 6 years; repairing inlets every 12 years.

11.8.1 NWA application

Initial cost: 350 ECU
Maintenance: 400 ECU
Total cost: 750 ECU

11.8.2 PSV application

Initial cost: 800 ECU
Maintenance: 400 ECU
Total cost: 1200 ECU

11.8.3 MEO application

Initial cost: 900 ECU
Maintenance: 700 ECU
Total cost: 1600 ECU

11.8.4 MSE application

Initial cost: 1625 ECU
Maintenance: 525 ECU
Total cost: 2150 ECU

11.9 Case Summary

To give a better view of the consequences of the location of the house, all the 4 ventilation systems have been evaluated for all three climates. Table 11.7 provides a summary for all the tools.

Table 11.7 Case study applied to three climates (mild, moderate, cold)

	System			
	NWA	PSV	MEO	MSE
Mild climate (Nice, Milano)				
Thermal Comfort	-	-	-	+ +
Noise Outdoor With soundproof System	- -	0 + +	+ + + +	+ + + +
Building Aspects	Replace ✌✌✌	Roof ✌✌✌	All ✌	Mainten ✌✌
IAQ iaq Condensation Pressure diff High RH wintertime	+ 0 ⚐	+ + + ⚐	+ + ⚐	+ + + ⚐ ⚐
Reliability Flow stability Performance over time	0 + +	+ + +	0 + +	+ + 0
Energy [GJ] Fan Heat	0.5 3.9	0.5 4.2	2.9 4.6	4.7 3.4
LCC (ECU) Initial Maintenance	350 400	800 400	900 700	1625 525
Moderate Climate (Amsterdam, London, Paris, Tohoku)				
Thermal Comfort	- -	- -	- -	+ +
Noise Outdoor With soundproof System	- -	0 + +	+ + + +	+ + + +
Building Aspects	Windows ✌✌✌	Plumb, Roof ✌✌✌	All ✌	Cnstr, Blg Service ✌✌
IAQ iaq Condensation Pressure diff High RH wintertime	0 - - ⚐	+ 0 ⚐	- 0 ⚐	+ 0 ⚐ ⚐
Reliability Flow stability Performance over time	0 + +	0 + +	0 + +	+ + 0
Energy [GJ] Fan Heat	0.5 12.6	0.5 15.8	2.9 11.0	4.7 9.7
LCC (ECU) Initial Maintenance	350 400	800 400	900 700	1625 525
Cold Climate (Stockholm, Ottawa, Minneapolis, Sapporo)				
Thermal Comfort	- -	- -	- -	+ +
Noise Outdoor With soundproof System	- -	0 + +	+ + + +	+ + + +
Building Aspects	Furnish ✌✌	Roof ✌✌	All ✌	Lay out ✌✌
IAQ iaq Condensation Pressure diff Dryness	0 0 ⚐	+ + + + ⚐	0 + + ⚐	+ + ⚐ ⚐
Reliability Flow stability Performance over time	+ + +	0 + +	0 + +	+ + 0
Energy [GJ] Fan Heat	0.5 48.4	0.5 55.9	2.7 53.2	4.7 31.5
LCC (ECU) Initial Maintenance	350 400	800 400	900 700	1625 525

Appendix

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