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Occupant behaviour and attitudes with respect to ventilation of dwellings

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Contributed Report 08

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Foreword by the AIVC

This report has been produced in the framework of the EU RESHYVENT project (Cluster Project on Demand Controlled Hybrid Ventilation in Residential Buildings with Specific Emphasis on the Integration of Renewables).

This report deals with the issue of occupancy behaviour and acceptance, with a very important aspect for the introduction of new advanced technologies, especially in the residential sector. This is especially the case for demand controlled ventilation. How much shall the occupant be able to influence the ventilation? Health aspects have to be taken into account, which the user might not always be able to judge.

This working document gives information on how occupants use different ventilation provisions and systems, why they ventilate as they do and which moderating factors play a role.

Further special attention is paid to promoting and restraining factors for acceptance of new ventilation devices. The method used is a study of literature.

RESHYVENT

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Executive summary

A very important aspect for the introduction of new advanced technologies, especially in the residential sector, is the acceptance of the occupants and the degree of interaction between a ventilation system and the occupants. This is especially the case for demand controlled ventilation. How much shall the occupant be able to influence the ventilation. Health aspects have to be taken into account, which the user might not always be able to judge. This working document gives information on how occupants use different ventilation provisions and systems, why they ventilate as they do and which moderating factors play a role. Further special attention is paid to promoting and restraining factors for acceptance of new ventilation devices. The method used is a study of literature.

With respect to the question how occupants ventilate, among others, has been found e.g. that if air inlets are present, they are used on a variable way, but no difference between summer and winter periods.

Reasons why occupants ventilate (or not) are: indoor climate and air quality, outdoor climate and outdoor factors.

Further it appears that:

- The ventilation by behaviour is only partly related to the type of ventilation system. In the bedroom the behaviour tends to be independent of the system installed;
- There seems to be a relatively constant 'subjectively preferred' amount of total ventilation from mechanical devices and behaviour taken together.;
- Provision related factors who influence the ventilation behaviour are the possibility to regulate, user-friendliness, (causing) draught , way of hinging and pollution or rust;
- The aesthetic quality play a role.

As a matter of course the ventilation behaviour also is influenced by the household behaviour and social and personal factors.

There are a number of promoting and restraining factors for acceptance of ventilation devices. Factors for acceptance of ventilation systems are:

- quality of directions for use;
- good performance
- fulfilling the expectations
- user-friendliness
- adaptation, integration with usual daily behaviour
- comfort, health, safety promoting
- friendliness to install, to repair
- maintainability, ability to clean
- aesthetics and architectural adaptation
- low cost, financial profit (energy saving)

Further general conclusions are:

- In a substantial proportion of the dwellings the occupants are dissatisfied about their ventilation provisions. This means that there is a market for better ventilation provisions;
- Occupants are often not 'average people'.;
- Occupants must be able to intervene in a simple way with an automatic system.

Contents

1 General

In the Netherlands about 20% of the occupants is dissatisfied about the possibility to ventilate [Passchier, 2001]. In France this percentage is of the same order: 27% in apartment buildings and 13% in dwellings [Liddament, 2001]. Moreover a substantial number of the population (at least 20%) is susceptible to indoor air pollutants (e.g. allergens) and/or bother with so called 'Building-Related Illnesses' (BRI), a 'sick building syndrome' (SBS) or a 'chemical hypersensitivity syndrome' [Maroni, 1995, Engvall, 2002b]. These are sufficient reasons to pay attention to the quality of ventilation systems in dwellings and to the occupants behaviour with respect to ventilation.

In international framework, research has been performed on this subject, especially in the years eighty, but also more recently. Results with respect to the ventilation behaviour of occupants have been reported by the Air Infiltration and Ventilation Centre (AIVC) [Dubrul, 1987]; and, more recently, summarised in [Liddament, 2001].

There are many types of ventilation provisions installed in dwellings. This study is based on the following devices. Per device rough ranges of estimated air flows are given at moderate mild winter conditions (5° C during daytime and wind speed < 5 m/s) [Dongen, 1990b]:

- (slot)vent (air inlets), often installed in window frame: 1-3 dm^3/s;
- ventlight (small window, horizontally hinging): 8-15 dm^3/s;
- casement window (vertically hinging) or pivot window (horizontally hinging) opened from ajar (15 dm^3/s) to widely (100 dm^3/s);
- inward door open: 42 dm^3/s (at low temperature differences) - 83 dm^3/s (at relative high temperature differences);
- ventilator on low (standard) speed: 17 dm^3/s;
- ventilator on high speed (in living room): 28 dm^3/s
- balanced mechanical ventilation: 7 dm^3/s (bedroom) – 21 dm^3/s (living room)

The main 'objective' roles of ventilation in dwellings (including flat-apartments) are to:

- provide air for metabolism;
- provide combustion air for fuel burning appliances;
- dilute and remove pollutants (especially CO_2, metabolic odour, NO_x, water vapour, moisture, (tobacco)particles, VOC, radon);
- cool for thermal comfort.

However, how and why occupants ventilate is influenced by 'subjective' factors (especially to prevent discomfort and health problems), based on their perceived quality of the indoor air and climate, 'household rules' by habit and on knowledge from information. Summarised, the key reasons why occupants ventilate are:

- to get fresh air;
- to remove odour;
- to remove stale air and condensation;
- to air during domestic activities;
- to remove tobacco smoke.

Reasons not to ventilate are:

- to prevent draught;
- to maintain a preferred temperature level;
- to protect inhabitants from adverse climate (i.e. cold and rain);
- to preserve privacy and safety;
- to reduce outside noise and pollution.

In view of the quality of the indoor climate and the user interaction improvements, among others, are proposed by [Blomsterberg, 1995].

- to reduce draught from outdoor air vents;
- to reduce sound from (balanced) ventilation systems;
- to make more readable operating and maintenance instructions for heating and ventilating systems.

The following contribution is mainly based on Dutch studies on ventilation behaviour, but on some places added with information from studies in other countries (especially Sweden). It is assumed that the results of the Dutch studies can be generalised to other countries in NW Europe. The studies refer to the behaviour in the eighties in moderately air tight dwellings [Dongen, 1989] and [Dongen, 1990a, 1990b] and to two recently published surveys on indoor air quality, ventilation behaviour and health. One refers to dwellings, representative for the Dutch rented dwelling stock [MarkTracé, 2002]. This study is based on 925 questionnaires, taken in dwellings (50% apartments). The mean air tightness of the dwellings is moderate: generating a mean airflow of 113 dm^3/sec (at 10 Pascal). In 48% of these dwellings a dwelling related mechanical exhaust ventilation system has been installed, the other 52% are only natural ventilated, however often added (especially in the kitchens) with local window- or wall ventilators, or with vapour hats.
The other survey, using the same questions on ventilation behaviour, was held in highly insulated and air tight newly build dwellings (693 dwellings, 50% apartments) with a mean airflow of about 60 dm^3/sec (at 10 Pascal) [MarkTracé, 2001, Steenbekkers, 2002]. In 350 of them (33% apartments, 26% rented) mechanical exhaust ventilation was installed, in the other 343 dwellings a balanced ventilation system with heat recovery.

Chapter 2 describes primarily **how** occupants ventilate. Ventilation is defined here as a more or less continuous flow of supply and exhaust air which are created by behaviour, by using (slot)vents, vent lights or windows set ajar, and by mechanical devices.

Chapter3 deals with **why** occupants ventilate as they do and which moderating factors play a role.

Chapter 4 focuses on the promoting and restraining factors for acceptance of new ventilation devices.

2 The way occupants ventilate

The results on how occupants ventilate are shown in Table 1 and Table 2 (based on the ventilation provisions, mentioned in Chapter 0 [MarkTracé, 2001, 2002]). They especially refer to the use of specific ventilation devices, (slot) vents and vent lights, in a moderate winter situation (5° C during daytime and wind speed < 5 m/s).

2.1 Use of (slot) vents

The use of (slot) vents during a moderate winter in Dutch dwellings with mean and high air tightness is shown in Table 1. This behaviour seem to agree highly with results from a Swedish survey where was found that slot vents were opened in 68% of the living rooms and in 70% of the bedrooms during winter. They were never opened in 16% of the living rooms and in 6% of the bedrooms [Blomsterberg, 1997].

Table 1 *Use of (slot)vents in different rooms (in percentage of dwellings, if present), and in dwellings with mean or high tightness*

	living room		kitchen		main bedroom		second bedroom	
air tightness	**mean**	**high**	**mean**	**high**	**mean**	**high**	**mean**	**high**
hours open (24h):								
0	20 (16)*	5	14	10	15 (6)*	5	16	-
0 – 1	9	9	5	11	3	1	4	-
1 – 4	9	6	10	8	5	4	3	-
4 – 8	5	8	7	7	5	5	4	-
8 – 16	4	8	3	4	4	7	4	-
nearly always (22h)	54	64	61	59	69	78	69	-
mean hours open	12.9	15.7	14.5	14.1	16.1	18.4	16.2	-

* result of Blomsterberg, 1997.

Table 1 tells us the following:

- Except in kitchens, in the newly build highly air tight dwellings the (slot)vents are used and opened more than in the mean (moderately) air tight dwellings;
- If air inlets are present, they are used on a variable way in about 25-30% of the living rooms, and in about 15% of the bedrooms. In the other cases they are whether (nearly) always closed (in the moderately air tight dwellings in about 15-20% of the cases, in highly air tight dwellings in 5-10% of the cases), or (nearly) always opened (in about 50-80% of the cases).

2.2 Use of vent lights

The use of vent lights during a moderate winter in Dutch dwellings (if present) is shown in Table 2. Since vent lights are present in only 10% of the highly air tight dwellings, the results refer to the mean airtight dwellings.

Table 2 *Use of vent lights (fully or half opened) in different rooms (in percentage of dwellings if present)*

	living room		kitchen		main bedroom		second bedroom	
width of opening	**fully**	**half**	**fully**	**half**	**fully**	**half**	**fully**	**half**
hours open (24h):								
0	33	43	22	41	30	46	30	37
0 – 1	18	21	15	13	7	6	12	11
1 – 4	18	12	26	16	11	15	17	16
4 – 8	10	9	14	8	9	6	9	8
8 – 16	5	3	7	4	7	5	5	6
nearly always (22h)	16	11	17	16	36	23	26	22
mean hours open	5.2	3.7	6.1	4.7	9.6	6.4	7.3	7.0

From Table 2 can be derived that:

- In about 60% of the main bedrooms and in about 50% of the second bedrooms the vent lights are opened fully or ajar permanently. If they are opened fully, it is at most in the main bedroom (in about 35% of these bedrooms always opened). In the kitchen the vent light is used most variable;
- In about 30% of the cases vent lights are never opened fully and in about 40% never half (partly) opened.

2.3 Use of mechanical exhaust ventilation

If mechanical exhaust ventilation is present, in the mean air tight dwellings the ventilation system is not used (off) in 17% during daytime and in 24% during the night. If the ventilator runs and the occupants can choose the running speed, it is put on slow position in 51% of the cases during daytime and in 62% during the night.
In the highly air tight dwellings the percentages 'off' are 16 during daytime and 21 during night; the percentages 'slow' are 66 and 69 respectively.

2.4 Use of inside doors

In the moderately (mean) air tight dwellings inside doors (to the hall or staircase) are opened (nearly) always in about 50% of the living rooms, 75% of the kitchens (including 'open' kitchen rooms) and in 60% of the bedrooms. In the highly air tight dwellings the use of the inside doors was comparable: 45% opened in the living room and also 60% opened in the bedroom(s).

2.5 Additional airing

In all cases additional air flows are created by using windows. It is called airing here: the opening of windows fairly (more than handwidth) wide.
Table 3 shows the use of windows in general to air in mean air tight dwellings during mild winter periods [MarkTracé, 2002].

Table 3 *Airing through windows in general (handwidth – widely opened) in mean air tight dwellings (in percentages)*

	living room		kitchen		main bedroom		children's bedroom	
window opening	**handw.**	**widely**	**handw.**	**widely**	**handw.**	**widely**	**handw.**	**widely**
hours open (24h):								
0 (never)	53	33	42	31	29	27	30	41
0 – 1	29	48	29	42	18	26	20	32
1 – 4	9	13	22	20	16	20	24	16
4 – 8	4	3	4	3	15	13	11	5
8 – 16	2	1	1	1	6	6	5	2
nearly always (22h)	3	2	3	3	16	9	9	4

From Table 3 can be derived that in 25% of the main bedrooms a window is always opened for airing (mostly in addition to ventilation).
In the newly build highly air tight dwellings with mechanical exhaust ventilation and (slot)vents, in addition windows are opened (from ajar to widely) daily (it is unknown how long) in 20% of the living rooms, in 39% of the kitchens and in 48% of the main bedrooms [MarkTracé, 2001].
In the highly airtight dwellings with balanced ventilation systems these percentages are higher: 40%, 32% and 67%.
To compare: from a Swedish study in modern one-family houses (with exhaust ventilation) during heating season it appeared that in 90% of these dwellings at least airing takes place to cross ventilate dwellings for a couple of minutes. In 10% of the dwellings this is continuously for a day or night [Blomsterberg, 1995]. In another survey of [Blomsterberg, 1997] daily airing is reported in 21% of the dwellings (60% during whole day, 30% a couple of hours). And in a Danish study is reported that in 74% of the dwellings airing with cross flow takes place daily [Gunnarsen, 2001].

In 54% of the moderate airtight dwellings and in 90% of the highly air tight dwellings extra exhaust ventilation provisions are installed in the kitchens (vapour hoods, window- or wall ventilators). If they are installed, they are used in about 90% of the cases.

It can be concluded that:

- during a mild winter period in nearly all dwellings (90% at least), independent of the air tightness, one or more windows are used for additional airing during some time. In about 25% of the dwellings in the Netherlands this is always the case.

2.6 Trends in ventilation behaviour

In a survey, performed in the years 1996 – 1997, to evaluate an information campaign on a healthy indoor environment, the ventilation behaviour has been studied in 1153 dwellings in four municipals in the Dutch province North-Holland [Steenbekkers, 1997]. A question was 'how do you ventilate' (defined as providing continuously a certain rate of fresh indoor air by using (slot)vents, vent lights or windows set ajar). Results are given in Table 4. The results are compared to the results that are deduced from [Van Dongen, 1990b].

Table 4 *Ventilation by behaviour through (slot)vents, vent lights or windows set ajar in moderate (mean) air tight dwellings*

	living room		kitchen		bathroom		main bedroom	
1997, 1990 studies:	**S'97**	**D'90**	**S'97**	**D'90**	**S'97**	**D'90**	**S'97**	**D'90**
hours open (24hrs)								
0 (never)	15	28	9	13	8	-	5	14
0 – 1	29	15	26	17	21	-	10	4
1 – 4	19	16	21	26	19	-	18	6
4 – 8	8	8	9	8	9	-	16	6
8 – 16	6	10	7	12	7	-	15	20
nearly always (22h)	23	24	27	25	35	-	35	50
mean hours open	6.8	7.5	7.9	8.1	9.6	-	10.9	13.8

Comparing the ventilation behaviour during the years it appears that:

- The ventilation provisions were more kept always closed 10-15 years ago than at present;
- The percentages of dwellings in which the ventilation provisions (nearly) always are opened did not change during the years in the living rooms and the kitchens;
- In the main bedroom the provisions are clearly shorter opened nowadays. A reason for this might be that more often dwellings are not occupied, so windows are more closed for reasons of burglary e.g. (see Section 3.6).

3 Moderating factors to behaviour

3.1 Indoor climate and air quality

The main reason why occupants ventilate is to attain a specific **indoor air quality** and **thermal comfort**, which are experienced as sufficient for themselves: to feel comfortable and healthy. Different studies give insight into the prevalence of indoor climate and indoor air problems.

Table 5 shows the percentages of dwellings with (at least) regular or often complaints or dissatisfaction with specific aspects.

Table 5 *Indoor environment problems*

	Steenbekkers 1997 (Netherlands)	MarkTracé, 2001 (Netherlands)		MarkTracé, 2002, rented dwellings (Netherlands)	Engvall, 2001,2002a (Sweden, in 1993)
		bal.	mech. exh.		
Musty odour	15	11	14	19	17
dry air	19	41	35	18	38
dusty air	-	47	40	30	27
draught (slot)vents/ inflow (bal)	21	17/42	53	30	37 (44)*
Mould	12	6	9	24	22 (Denmark '99)**
condensation on windows	(34)	15	18	30	29
noise annoyance ventilator (often, always)	7 (often) 3 (always)	12 (often) 16 (always)	7 6	9 (often) 8 (always)	- -

* source: Blomsterberg, 1997
** source: Gunnarsen, 2001

Indoor climate preferences, especially the **temperature**, appear to generate high correlation with the way windows and ventilation provisions are used. From [Dubrul, 1988] can be summarised that the higher the preferred thermostat setting was for the living room and for the bedrooms (or preferred uniformity of the temperature in the whole dwelling), the less windows were opened.
It also appeared that most people in countries in NW Europe with moderate climate like The Netherlands, prefer a 'fresh' bedroom ($< 17^{o}$ C) to sleep. This explains the fact that bedroom windows are opened for much longer periods than the windows in other rooms (even at freezing temperatures outside). From [MarktTracé 2002] appeared that in the representative Dutch (rented) dwelling stock only 30% of the main bedrooms the (radiator) heating was used. The mean height of the thermostat in the living room in these dwellings was 19.4^{o}C during daytime and 15.2 ^{o}C during night [De Gids, 2003b]). The need for fresh air in bedrooms is associated to health relating beliefs and experiences such as headaches at wakening. However in Sweden (and may be in other cold winter climate regions) people prefer low temperature differences between living room and bedroom, so relative high temperatures in bedrooms [Blomsterberg, 1997].
Besides thermal comfort, the ventilation behaviour is influenced by the experienced **wetness** or **dryness** of a dwelling. When the indoor climate is experienced as too humid, in about 65% of the dwellings the occupants ventilate more. When the indoor climate is experienced as too dry in about 45% of these cases people ventilate more [MarktTracé 2001, 2002].

Condensation on windows is an important 'trigger' to open ventilation provisions. However, except from the moisture production (see Section 3.7) this highly depends on a dwelling related factor: the type of pane (single or 'insulated') in the windows.
With respect to the air quality can be referred to a recent Swedish study in which the 'subjectively' **experienced air quality** is associated to specific indoor air sources or qualifications [Engvall, 2002a]. The perceived indoor air quality was most strongly related to fresh/stale air, dry/humid air, musty odour, and own cooking smell.
The perceived air quality, dry/humid, fresh/stale, pungent **odour** and musty odour correlates all most highly with the ventilation of the bedrooms (the air quality and musty odour also with the ventilation of the living room). The condensation inside the window and mouldy odour correlates highest with the ventilation of the bathroom; cooking smell (also from neighbours) with the ventilation in the kitchen (of course), and clean/dusty and smells from outside correlates most high with the ventilation in the living room.

It can be concluded that:

- Occupants react to indoor air quality indicators which can be perceived by their organs of senses;
- A single window pane might be a good indicator of wetness in a dwelling.

3.2 Outdoor climate

It is obvious that the outdoor climate (**temperature, sunshine, wind speed** and **wind direction**) is a very important factor for ventilation and airing behaviour. The judgement of the indoor air quality aspects is related to the (general) ventilation preferred in the different seasons of the year and in different rooms of the dwelling. It appeared that in general the perceived air quality correlates most high with the ventilation during winter.
Occupants use windows/doors to cool during summer. In nearly 80% of the dwellings occupants say to do this. In a Dutch study in a ten storey high flat-building, it was found that (controlled by wind speed, wind direction and sunlight), at a mean temperature/24-hours day of 19^{o}C, the length of airing of the living rooms (by a balcony door) was about 13 hours on average in 80 apartments. At 14^{o}C this was 7 hours and at 5^{o}C about 2 hours [Dongen, 1990a; Cornelissen, 2002]. If vent lights were used in the living rooms they were opened 22 hours on average at an outdoor temperature of 19^{o}C, 16 hours at 14^{o}C and 3.5 hours at 5^{o}C (see Figure 1).
The outdoor climate also determines the width of opening of the windows and the use of inside doors (more opened under warm circumstances). Due to radiation effects the orientation of windows to the sun also plays an important role. And wind speed and wind direction in relation to the hinging of windows is of influence.

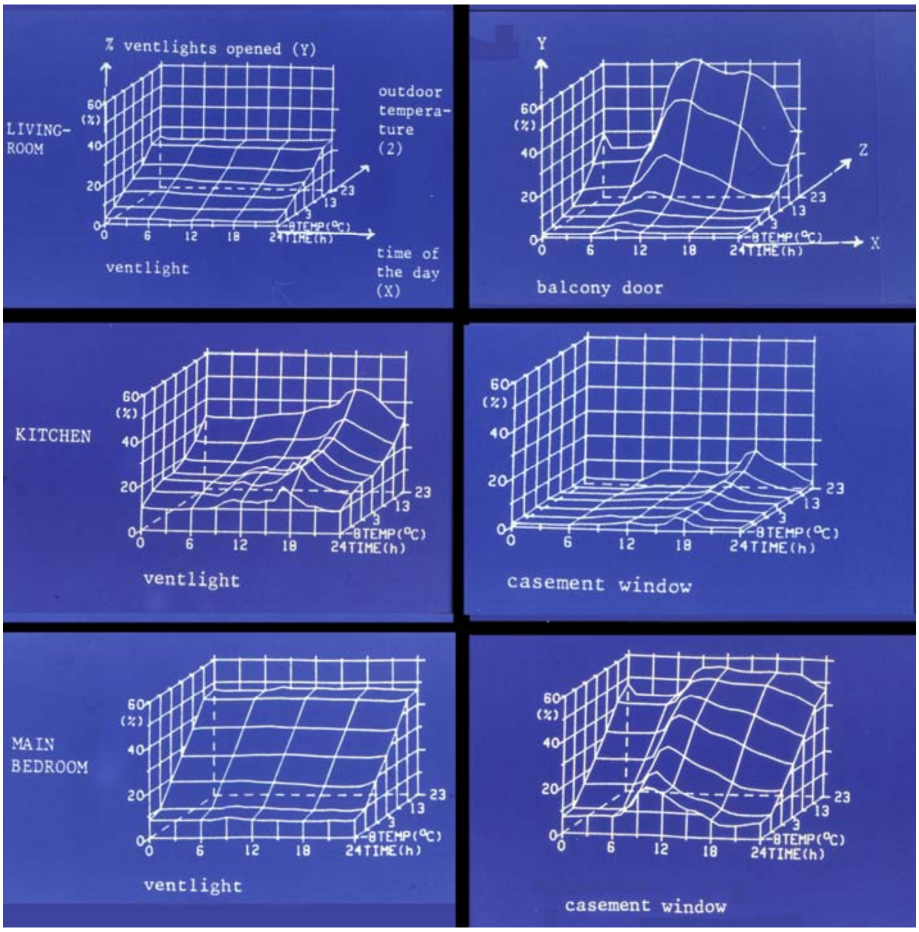

Figure 1 *The use of ventilation provision (total % opened windows or vent lights in 80 apartments in a ten storey high flat-building) (Y axis) as a function of outdoor temperature (Z) and the time of the day (X). Shown are the use of the ventlight and the balcony door in the living room (row on top), the use of the provisions (vent light and casement window) in the kitchen (second row) and in the main bedroom.*

With respect to ventilation behaviour by (slot)vents, the behaviour during moderate winter situations has been shown above (Table 1). In the Dutch study in the highly airtight dwellings occupants were also asked to refer to warm weather situations [MarktTracé, 2001]. It appeared that, apart from the use of windows, the (slot)vents were opened in 95% of the cases (fully opened in 90% of the living rooms and in 95% of the bedrooms) at warm weather conditions. At cold weather conditions this percentage was 85% (fully in 45% of the living rooms and in 60% of the bedroom). So the difference in use is restricted. The use of mechanical exhaust ventilation did not differ at all between cold or warm weather.
In a Dutch study in dwellings with heavy noise abatement measures (against aircraft noise), including special ventilation devices, occupants closed the fresh air inlet, necessary for the heating furnace, with sheets during a cold and windy winter period (< -10°C) [Dongen, 1994]. It can be assumed that in a number of these dwellings this necessary fresh air supply opening is kept closed permanently. As a matter of fact shutting systems of (slot)vents or windows can temporary freeze under strong winter conditions. However, it also appeared that systems with balanced ventilation and heat recovery can freeze during these cold winter periods, due to condensation in the system and a too short chimney channel [Dongen, 1985].

Besides temperature and sunshine, also wind direction and wind speed play a role using (slot)vents. Occupants ventilate less than preferred if (cold) air flows (**draught**) come through (slot)vents or vent lights, especially on places where the occupants use to sit or lie or where

plants are growing (fear for louses) [MarktTracé 2001, 2002]. In 22% of the moderately air tight dwellings (both with and without mechanical exhaust ventilation) this is the case, in about 10% of the highly air tight dwellings with mechanical exhaust ventilation and in 5% of the highly air tight dwellings with a balanced ventilation system.
In a Swedish study draught complains 'somewhere in their home' were reported in 42% of modern dwellings with exhaust ventilation and in 23% of these dwellings with a balanced heating and ventilation system [Blomsterberg, 1995]. In another publication draught complains were reported in 44% of the dwellings. About half of the draft complains are related to windows and/or slot vents in windows [Blomsterberg, 1997].

Above findings lead to conclusions that:

- During summer windows are opened on average longer and more widely to cool;
- The use of slot vents do not differ largely between summer and winter periods;
- The use of ventilation provisions is influenced by (cold) draughts, effects of freezing and by the experienced humidity and dryness of the indoor climate

3.3 Type of ventilation devices

The influence of specific ventilation systems in a dwelling on the active ventilation behaviour of the occupants is reported in [Dongen, 1990b]. With respect to the opening of windows (for airing, or ventilating (ajar)), vent lights or (slot)vents and mechanical ventilation on high speed (see Chapter 0), the following results (referring to (mild) winter conditions) can be shown in Figure 2 and Figure 3. In these figures the following types of ventilation are compared:

- Natural ventilation through passive stacks only;
- Mechanical exhaust ventilation;
- Balanced mechanical ventilation.

The use of ventilation devices by active behaviour at (mild) winter conditions is shown in terms of mean hours opened per 24 hours/day in the different rooms (Y axis) and in percentages of dwellings. The results of [MarktTracé, 2001] could not be included in the figures because no questions were posed on length of time of opening provisions. However with respect to the inside doors no difference was found in (partly) opened or closed doors between dwellings with mechanical exhaust ventilation and with balanced mechanical ventilation.

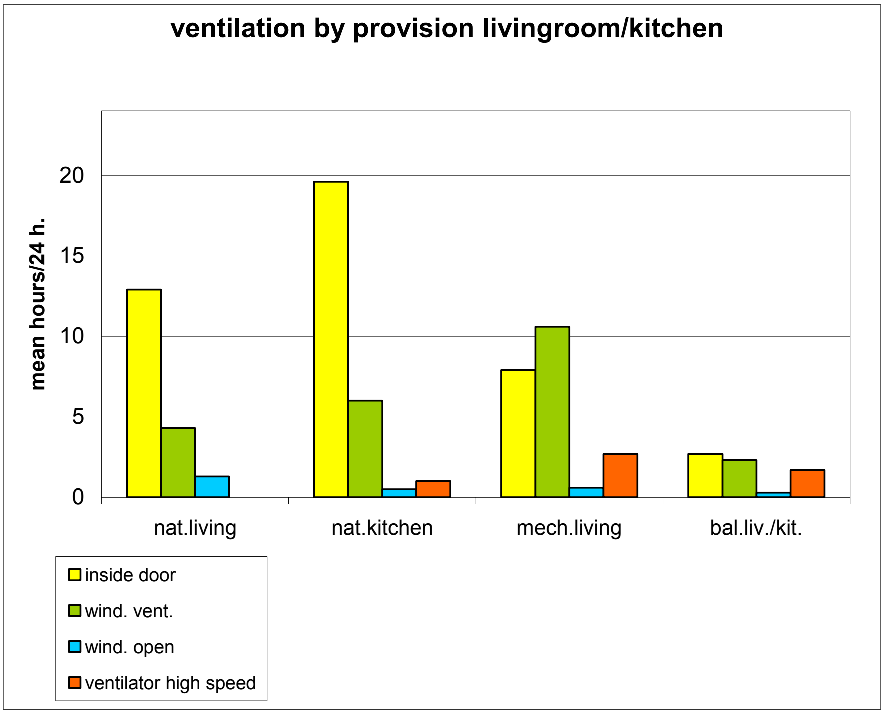

Figure 2

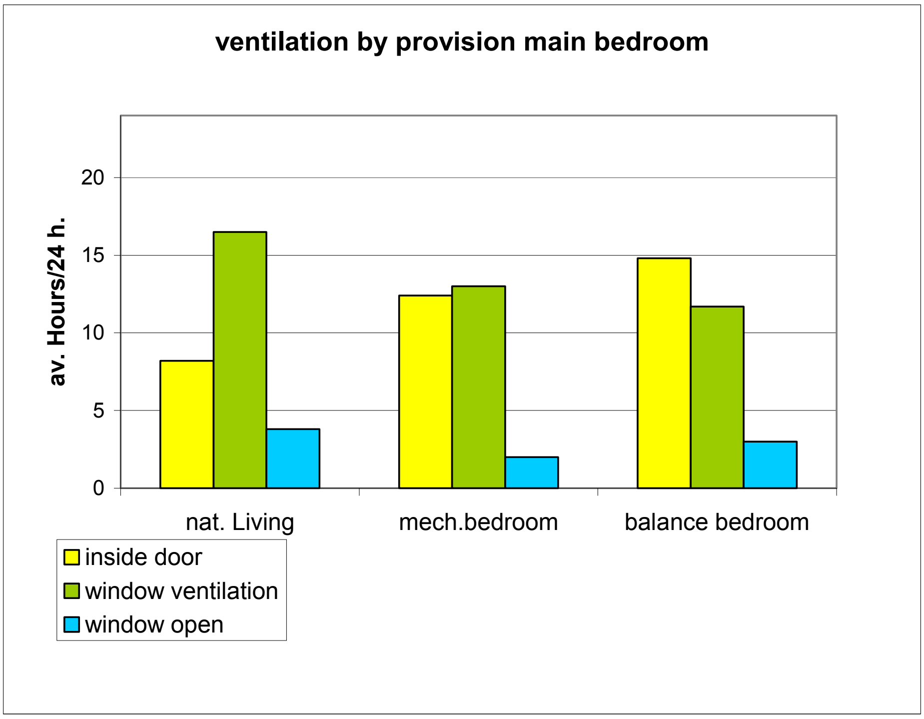

Figure 3

Table 6 shows the percentages of dwellings where windows in living rooms and main bedrooms were opened to air (more than ajar) longer than one hour per 24 hours/day, and vent lights, (slot)vents and windows ajar were opened more than eight hours per 24 h day. The last column refers to the results of a Swedish study [Blomsterberg, 1995].

Table 6 *Percentages rooms with > 8 hours/24 day ventilation by vent lights, (slot)vents and windows ajar and > 1 hour/24 day airing at different types of ventilation provisions and rooms during (mild) winter conditions*

	living room		main bedroom		Sweden, dwelling**
	airing >1h	ventilating >8h	airing >1h	ventilating> 8h	
natural ventilated only (n=137)	25	20	50	75	-
mechanical exhaust ventilation (n=133)	10	45	25	60	60
balanced mechanical ventilation (n=145)	5	10*	40	60*	25

* mostly by windows put ajar, because (slot)vents are not installed in principal
** source: Blomsterberg, 1995

From calculations based on the occupants' use of windows, vent lights, (slot)vents and mechanical provisions in the years eighty, it was estimated that average amount of 'subjectively preferred' air exchange for living rooms was about 175 m3/hour or 50 dm3/sec (24 hours average) [Dongen, 1990b]. Independent of the type of ventilation provisions, there seems to be a certain constant total amount of air exchange, which the majority of the occupants strive to obtain in order to feel comfortable. Recently this finding is confirmed by real airflow measurements in a sample of 100 dwellings based on [MarkTracé, 2002]. In half of the dwellings an airflow rate was measured between 40 and 60 dm3/sec (24 hours average). In 20% of the dwellings this was less than 30 dm3/sec [De Gids, 2003b]. An important conclusion is that no relation has been found between the measured air flows and the air tightness of the dwellings, nor between the measured mechanical exhaust and the measured ventilation of the dwellings. This is due to the 'compensating' ventilation and airing behaviour of the occupants (see also Section 2.6).

From the above mentioned results it can be concluded that:

- The ventilation by behaviour is only partly related to the type of ventilation device installed in the dwellings: in the living room the two mechanical ventilation systems tend to influence the ventilation by behaviour, in the bedroom the behaviour tends to be independent of the system installed;
- There seems to be a relatively constant 'subjectively preferred' amount of total ventilation from mechanical devices and behaviour taken together. This amount of ventilation (air flow) appears to be higher than the regulated (and assumed as sufficient) air flows in dwellings with balanced ventilation systems. Reasons for this additional active ventilation behaviour are given below.

3.4 Provision related factors

Important factors for how and why people ventilate are the **possibility to regulate** the ventilation systems and provisions on a way the occupants like, and the **user-friendliness** (see also Section 4.3). If windows cannot be opened stepwise, especially put ajar, or (slot)vents are stick fast, they are not used or closed forever.
In newly build highly air tight dwellings, occupants ventilate less than preferred by them in 5% of the dwellings with mechanical exhaust ventilation and in 10 % of the dwellings with balanced mechanical ventilation [MarktTracé, 2001]. In the mean moderately air tight Dutch dwellings with only natural ventilation or with mechanical exhaust ventilation, this percentage also was about 10%. Based on the results in [MarktTracé, 2001] it is found that a user-friendly ventilation system leads to less 'less ventilating than preferred', for instance in situations where occupants smoke [Steenbekkers, 2002]. The need to (keep) open inside

doors of bathrooms, is also viewed as a user-unfriendly measure and is perceived as health risk (see also Section 4.4).

Draught problems also lead to changing ventilation [Steenbekkers, 2002]. Comparing the mechanical exhaust ventilation system with the balanced ventilation system, both in highly air tight dwellings, it appeared that in dwellings with balanced ventilation the occupants have less nuisance from draught from windows or (slot)vents, but more nuisance from draught from mechanical air inlets. How (wide) windows are opened also depends on the way their **hinging** in relation to the wind direction.

Few information has been found about the influence of **pollution** or **rust** e.g. on the functioning and usability of ventilation provisions. In dwellings with balanced mechanical ventilation there is reported more pollution around the inlets and exhaust provisions than in dwellings with mechanical exhaust ventilation only. From [MarktTracé, 2002] it appeared that in nearly half of the households (48%) ventilation provisions (e.g. (slot)vents) and systems are never cleaned, nor filters are exchanged. And in about 10% of the dwellings this was more than 3 years ago. In a French study two third of the occupants said that they cleaned ventilation vents and systems at least once a year, so one third did not [Liddament, 2001].
This means that can be assumed that in practice the functioning of the ventilation often is sub-optimal and even may lead to health risks. There are indications that pollution, caused by low or no maintenance, may decrease the capacity of the exhaust airflow with 15-25% after 5 years and with 75% after 15 years [De Gids, 2002a].
No information is known about the number of defect or not functioning ventilation provisions.

Slot vents need to be designed and installed on such a manner that they are not a source of **noise** (whistling, rattling) at high wind pressure. If this is the case the occupants ventilate less than preferred. In a recent Dutch study in 11% of the dwellings this was the case [MarktTracé, 2002].
Most important sources of noise are electric power driven mechanical ventilators. From [Dongen, 1985] it is known that an equivalent sound immission level of 30 dB(A) into the living room already gives rise to about 25% at least 'sometimes' annoyed occupants. At a sound level of 34 dB(A) this percentage is already 40%. In Table 4 the percentages of dwellings are shown in which occupants often or always are annoyed in the Netherlands. The problem is most high in dwellings with a balanced mechanical ventilation system. In 28% of those dwellings occupants are annoyed 'always' or 'often'. In 37% of these dwellings this was the case 'sometimes' [MarktTracé, 2001]. In newly built dwellings with mechanical exhaust ventilation these percentages were 13% and 38% respectively. Due to this noise from the systems 17% of the respondents with newly build balanced ventilation systems and 11% of the respondents with mechanical exhaust ventilation say to ventilate less than preferred. (Unconscious) sleep disturbances (changing sleep stages, reduction of REM sleep) are already measurable at a background level of 30 dB(A), 8h. With respect to low frequencies this is the case at still lower sound levels [Berglund, 2000].

The **aesthetics quality** will play a role too. If the provisions are not adapted to the architecture of the building or the style of the interior, occupants will remove or change these provisions [Dongen, 1994].

This leads to the following conclusions:

- ventilation provisions ought tot be user-friendly (for all; young and old) and good designed to regulate, to clean and to maintain or repair;
- The use of ventilation provisions is highly influenced by noise from mechanical ventilators or by whistling, rattling noises caused by wind pressure;
- Special attention ought to be paid to ventilation provisions which easily can be cleaned;
- ventilation provisions ought to be strong and durable, and esthetical justified;
- problems related to ventilation devices are not predominantly caused by 'wrong' household behaviour of the occupants, but by technological and design solutions which are insufficiently adapted to the behavioural patterns and comfort wishes of the inhabitants.

3.5 Architectural factors

Architectural factors play a role of course. The function (type of) of rooms and types of ventilation systems and provisions installed are important (see above), the location of rooms in the **dwelling plan** (e.g. prevent dwelling plan with inside bathrooms). Functions of rooms (open- or closed kitchens) and the orientation of windows to sun and wind (see Section 3.2) and outdoor (environmental) factors (see Section 3.6) also influence the ventilation behaviour. Important too are the location of the inlet and outlet (slot)vents to prevent draught (see Section 3.2), the hinging of the windows (see Section 3.4) and whether thresholds are present under inside doors.
A **common heating system**, which cannot be well controlled (for instance in apartment buildings) may also influence the ventilation and airing for reasons of cooling.
In Section 3.3 already has been mentioned that no relation was found between the measured air flows of ventilation and the air tightness of the dwellings. Occupants ventilate less when the basic natural ventilation through **cracks** is higher (air tightness lower) and when the **volume of rooms** is smaller.

A conclusion is that:

- architects need to be conscious and educated about the necessity of 'good ventilation design', especially in relation to the dwelling plan.

3.6 Outdoor factors

Except provision related noise, another source of noise leads to less ventilation than preferred: outside **noise** caused by traffic, aircraft, industry, neighbours, etc.). In about 30% of the Dutch dwellings people regular close or keep closed ventilation provisions because these noise sources. **Odour** from industrial, agricultural or traffic related sources is another environmental factor which leads to closing ventilation provisions. There are indications that in about half of the dwellings that are regularly exposed to odours (in about 10% of the Dutch dwellings this is the case) windows are closed [Passchier, 2001].
Ventilation provisions, especially slot vents and filters are very susceptible to **(dust) pollution**, as well from outside as from inside the dwellings. In Section 3.4 already the risk of pollution of the devices has been mentioned.

Another important reason to ventilate less than preferred caused by an outdoor factor, is fear for **burglary**. In [MarktTracé, 2002] 37% of the respondents referred to it (no difference between dwellings with and without mechanical exhaust ventilation).

Above findings lead to the conclusion that:

- Special attention ought to be paid to ventilation provisions which can reduce outside noise;
- Special attention ought to be paid to ventilation provisions that are 'burglary safe'.

3.7 Household behaviour

The daily household routine is a very important factor, which influences the ventilation behaviour. In Figure 1 (see Section 3.2) the (mean) daily pattern can de recognised (24 hours pattern on the X-axis): waking up, airing bedroom, airing (cleaning) living room, cooking, evening activities, sleeping. It appeared that this routine is very consistent and hardly to influence by an information campaign (at best 3-5% reduction of energy use; with the least influence on the older age group and the lowest income group) [Dubrul, 1988; Steenbekkers, 1997].
Aspects of this behaviour are **presence at home**, and time and intensity of **cleaning activities**, **cooking** and **bathing** and **drying clothes**.
If the occupants are not home (leaving their dwellings) in 50-65% of the cases they change the ventilation: whether they close windows and vent lights (35%) (e.g. to prevent burglary), or they open (slot)vents (10-20%) [MarktTracé, 2002, 2001]. In [Dubrul, 1988] was reported that if dwellings which were not occupied during the daytime, windows were used more often during the evening and night, so that over a 24 hour period there was little difference between dwellings which were occupied during the day and those which were not.
During and shortly after cleaning activities (dust removing, vacuum cleaning, mopping floors) in 25-40% of the households there is extra ventilation, especially by opening windows and vent lights [Steenbekkers, 1997, MarktTracé, 2002, 2001]. During cooking ventilators or vapour hoods are put on a higher speed and/or windows are opened in 85%-90% of the dwellings. After bathing in 65-85% of the dwellings a window or vent light, if present, and/or the inside door are opened, to get rid of the vapour. And in about half of the dwellings there is more ventilation when clothes are dried.
In more than 90% of the dwellings occupants vent more to get rid of specific odours (e.g. from cooking) [Steenbekkers, 1997].
In a Danish study in apartments no direct relation was found between the amount of air change and the air humidity. However, the behaviour of the occupants, when it comes to drying clothes indoors (21% dried clothes in bathrooms, 21% in drying or laundry-rooms), was significant for the moisture content in the apartment [Gunnarsen, 2001]. In the same study was found that in 27% of the dwellings occupants daily air their duvets, in 43% at least once every 14 days.
A very different behavioural aspect, however very important, is the **renovation** by owners or succeeding 'new' owners of (detached) houses. In a Danish study is reported that between 20% and 40% of households got new windows, carports or extensions and more than 50% got a new kitchen [Gram-Hanssen, 2000]. It can be assumed that in other countries the same activities take place more or less. In Section 4.4 is reported that of older dwellings is associated with an increase of Sick Building Syndrome symptoms, supposed to be caused at least partly by the introduction of new plastic materials [Engvall, 2001].

It can be concluded that:

- in each household fairly stable behavioural routines take place. However these are hardly to influence and need 'tailored maid' advises;
- the effects of renovations or reconstruction of dwellings on the ventilation need special attention.

3.8 Social and personal factors of behaviour

Main reasons why occupants ventilate are related to the effects of their behaviour. In Section 3.7 presence at home, cleaning activities, cooking, bathing and drying clothes are already mentioned as factors, which influence the ventilation. Smoking is a very important other factor. In about 75% of the dwellings where people smoke occupants try to get rid of the odour by extra ventilation [Steenbekkers, 1997]. Also a clear correlation between smoking behaviour and the airing and ventilation of living rooms was reported by [Dubrul, 1988]. Where occupants smoke, on average, for twice as long is ventilated, even when mechanical ventilation systems have been installed.
After **visits** the occupants ventilate more in 85% of the dwellings.
The **number of persons** in a dwelling (or a specific room) influences the indoor effects of above mentioned activities and consequently the ventilation behaviour. However, in general the fixed (regular) number of occupants in a household is only partly related to the use of windows, vent lights or (slot)vents. A positive relation has been found between the number of occupants and the use of the high speed of the (exhaust) ventilator (if these provision is present) and the use of the provisions in bedrooms. On average a window in a childrens bedroom is opened about half as long as in a parents bedroom. The regular number of occupants is not clearly related to the length of ventilation or airing in the kitchens and living rooms.
Also the presence of **pets** (cats, dogs) and **plants** (the risk of louses) influence the ventilation behaviour: windows (or cat-shutters e.g.) and inside doors need to be opened or closed. And there are indications that in weekends the '**husband'** does moderate the daily routine during the week, performed by the 'housewives', for reasons of comfort or energy saving attitudes [Dubrul, 1988].

In a recent study appeared that in 17% of the dwellings occupants say to ventilate less than preferred for reasons of energy costs [MarktTracé, 2002]. In [Steenbekkers, 1997] this percentage was about 10%. Occupants who are **less energy conscious** tend to ventilate more. Also is found that when occupants pay a collective energy bill, based on the mean energy use of the different apartments, windows were kept more open. However, in general the relationship between **energy saving attitudes** and energy saving behaviour is very weak in practise [Dubrul, 1988].
Also there are indications that in households where **respiratory diseases** (COPD or asthma) and/or **allergic** diseases (e.g. hay fever) occur (at least in about 20% of the households on average; see Section 4.4) the occupants ventilate (and air) more than on average and do change the ventilation flows more frequently in special occasions [Steenbekkers, 2002]. COPD or asthma patients more often complain about 'too warm' in their dwelling. And to prevent moisture problems (which promote allergens from moulds and house dust mites) for reasons of health it is advised to them to apply a high level of ventilation in their dwellings (see also Section 4.4).
Furthermore it was found that **higher educated** people, **elderly** people and occupants who **rent** their dwelling complain more about 'less ventilation than preferred'. There is found a light tendency that occupants of rented dwellings use their windows more for airing, but

possibly this is also related to specific moderating factors mentioned above, such as presence at home, age, health and dwelling characteristics like a common heating system. As COPD patients, elderly people also complain more about too high temperature.

Above findings lead to the conclusions that:

- Occupants are often not 'average people'. Ventilation provisions need to be very flexible in use because there are a number of moderating personal and social factors that lead to different preferred ventilation rates at different circumstances (including phases of a households 'lifecycle').

4 Promoting and restraining factors for acceptance

Many of the mediating factors mentioned in the former chapters, are important as promoting and restraining factors for the acceptance of new ventilation devices.

4.1 Performance

Most important is the performance of the provision. Does it function as developed: creating air flows which are sufficient for a sufficient or good (or demanded) indoor air quality? In this case, combined with another quality: reducing the total energy use (fuel and electricity) necessary for heating, cooling and ventilation.
The (dis)satisfaction about the main types of ventilation systems applied in the Netherlands is as follows (Table 7) [MarktTracé, 2001, 2002, combined]:

Table 7 *Satisfaction with different ventilation systems (in %)*

	natural ventilation (n=451)	mechanical exhaust ventilation (n=763)	balanced mechanical ventilation (n=344)
very satisfied	3	11	17
satisfied	45	63	59
dissatisfied	42	22	19
very dissatisfied	10	4	5

From Table 7 can be concluded that the occupants are dissatisfied in about half of the dwellings with only natural ventilation (10% very dissatisfied). Where mechanical exhaust ventilation or balanced ventilation have been installed, the occupants are dissatisfied (5% very) in about 25% of the dwellings.

Of the occupants in the highly air tight dwellings with balanced ventilation systems (with heat recovery) 18% is dissatisfied about the supply air quality, versus 7% in the dwellings with mechanical exhaust ventilation [MarktTracé, 2001]. No difference was found between winter and summer conditions. Dissatisfaction about the exhaust flow from the kitchen, toilet and bathroom was expressed in 29% of the dwellings with balanced ventilation and in 23% of the dwellings with exhaust ventilation.
In general, in the moderately air tight dwellings, representative for the mean Dutch housing stock, circa 12% is dissatisfied about the supply of fresh air and circa 17% about the exhaust flow [Steenbekkers, 1997].

Above findings leads to the conclusion that:

- In a substantial proportion of the dwellings, whether newly built and highly air tight, or old and moderately (mean) air tight, the occupants are dissatisfied about their ventilation provisions. This means that there is a market for better ventilation provisions. If they are really better, this is a promoting factor as such.

4.2 Information

In a Danish study a significant difference was found between the available ventilation systems and to what the occupants had stated in the questionaires that were used. These differences between the knowledge of the occupants regarding ventilation indicate that many occupants are not aware of the presence, functionality and use of these installations

[Gunnarsen, 2001]. This undoubtedly will be the same in other countries. In the Netherlands from [MarktTracé, 2002] appeared that in only one third of the dwellings with mechanical exhaust ventilation the occupants were informed about the operation of this system. If informed, 20% of them judged this information as poor or insufficient. In Sweden this judgement was given by 20-50% of the respondents [Blomsterberg, 1995].
Based on the data with respect to highly air tight dwellings, it appears that the satisfaction about the ventilation system is related to the information given tot the occupants [Steenbekkers, 2002]. Moreover, sufficient information leads to less problems with draught from mechanical supply flows, less indoor air problems like 'dry air' and 'dustiness' and less self-reported health complaints. However, more annoyance was reported caused by the noise from systems (see Section 3.4).
However, in general it must be stressed that the implementation of information is most difficult in the older age group and in the lowest income groups [Dubrul, 1988].

Conclusion:

- Good directions for use, information and maintenance to the occupants (and probably also to installation firms and architects) about the possibility and functioning of the ventilation system in different circumstances are essential promoting factors.

4.3 User-friendliness

The importance of user-friendliness has already been mentioned in Section 3.4.
Except for the studies mentioned, few studies are known about the evaluation of the user-friendliness of ventilation systems in practice. Especially referring to modern solutions, the development of domotica products is of interest. Domotica can be defined as technical devices who can integrate and automatize routine households tasks and services by means of electronic appliances. Domotica is applied in 'smart homes', but often these dwellings are part of experimental demonstration projects and not permanently used in 'normal' daily household circumstances. Evaluation reports are scarce. An exception is the application of domotica in dwellings for elderly people in the Netherlands [Dorrestein, 2001]. Although ventilation devices were not part of the domotica applied (functions were: alarming for social/medical reasons and for burglary, automatic lighting ignition in halls, bedroom and bathroom, a visual entrance monitor system and an electric curtain closing/opening help), the results of the evaluation are of relevance to get insight into promoting and restraining factors for the implementation of automatic devices.

From the evaluation report can be concluded that:

- a domotica device must be perceived by the occupants as useful (e.g. providing safety, health and comfort). So listening to the 'demand-side' is essential ('energy saving' as only argument is not a sufficient quality for occupants);
- in principal an automatic device must be adapted to the household routines;
- the device need to function as expected. 'Growing pains', bugs and failures are decisive for use or not use. The same counts for insufficient sustainability (strength);
- occupants must keep freedom of choice, so must keep possibilities to intervene into an automatic system. This intervention possibility must be simple (off – on) and good designed;
- the implementation of domotica always cost more time than expected; occupants need time to get used to a device;

- a good scheme for informing the occupants (and installation firms) and for feedback is crucial. If people move to a (new) dwelling with domotica devices, these devices are not among the first of interest and attention.

These conclusions subscribe to conclusions mentioned in [Liddament, 2001] about 'automatic controls' like 'humidistats' (for relative humidity control) which are coupled to extract fans located in 'wet' rooms. They were often grossly inaccurate, subject to drift over time and were lacking in any convenient means of calibration.

4.4 Health

If systems are experienced as 'healthy' this is a promoting factor of importance. 'Healthy' systems are systems which create unfavourable conditions for allergens and pollutants and which do not create aspects as draught, cold radiation, too much heat or too much noise. There are a number of a-specific health complains which are often associated with the quality of the (indoor environment or) dwelling. The prevalence of Sick Building Syndrome (SBS) symptoms is found to be higher among **females** than man and to be more common in **newer buildings** [Engvall, 2000]. Also a major reconstruction of older dwellings is associated with an increase of SBS, supposed to be caused, at least partly, by the introduction of new plastic materials [Engvall, 2001]. In Sweden the proportion of 'risk' buildings was estimated on 5% when built before 1961, 10% built between 1976-1984 and 15% in the newest buildings (although with the widest dispersion). In Germany was estimated that about 6% of the population do have health complains which are exclusively related to their dwelling [Seifert, 1990]. In the Netherlands the prevalence of 'real' Building Related Illnesses or Sick Building Syndrome (SBS) is unknown. However from [MarkTracé, 2001] appeared that self reported health complaints are associated by the respondents in 12% of the highly air tight dwellings. In Table 8 the prevalence of complains is shown based on Dutch studies and based on a Swedish study (the prevalence of weekly or often).

Table 8 *Prevalence of health complains or SBS-symptoms (in Sweden: often or weekly)*

	Steenbekkers, 1997 (Netherlands)	MarkTracé, 2001 (Netherlands)		MarkTracé, 2002 (Netherlands) rented dwellings	Engvall, 2002a (Sweden, 1993)
		bal.	mech. exh.		
ocular (tired or tearing eyes)	27 (tired eyes)	15	8	21	7
nasal (dry nose or lips)	-	15	14	25	12
throat (sore)	25 (dry)	6	7	15	7
facial dermal (itching or dry)	14 (itching) 27 (dryness)	12	14	21	7
headache (general)	31 (general)	10	10	28	7
fatigue (fatigue or concentration)	31 (general)	10	7	20	21
COPD/asthma/allergy	22 (pollen allergy)	17	18	22 (COPD)	18 (pollen allergy)
good health (general)	81	83		62	-

The (partly) different outcomes of the studies may be explained by somewhat different questionaires (Steenbekkers: *bothered once in a while last year*; MarkTracé: *bothered by*; Engvall: *bothered often or weekly*) and different general health conditions, associated with differences in age and social economic and educational level of the occupants.
A relation was found between **building dampness** in dwellings and a pronounced increase of symptoms compatible with the SBS, even when adjusted for possible confounding by age, gender, population density and building-related risk factors [Engvall, 2001].

In [Engvall, 2000] was reported that no consistent relation was found between the type of ventilation system and SBS. In [Engvall, 2002b] the prevalence of SBS again is related to types of heating systems, ventilation systems, and energy saving reconstructions in older, partly reconstructed, dwellings. Compared were: dwellings with community heated water versus oil combustion, electric heating, wood heating and dwellings with exhaust ventilation, supply/exhaust (balanced) ventilation and other systems versus natural ventilation only. Results of a multiple logistic regression analyse are that compared with natural ventilated dwellings, in dwellings with **exhaust** ventilation occupants **less** complain about their eyes, nasal problems and cough, but **more** complain about their throat, facial skin problems and tiredness. In dwellings with a supply/exhaust (**balanced**) ventilation system were **less** problems with eyes, nasal problems, throat problems, facial skin problems and tiredness and **more** complains about cough and headache. The exchange of ventilation system (from natural to mechanical) was associated with an increase of nasal symptoms, throat irritation and tiredness. The **sealing** of window frames was **not** associated with any increase of symptoms.

In the Netherlands, based on the data of [MarktTracé, 2001] with respect to highly air tight dwellings with mechanical exhaust ventilation or balanced ventilation (with heat recovery), [Steenbekkers, 2002] analysed health as dependent and as an independent factor in relation to dwelling, the ventilation systems and person related factors.
It appeared that, if health (assessed by three health indicators) is viewed as *dependent variable,*

the *self-reported health* complains is associated to:

- insufficient information about the ventilation system (independent of the type of system);
- temperature differences between feet and head level;
- other indoor air problems (e.g. perceived dry air, dustiness);
- open inside door of bathroom
- dissatisfaction with the dwelling;

the *dwelling attributed health problems* are associated to:

- complains about moisture;
- balanced ventilation in dwellings;
- other indoor air problems (e.g. perceived dry air, dustiness);
- dissatisfaction with the dwelling;
- higher educated occupants (as a background variable)

the perceived health of *COPD/asthma diagnosed people* is associated to:

- other indoor air problems (e.g. perceived dry air, dustiness);
- number of smokers in dwelling;
- changing of ventilation at special occasions

If the three health indicators are viewed as *independent variables* it appeared that:

the *self reported health* is associated to:

- complains about moisture;
- less ventilation than preferred (especially by higher educated people and by elderly people);
- too high temperature (COPD/asthma patients do have more problems with high temperature in dwellings, as well as elderly people);

- temperature differences between head and feet (especially woman);
- other indoor air problems (e.g. perceived dry air, dustiness);
- odour annoyance from outside (especially elderly people)

the *dwelling attributed health* is associated to:

- complains about moisture;
- other indoor air problems (e.g. perceived dry air, dustiness);
- noise annoyance from ventilator(s);
- higher educated occupants (as a background variable)

the perceived health of *COPD/asthma diagnosed people* is associated to:
- complains about a too warm dwelling

Above findings lead to the conclusions that:

- in general health problems are not directly related to the type of ventilation system, but if occupants perceive health problems, these problems (except draught) are associated to those perceived indoor air and climate problems, which are often especially related to balanced ventilation systems;
- insufficient information to the occupants about the ventilation system in their dwelling may promote health problems.

4.5 Summarized factors for acceptance

To summarize: factors for acceptance of ventilation systems are:

- quality of directions for use, information and maintenance to the occupants, as well as to installation firms and architects;
- good performance (reliability, ironing of bugs, sustainability, low damage risk)
- coming up with expectations
- user-friendliness for all (young and old)
- adaptation, integration with usual daily behaviour
- comfort, health, safety promoting
- friendliness to install, to repair
- maintainability, ability to clean
- aesthetics and architectural adaptation
- low cost, financial profit (energy saving)

And, provided above quality aspects:

- multifunctional, party aspects (air flow-, temperature regulation, energy monitoring)
- adaptation and integration with other technical, monitoring and automatic control systems (domotica devices)

5 Summary and conclusions

With respect to the question how occupants ventilate, among others, has been found that:
- If air inlets are present, they are used on a variable way in about 25-30% of the living rooms, and in about 15% of the bedrooms. In the other cases they are whether (nearly) always closed (varying from 5-20%) of the cases, or (nearly) al-ways opened (in about 50-80% of the cases);
- Except in kitchens, in the newly build highly air tight dwellings the (slot)vents are used and opened more than in the mean (moderately) air tight dwellings;
- The use of slot vents do not differ largely between summer and winter periods;
- During a mild winter period in nearly all dwellings (90% at least), independent of the air tightness, one or more win-dows are used for additional airing during some time;
- If mechanical exhaust ventilation is present, in the mean air tight dwellings the ventilation system is not used (off) in about 17% of the dwellings during daytime and in about 23% during the night.
- Inside doors (to the hall or staircase) are opened (nearly) always in about 50% of the living rooms, 75% of the kitchens (including 'open' kitchen rooms) and in 60% of the bedrooms.

Reasons why occupants ventilate (or not) are:
- Indoor climate and air quality, e.g. temperature, experienced wetness (condensation), dryness, freshness, odour and draught;
- Outdoor climate, e.g. temperature, sunshine, wind speed and wind direction;
- Outdoor factors (noise, odour, pollution, risk of burglary)

Further it appears that:
- The ventilation by behaviour is only partly (especially in the living room) related to the type of ventilation system. In the bedroom the behaviour tends to be independent of the system installed;
- There seems to be a relatively constant 'subjectively preferred' amount of total ventilation from mechanical devices and behaviour taken together. This amount of ventilation (air flow) appears to be higher than the regulated (and assumed as sufficient) air flows in dwellings with balanced ventilation systems;
- Provision related factors who influence the ventilation behaviour are the possibility to regulate, user-friendliness, (caus-ing) draught , way of hinging and pollution or rust;
- The aesthetic quality (argument for removing) and architectural factors of dwellings (dwelling plan, volume of rooms, air tightness) play a role.

As a matter of course the ventilation behaviour also is influenced by:
- The household behaviour: presence at home, cleaning activities, cooking, bathing, drying clothes and renovation activi-ties;
- Social and personal factors: smoking, visits, number of persons, pets, plants, attitudes with respect to energy use, health, education, age and gender.

There are a number of promoting and restraining factors for acceptance of ventilation devices. Factors for acceptance of ven-tilation systems are:
- quality of directions for use, information and maintenance to the occupants, as well as to installation firms and archi-tects;
- good performance (reliability, ironing of bugs, sustainability, low damage risk)
- coming up with expectations
- user-friendliness for all (young and old)
- adaptation, integration with usual daily behaviour

- comfort, health, safety promoting
- friendliness to install, to repair
- maintainability, ability to clean
- aesthetics and architectural adaptation
- low cost, financial profit (energy saving)

And, provided above quality aspects:
- multifunctional, party aspects (air flow-, temperature regulation, energy monitoring)
- adaptation and integration with other technical, monitoring and automatic control systems (domotica devices)

Further general conclusions are:
- In a substantial proportion of the dwellings (25-50%), whether newly built and highly air tight, or old and moderately (mean) air tight, the occupants are dissatisfied about their ventilation provisions. This means that there is a market for better ventilation provisions;
- Occupants are often not 'average people'. Ventilation provisions need to be very flexible in use because there are a number of moderating personal and social factors who lead to different preferred ventilation rates at different circum-stances (including phases of a households 'lifecycle');
- Occupants must keep freedom of choice, so must keep possibilities to intervene into an automatic system. This inter-ven-tion possibility must be simple (off – on) and good designed;
- In general health problems are not directly related to the type of ventilation system, but if occupants perceive health prob-lems, these problems are often associated to those perceived indoor air and climate problems, which are often especially related to balanced ventilation systems;
- Insufficient information to the occupants about the ventilation system in their dwelling may promote health problems.

6 References

Berglund B, Lindvall Th, Schwela DH, Goh K-T. Guidelines for Community Noise. WHO report, Ministry of the Environment. Singapore, 2000.

Blomsterberg Å, Carlsson Th. Indoor climate and user interaction in modern Swedish one-family houses – results using a questionnaire. Swedish National Testing and Research Institute. Borås, Sweden, 1995.

Blomsterberg, Å, Jönsson M. Summary of a pilot study: Efficient use of electricity for ventilation in dwellings. Swedish National Testing and Research Institute, 1997.

Cornelissen HJM, Dids, WF de, Phaff, JC. Bewonersgedrag en ventilatie. een inventarisatie van en een enquête naar het gebruik van ventilatievoorzieningen *(Occupants behaviour and ventilation. An inventory of and a questionnaire study on the use of ventilation devices)*. TNO-report 2000-G&I-R004. Delft, 2002.

Dongen JEF van, Phaff JC. Ventilation behaviour in Dutch apartment dwellings during summer, In: Lunau, F. and G.L. Reynolds (eds.). Indoor Air Quality and Ventilation. Selper Ltd (ISBN nr. 0-948411-06-6), London, 1990a.

Dongen JEF van, Phaff, JC. Ventilation behaviour and indoor air problems in different types of newly built dwellings. In: Environment International, Vol. 15, pp. 95-106, 1989.

Dongen JEF van, Steenbekkers JHM, Miedema HME. Waardering van geluidwerende voorzieningen in woningen rond Schiphol *(Evaluation of noise abating measures in dwellings around Amsterdam Schiphol Airport)*. Leiden: TNO Preventie en Gezondheid, 1994. Publ.nr. 94.084.

Dongen JEF van. Ervaringen en gedrag van bewoners in woningen met verschillende verwarmingssystemen; onderzoek in het demonstratieprojekt Westenholte te Zwolle. *(experiences and behaviour of occupants in dwellings with different heating systems)* Leiden, NIPG-TNO, 1985.

Dongen JEF van. *Inhabitants behaviour with respect to ventilation*. Paper t.b.v. 7th AIC Conference; Occupant interaction with ventilation systems. In: Supplement to Proceeding. AIVC, Bracknell, U.K., 1986, pp. 67-90.

Dongen JEF van. *Noise annoyance from sanitary appliances, ventilators and gas burner furnaces in dwellings*. In: Proceeding Inter-Noise 1985, Munich, september 1985, pp. 1017-20

Dongen JEF van. The influence of different ventilation devices on the occupants behaviour in dwellings. In: Proceeding on 11 th AIVC Conference, Belgirate (Italy), 1990b.

Dorrestein A, Daal P van. Een domoticahuis voor ouderen. De eerste ervaringen van vijf Brabantse domoticaprojecten. Tussentijdse rapportage *(A domotica dwelling for the elderly. The first experiences in five projects in the province of Brabant; interim report)*. PON, Tilburg, 2001.

Dubrul C, et al. IEA Annex VIII. *Inhabitant's behaviour with respect to ventilation*. Final main report and Identification cards. AIVC, Bracknell, U.K., 1987.

Engvall K, Norrby C, Bandel J, Hult M and Norbäck. *Development of a Multiple Regression Model to Identify Multi-Family Residential Buildings with a High Preval;ence of Sick Building Syndrome (SBS)*. In: Indoor Air 2000; 10: 101-110.

Engvall K, Norrby C, Norbäck D. *Sick Building Syndrome (SBS) in relation to energy conservation, and reconstruction in older multi-familiy houses in Stockholm*, Sweden. In: Proceedings Indoor Air 2002b.

Engvall K, Norrby C, Norbäck D. *Sick building syndrome in relation to building dampness in multi-family residential buildings in Stockholm*. In: Int Arch Occup Environ Health (2001) 74: 270-278.

Engvall K, Norrby C, Sandstedt E. *A sociological approach to validate a questionnaire for the assessment of symptoms and perception of indoor environment in dwellings*. In: Proceedings Indoor Air 2002a.

Esbensen Consulting Engineers. *A survey of Danish studies on behavioural and social aspects*. RESHYVENT Report No: RESHYVENT-WP2-TR-1, 1st.draft Sept. 17, 2002

Gids W de. Landelijke monitoring ventilatie (*National monitoring ventilation*). Report with measurements in sample of dwellings from [MarkTracé, 2002]. To be publish in 2003. TNO Bouw, Delft: 2003b

Gids W de. Verbal information and Graph shown by De Gids, TNO Bouw, Delft: 2003a

Gram-Hanssen K, Bech-Danielsen C. Renovation of detached houses – views on architecture and ecology. Danish Building and Urban Research, Bulletin, No.134; 2000.

Gunnarsen l. *Humidity, ventilation, mould and house dust mites – A cross sectional study in apartments*. Danish Building and Urban Research, No.009 By og Byg Results; 2001.

Liddament MW. *Occupant Impact on Ventilation. Technical Note AIVC 53*. AIVC/INIVE EEIG, Brussels, 2001.

MarktTracé. Onderzoek Balansventilatie *(Investigation of balanced ventilation)*. Groningen, maart 2001.

MarktTracé. TNO-enquête ventilatie en gezondheid *(TNO-questionnaire study on ventilation and health)*. Groningen, februari 2002.

Maroni M, Seifert B, Lindvall Th. Indoor Air Quality, a comprehensive reference book. Elsevier Science B.V. Amsterdam, 1995.

Passier-Vermeer W, et al. Milieu en Gezondheid 2001. Overzicht van risico's, doelen en beleid *(Environment and Health.. Outline of risks, targets and policy)*. TNO-PG rapport 2001.95. Leiden: 2001.

Seifert B. Man and the indoor environment. Berlin: Institüt für Wasser-, Boden- und Lufthygiene; 1990.

Steenbekkers JHM, Dongen JEF van. Evaluatie van de effectiviteit van voorlichting naar een gezond binnenmilieu *(Evaluation of the effects of an information campaign on a healthy indoor environment)*. TNO-PG, Leiden: december 1997. Publ.nr. 97.030.

Steenbekkers JHM, Miedema HME, Vos H. Gezondheid en tevredenheid in energiedichte woningen *(Health and satisfaction in energy-tight dwellings)*. TNO-rapport 2002.042. Leiden: TNO Preventie en Gezondheid, 2002.

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