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## Annex 27 - Domestic Ventilation , Occupant Habits' Influence on Ventilation Need


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# Annex 27 - Domestic Ventilation.
# Occupant Habits´ Influence on Ventilation Need.

## Synopsis

The Annex 27 (A27), Evaluation and Demonstration of Domestic Ventilation Systems, is given a genaral introduction. The habits varys a lot between individuals, the dwellings are of various sizes with various numbers of occupants being at home for longer or shorter times. Those facts needed to be collected in the beginning of the annex.

In this paper background data will be given to make it possible to discuss the varied need for outdoor air supply in dwellings. Data for the parameters have been collected from many sources. Often the original purposes of the studies were quite another than discussing the required outdoor air supply. Sometimes the sources can be found outside the research field of the built environment.

Statistical data will be given on dwellings such as size, number, construction year, persons/dwelling, and also concerning the use of the dwelling and the occupants´ habits. The variation can be over the duration of the building. For the short time variation we can find some sources on time spent in dwellings, shower habits, water consumption, cooking time, use of appliances in the dwelling, number of pot plants, window airing and smoking habits.

## 1 Introduction

This paper consists of two parts. In the first part is briefly given a presentation of the newly started Annex 27 (A 27), Evaluation and Demonstration of Domestic Ventilation Systems. The main aim is to give the frame of the work and the direction of how to proceed. During forthcoming conferences results from this annex will be presented.

The second part gives data from various sources on occupants´ habits. Most of those habits are influencing the needed ventilation rate. As there is a great variation between individuals, avail-able data has been collected to give both average and extreme values. In order to establish real cases for the simulations, data has been collected from as many countries as possible, also outside the participating countries. When comparing the data from the individual countries some common trends can be found and also that some countries have similarities.

## 2 Annex 27 - Domestic Ventilation Systems

The new annex, A 27, started in April 1993 as a result of discussions in conjunction with AIVC-meetings. The work planned will use the results of several of the finished and ongoing annexes and put the parts together in order to find tools for practitioner to evaluate domenstic ventilation systems also at the desk facilitating a better jugement of the expected outcome of a selected system. The official participants in the A 27 are Canada, France, Japan, The Netherlands, Sweden, UK, and USA. As observers have acted Belgium, Finland, Norway, and Switzerland. Those countries have a total number of 225 million dwellings with a useful floor space of about 27 000$\bullet 10^6$ $m^2$.

## 2.1 Background

The rate of outdoor air supply as well as comfort aspects associated with air distribution and the ability of the systems to remove pollutants are important factors to be considered at all stages in the building lifecycle. As distinct from a work place, occupants in dwellings can vary across a wide span from an allergic infant to a well trained sportsman, from active outgoing people to elderly confined to a life indoors.

During the lifetime of a building its dwelling occupational pattern vary. This results in a varying need for supply air to obtain acceptable indoor air climate and to avoid degradation of the fabric. Emissions from building materials are also time dependent. When the building is new or recently refurbished it may be necessary to dilute the emissions by extra supply air. In stand-ards 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.

Dwellings represent about 25 - 30 % of all energy used in the OECD countries. In the near future domestic ventilation will represent 10 % of the total energy use. Thus even relatively small reductions in overall ventilation levels could represent significant savings in total energy use. Improvement of residential ventilation is of concern in both existing and future buildings. The functioning of the ventilation system may deteriorate at all stages of the building process and during the lifetime of the building. Research in the recent years and in particular the IEA annexes now makes it possible to formulate methods to evaluate domestic ventilation systems.

## 2.2 Objectives

The objectives of A 27 are: **to** develop tools, for evaluating domestic ventialtion systems; **to** validate the methods and tools with data obtained from measurements; **to** demonstrate and evaluate ventilation systems for different climates, building types, and use of the dwellings

The methods, tools, and systems are intended for existing and future residential buildings that require heating. The target group is composed of standard and policy makers, developers in industry, and ventilation system designers.

## 2.3 Scope of the annex

The annex is divided into three subtasks described briefly in table 1. Most of the work in Subtask 1 is done and the main efforts are now spent on Subtask 2.

***Table 1 Scope of the annex***

| **Subtask 1**<br>***State of the Art*** | **Subtask 2**<br>***Development and Validation of Evaluation Methods*** | **Subtask 3**<br>***Evaluation, Demo, and Application of Current and Innovative Vent Systems*** |
|---|---|---|
| **1.** Give an overview of typical and frequently used systems<br>**2.** Background and reasons for exist-ing systems and standards<br>**3.** Review exist. evaluation method<br>Report Nov 1994 | **1.** Define evaluation parameters<br>**2.** Select methods<br>**3.** Develop tools<br>**4.** Validate methods and tools<br>Report mid 1996 | **1.** Use the methods and tools developed for a set of variables (climates, building types, users, constructions, new, renovated, and existing buildings<br>**2.** Demo good performance of priniply different ventilation systems<br>**3.** Demo innovative systems<br>Report mid 1998 |

# 3 Occupants´ habits

The main objective bringing together detailed information about the occupants´ pattern in dwellings is to identify most of the cases, say 90 %, that have influence on the needed outdoor air supply. When these boundary conditions are identified, realistic cases can be set up and assumptions made for occupants´ habits so that simulations can be made. In the first section is shown statistical data on housing in as many OECD countries as possible and in the second users´ habits. The facts has been collected both from technical reports but also from quite another studies such as market surveys. Some studies are only made in one country and can be said to be week but on the other hand indicates a pattern that is general. The study also aimed at giving evidences to the starting point that the needed outdoor air rate varys over the time during the lifecycle of a dwelling illustrated in figure 1.

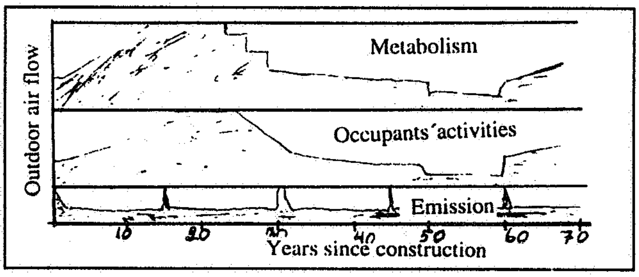


*Figure 1. Long time ventilation need*

### 3.1 Data on housing

With data on housing it makes it possible to see that many dwellings are not that densed populated that the codes and standards have assumed when making the rules. When studying severel countries´ data it makes it possible to give an estimation of the trends that might be possible e.g. the growing number of elderly people gives more households with only one person. The data given here are the useful dwelling space alone, as it is the more proper figure for discussing needed ventilation.

The 14 OECD countries, see table 1, with a population of about 700 million, have approximatly 280 million dwellings with a useful floor space of 32 000 million m$^2$. However, there is a great variation of the useful floor space from country to country. The largest dwellings are in North America (134 m$^2$ - 152 m$^2$) whilst the smaller are in Japan (89 m$^2$)and Europe (65 m$^2$ - 110 m$^2$). When looking on the construction years we can get an opinion of the future need for new dwellings or if it needs to be refurbished. From data four different groups can be identified, see table 1. Another factor to be considered is if the dwellings are in blocks of flats or single family houses. Studies have indicated that people living in flats tend to make more complaints than in single family houses. One interpretation given is, that people in flats have a feeling they can not manage the situation, and here in particular the ventilation system.

*Table 1 Construction years of dwellings. Ref. 1, 2, 21, 22, 23*

| Before -1945<br>40 - 50 % constructed | 1946 - 1970<br>≈ 50 % constructed | 1971 - and later<br>≈ 50 % constructed | Even distributed with<br>1/3 in each period |
|---|---|---|---|
| Belgium, Denmark,<br>France, UK | Germany, Italy,<br>Sweden | Canada (?), Finland,<br>Japan, Netherlands,<br>USA | Norway, Switerland, |

The distribution between flats and single family houses varys greatly. UK has 83 % of the dwellings in single family houses whilst the opposite is Switzerland with only 31 %. Japan and North America have about 65 % whilst most of the European countries have figures around 50 %, except Belgium, Denmark, and The Netherlands with figures closer to that of North America. Ref. 1, 3, 10, 11, 13, 22, 23, 27.

### 3.2 Dwelling usage

In this section will be given figures on how the dwelling is used both the population density and the variation of activities and time spent in the dwelling. As can be seen in table 2 the number of persons/dwelling (p/d) vary from 3.2 p/d to 2.1 p/d and most countries around 2.5 p/d. The area/person can vary from 27 $m^2$ to 61 $m^2$ giving a much larger volume for persons in some of the countries.

If the ventilation rate is going to be more adapted to the individual demand and the activity at hand the ***number of persons/household*** is of interest. If this is coupled to the size of the dwelling we can get an opportunity to give the boundaries for the needed ventilation rates. As can be seen in table 2 there is only 2 persons in nearly 60 % of the dwellings with the exceptions of Japan and Italy. The trend is that with a growing number of an elderly population the fewer persons/household. Families with 5 persons or more are not very frequent, less than 10 % of the households, with the extremes, 5 % of the households, in Denmark, Germany, and Sweden. In a study in Sweden it was found that only 1/4 of the households had children.

***Table 2 Number of persons/household, % of all dwellings Ref. 1, 2, 3, 13, 21, 23, 24.***

| Country | Persons/ dwelling | Area $m^2$/person | Number of persons/household (distribution %) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 - |
| Belgium | 2.7 | | 26 | 30 | 18 | 16 | 9 |
| Denmark | 2.2 | 49 | 34 | 33 | 15 | 13 | 5 |
| Finland | 2.5 | 30 | 31 | 29 | 17 | 15 | 8 |
| France | 2.7 | 32 | 25 | 28 | 19 | 16 | 12 |
| Germany | 2.5 | 35 | 33 | 29 | 18 | 14 | 6 |
| Italy | 3.2 | 29 | 22 | 24 | 23 | 21 | 10 |
| Japan | 3.2 | 28 | 18 | 20 | 18 | 23 | 21 |
| Netherlands | 2.6 | | 27 | 30 | 15 | 19 | 9 |
| Norway | 2.5 | 43 | 35 | 26 | 15 | 15 | 8 |
| Sweden | 2.1 | 47 | 40 | 31 | 12 | 12 | 5 |
| Switzerland | 2.6 | 34 | | | | | |
| United Kingdom | 2.7 | 27 | 24 | 33 | 17 | 17 | 9 |
| Canada | 2.8 | | 21 | 30 | 18 | 19 | 12 |
| U.S.A. | 2.3 | 61 | 25 | 33 | 16 | 17 | 9 |

From table 2 can be seen that ***1-person-household*** is more frequent in Europe, about 1/3 of all households. In Japan and North America about 1/5 of the households consist of one person. The trend in Europe since 1950 has been an increase from about 1/5. In USA the trend was the opposite. 1950 was 1/3 a 1-person-household and 10 years later 13 %. The general trend has been that the number of one-person-household doubled during 40 years, but in Japan the increase was 4 times. Ref. 1, 14, 24.

The number of persons/household can also be compared with ***persons/bedroom*** giving an estimation of the size of the dwelling. This value indicates if outdoor air is "needed". As a general trend most of the households with 5 or more persons have more bedrooms because the frequency of more than 2 persons/household is very low except in Finland, France%, and UK. Those countries have the same frequency as for 5 person/household. The frequency of less than 1 person/bedroom varys from less than 20 % in Finland, France, and The Netherlands; 30 - 35 % for Germany, Sweden, Switzerland, UK, and Belgium (40 %); finally about 50 % Denmark, Japan, Norway, Canada, and USA. Ref. 1, 23.

It is well know by planners that the number of children is on its maximum about 10 years after completion of a housing development. When the children have grown up and moved the number of persons living in each dwelling becomes fewer. This situation is illustrated in figure 2 showing that in single family houses constructed after 1971 there are 3.5 persons/house, while in the older houses there are only 2.5 persons/house. The long time perspective of the needed outdoor air flow rate can also be seen when studying the moving frequency, see figure 3. Highest frequency has young people moving away from their parents. Then they settle a family, it grows and a larger dwelling is needed. At the age of 35 the family is stable and the final size of the dwelling has been reached. The interest to move away from the dwelling that a family had at the age of 45 is very small.

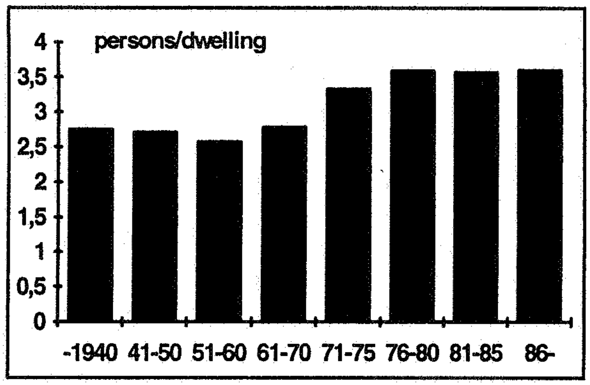


*Figure 2 Number of persons living in single family houses, various construction years, Ref 18*

The ***time spent in a dwelling*** varys within a great range. Elderly people are spending more time at home than young adults. About 30 % of employed men have their lunch at home. For women about 60 % are at home most of the daytime, except singles. The time spent in the kitchen varys both with the area of the kitchen and with cultural habits. French women spend twice the time in the kitchen compared to women in USA and it does not matter if the woman is a housewife or employed. Housewifes are working doubled time in the kitchen compared to employed women. Housewifes are working in the kitchen from 1.6 h to nearly 3 h and men about 5 min each day. Ref. 5, 26.

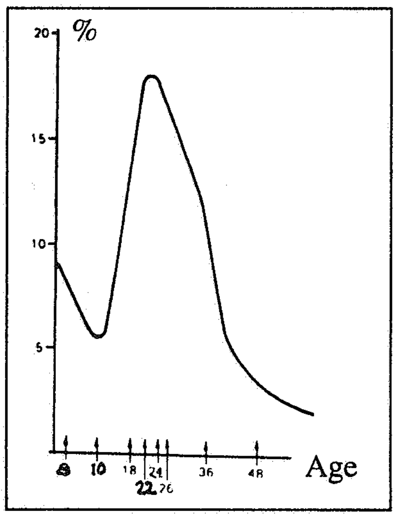


*Figure 3 Moving frequency for different ages, in Sweden. Ref. 18.*

There is a large span in the average ***indoor temperature*** between countries. Also between single family houses and flats there is a difference, higher in flats, ref 29. The deviation from the average temperature can be large and in some surveys it is found to be ±7 °C, ref 5, but more common is ±3. This might be influenced by the dressing habits and the long tradition of various indoor temperature in various rooms. However, having a great span in the temperature within the same dwelling causes discomfort.

In dwellings, where heating is necessary, the ***water vapour generation indoors*** is the most severe risk for the building because of the risk for condensation causing mould and house dust mites growing. How much water vapour, that is generated, depends on the number persons, their activities, and the use of water in the dwelling. The humidity can also be increased by the cooking habits.The seasonal variation of outdoor water vapour content increases the needed outdoor air for removal of the indoor generated water vapour.

The ***equipment*** in the dwellings indicates the possibility to produce moisture and other pollutants. In very close to 100 % of the dwellings there is a bath/shower. Another moisture source is the washing machine. About 85 % of the dwellings have such a machine. There are some doubts about this figure, which might indicate "access to a washing machine". Dishwasher is only used in 1/4 of the households except in USA, 60%. The percentage of central heated dwellings indicates the possible use of single room heaters, which can give pollutants directly to the room. In the Nordic countries and USA nearly 100 % are central heated, in Switzerland 50 %, and nearly no central heated dwellings at all in Japan, 3 %. Ref. 1, 2, 3, 4, 14, 23, 25.

The ***water consumption*** varys within a large range but average figures from Japan, The Netherlands, and Sweden are from 130 l/(person, day) to 190 l/p,d. The most interesting is the use of water for showering/bath and figures found goes from 45 l/p,d to 60 l/p,d. The water is used most frequently in the morning, 7 - 10 h, and in the evening 19 - 22 h.

When ***washing the clothes and drying*** it the water vapour content will be increased indoors. The most common way to dry the clothes is still to do it in the air. A study of 12 household (4 persons/household) measured the frequency of 4 times/week. A questionnaire to 1000 persons showed that more than 60 % washed 1 - 6 times each week. Ref. 7, 16, 17.

Most of the water vapour produced in a dwelling, besides from the metabolism, originates from ***body washing*** and very much depending on the habit to take a shower or a bath.. The variation in use of hot tap water can be in the ratio 1:20. A shower, today most used, gives a water vapour production of about 2600 g/h, ref 8. Another study, ref 15, shows that even with an exhaust fan, 100 % relative humidity will be reached after only 5 min of showering. In the above mentioned questionnaire 1000 persons, ref 16, 17, were asked there body-washing habits. The results shown in figure 4 and 5 can be summarized in the following points:

1. About 85 % of all are showering. Retired persons 70 %.
2. Men and women have the same showering habits.
3. Once a day 65 % are showering.
4. Twice a day 10 % are showering.
5. Nearly 20 % of the men aged 16 - 29 are showering twice a day and 10 % of the women.
6. Women takes shorter showers than men and is recognized especially for the busy period of the life at the age of 30 - 49 with work and children .

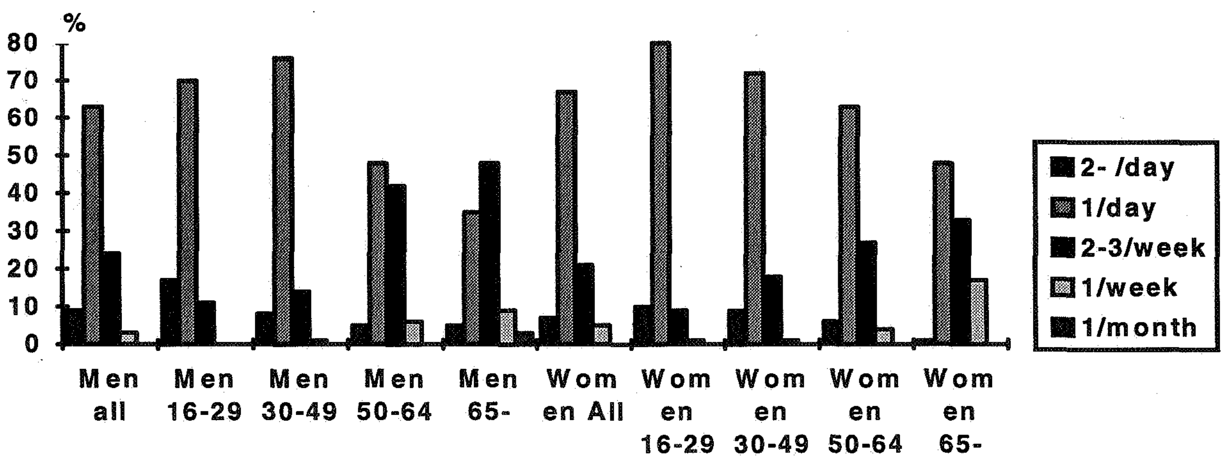


*Figure 4 Showering frequency. Ref 16, 17.*


*Figure 5 Duration of showering. Ref 16, 17.*

The number of ***pot plants*** is very depending on national habits. A market research, Ref 10, gave that Germany, The Netherlands, Switzerland, and Sweden are the countries in Europe with most pot plants in their dwellings. The result gives that pot plants are placed at the whole length of all the windows. A calculation applied on Sweden gives 0.25 -0.30 pot plants per $m^2$ dwelling area and need the air change of about 0.1 $h^{-1}$ to exhaust the water vapour.

Even if there is some uncertanty about the calculation of air flow through large openings a much bigger uncertanty will be the time when the windows are opened and the width of the opening. Other parameters are the constructions of the window, indoor temperature, and wind speed. Some conclusions found about ***window opening habits*** are:

* The same daytime and at night
* Proportional to the outdoor temperature
* Proportional to the inverted value of the wind speed
* Windows are not left opened when no person is present in the dwelling.
* Doubled when tobacco smoking is allowed.
* Regulate the temperature
* Depending on housewives´ habits when making up beds and cleaning the dwelling.
* Less when higher indoor temperature is prefered.
* Less amongst elderly people.
* No socio-economic correlation
* Increased when the room has direct solar radiation
* More when sunny outdoors

Actually it was found in ref 19, that the number of windows multiplied with the temperature difference was constant $n \bullet \Delta T = 2.2 \pm 0.4$ (n=fraction of windows opened; $\Delta T$= temperature difference) to be used at a temperature difference >7 $^{o}C$. However in a study on 85 single family houses was found $n \bullet \Delta T = 0.3 \pm 0.1$. The airing with fully opened windows were reported to be 5 - 10 min. (8 min according to questionnaires, 11 min according to interviews), ref 20.

***Smoking habits*** varys both between countries and within a country. Today about 30 % of the inhabitants are smokers and the smoking habit is nearly the same for men and women, with the exception of Japan where men are more and women less frequent smokers. Especially women that are smoking during pregnacy and staying at home with their infants can cause oversenitivity amongst their children. Adults´ own smoking habits will also cause oversensitivity that will lead to a demand for more outdoor air supply. Ref 28.

Other indoor pollutants that is depending on the occupants´ habits are ***nitrous gases*** from gas fired appliances. Here the building regulation goes towards a standard for direct exhaust by a chimney. However, for stoves and ovens it might be difficulties to exhaust all especially from the pilot flame as the cooker hood don´t work when there is no cooking going on.

Periodically ***volatile organic compounds (voc)*** will occur indoors. One is coupled to the cleaning habits and gives emissions weekly with some extra voc:s a few times yearly. The other type is voc from furniture, surface covering, and building fabric emitted once the building is constructed and then periodically when redecorating with an interval of 10 - 15 years, and major refurbishments after 30 - 40 years. Both types requires an increased outdoor air flow. In addition to the periodically emission types a daily emission occurs giving a base ventilation need by the use of deodorants (used by 50 % of men and 65 % of women), hair-spray and also daily use of detergents, soap etc and remaining emissions from furniture and building fabric.

To get an indoor climate that satisfy the individual need, also ***body odour*** has to be removed. The traditional tracer gas is $CO_2$ that is totaly harmless at levels in dwellings (<5000 ppm). The adaptation to the body odour is very quick and is nearly only sensed by people entering a room. The level is also a matter of how the dwelling is used. If the door to the bedroom is closed the level is more rapid increased. Most people have the bedroom door opened.

## 4. Conclusions

All the various habits may result in a demand for a variable outdoor air flow rate. Together with the great differences in dwelling size and number of persons living in the dwellings, it leads to a significant difference in the needed outdoor air flow rate if the rate/person is supposed to be the same for all.

The floor area varys from 65 $m^2$ to 152 $m^2$ giving a volume of 150 -365 $m^3$ with a ceiling height of 2.4 m. With the today´s outdoor air change rate standard of 0.5 $h^{-1}$ the flow will be 75 - 180 $m^3/h$. If combining the volume and the number of persons/dwelling the outdoor air flow goes from 6.5 l/s,p to 24 l/s,p if all dwellings had mechanical ventilation adjusted to the standard. A base ventilation is also needed of at least 0.1 $h^{-1}$ for the exhaust of daily voc and from pot plants. For weekly or monthly emissions window airing is one way to solve it.

The WHO European guidelines for indoor air quality require the dissatisfaction within a range from 10 % to 30 %. In a workshop at the Indoor Air conference 1993 it was recommended to lower the level to a nuisance threshold level placed at a dissatisfaction of 5 % of the occupants not more than 2 % of the time. The technical way to fulfil such a requirement (wish, recommendation) is to install a demand controlled ventilation system.

All these variables and habits led us in A 27 to make a set of assumptions when doing the simulations. Instead of trying to find an average pattern, which might have lead to a family that does not exist we made up cases to be studied. The variables for users´ behaviour are then used for making simulations. The assumptions that are needed and the parameters to be developed for tools are shown in table 4 to be simulated for different climates. In addition there are measurements planned on cases to be used in the annex for validation.

| *Table 4. Activities in A 27- Domestic Ventilation* | | |
|---|---|---|
| **Design assumptions** | **Occupants´ behaviour** | **Parameters (responsible country)** |
| • Example dwellings, 10 types with 1 - 5 rooms<br>• Ventilation systems, 7 types | • Standard families, 6 cases<br>• Combination families and ex. dwellings; crowded, average, and spacious<br>• Time at home and in individual rooms<br>• Window airing pattern<br>• Internal doors, temperature, metabolism | • Air quality (NL)<br>• Thermal Comfort (J)<br>• Energy (USA)<br>• Noise (NL)<br>• Life Cycle Cost (UK)<br>• Reliability (S)<br>• Moisture (F) |

All the variations in habits will result in a range of air flow rates for different situations. This paper gives the background for the hughe variation of the occupants´pattern in dwellings that is the major difference from workplaces giving a very hard task to solve. The detailed simulations will give the consequences for parameters concerning indoor air quality, energy, and life cycle cost at the selection of a certain ventilation system with certain occupants´ habits.

## 6 Acknowledgements

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