ENERGY EFFICIENT DOMESTIC VENTILATION SYSTEMS FOR ACHIEVING ACCEPTABLE INDOOR AIR QUALITY

3rd AIC Conference, September 20-23 1982, London, UK

PAPER D

THE IMPACT OF VENTILATION AND AIRTIGHTNESS ON ENERGY CONSUMPTION

A. LÖGDBERG

Ministry of Housing and Local Planning
Bostadsdepartementet
S-103 33 Stockholm
Sweden

Introduction

The impact of good airtightness and good thermal insulation on energy consumption and indoor climate in a number of detached houses has been described in a CIB report (Elmroth-Lögdberg 1980). All the houses had less than 1,0 air change per hour at 50 Pa - measured through pressure-testing - right after construction.

For the sake comparison, some houses with around 3,0 air changes per hour right after construction were studied. Each house had a floor area of 135 m^2.

Energy consumption

The total energy consumption in the five detached houses was measured over a three-year period. Corrections were made for variations in the number of degree-hours in the area.

The energy consumption of the houses under different periods is shown in table 1:

Table 1: Estimated and measured energy consumption 1978-81

Measurement period	Mean indoor temperature °C	Estimated energy consumption (kwh/year)	Measured energy consumption (mean value for five houses) (kwh/year)
Feb 78-Feb 79	19-20	18 400 - 19 600	18 550
Feb 79-Feb 80	19-20	18 600 - 19 600	18 800
Feb 80-Feb 81	20-21	19 600 - 20 500	19 400

From the table it can be seen that the measured energy consumption corresponds well to the estimate.

The air change was measured a number of times per year, and varied between 0,4 and 0,5 air changes per hour.

Necessary ventilation

From a hygienic point of view, an air change of 4 m^3/person and hour at an indoor temperature of 18^o C and a relative humidity of 60 percent is the minimum requirement to enable the indoor air to contain less than 0,5 per cent CO_2 (the highest value permitted in a work place according to the regulations of the Swedish Board of Occupational Safety and Health). There exists no corresponding figure for dwellings. With regard to such comfort requirements as smell, sufficiently low relative humidity and evaporation from building materials, an air change of 10 m^3 per person and hour is more adequate. (Ubisch, 1977). This means that a master bedroom requires a ventilation of around (10+10+5)=25 m^3/h if two adults and a child are to sleep in it.

Air change in individual rooms

Tracer gas measurements were carried out with the aim of verifying the air change in individual rooms where people spend long time (e.g. bedrooms).

In houses, ventilated through an exhaust air ventilation system, there are as a rule no air outlets in bedrooms, work-rooms etc. Instead, these are located in the wet rooms of the house (bathroom, laundry, W.C.) and in the kitchen. Bad air is blown out through the air outlet. Outdoor air is drawn into the house through air inlets (slot valves), usually placed just above the windows in those rooms where there are no air outlets.

The air change in the bedrooms has been measured in the five houses (which all have an airtightness of less than 1,0 air changes per hour at 50 Pa) and in a number of reference objects which all comply with the requirements of the Swedish Building Code, i.e. 3 air changes per hour at 50 Pa. The air change has been adjusted to the requirements of the Swedish Building Code, (i.e. 0,35 liters/second and m^2). This value corresponds to some 0,5 air changes per hour for the building as a whole.

The results presented here refer to a master bedroom with a floor area of 13 m^2. The doors of the bedrooms closed.

Table 2: Air change with the fan adjusted to 0,5 air changes per hour in the master bedroom with the slot valve open or closed. The bedroom doors were closed.

Fan adjustment	House with tightness of 1,0 at 50 Pa	House with tightness of 3,0 at 50 Pa	Recommended value
0,5 air changes/h valve closed	21	8	25
0,5 air changes/h valve open	29	18	25

According to the table, an air change corresponding to the recommended value of 25 m^3/h is only obtained in very tight houses. The figure also indicate that the slot valves have a decisive impact on the air change of the room.

Measurement of air change when the air flow is disturbed

All the measurements of air change presented above were made in the absence of any disturbances to the air flow, due to e.g. open doors or windows.

It is, however, not unusual that - especially in summer - one or more windows are slightly open for longer or shorter periods of time to air the room.

In order to determine whether the air flow from the master bedrooms was disturbed, measurements were carried out when two windows were slightly open in the living-room. As the windows could be locked in an airing position, with a window chink of only around two cm, this position was chosen for the measurements. The horisontal outer measurement of the window frames was 600 mm. All the measurements were carried out with the slot valves open or closed, and with the fan adjusted to give an air change of 0,5 air changes/h (0,35 liter/sec,m^2). The results of the measurements are shown in table 3:

Table 3: Air change in master bedroom with two windows on the second floor slightly open or closed.

Fan adjustment	Open windows, m^3/h	Closed windows, m^3/h
0,5 air ch/h, valves closed	6	9
0,5 air ch/h, valves open	13	19

The table indicates that the ventilation system is partly short-circuited if two windows are slightly opened (2 cm chink). The average air change was reduced by 45%.

A pilot study with a modified exhaust air ventilation system

On the basis of the experience of the measurements presented above, attempts were made to modify a conventional ventilation system in such a way that a sufficient air change could easily be obtained in e.g. bedrooms while the total air change in the house as a whole was reduced (so called "demand adjusted ventilation").

Experiments have been carried out in an area of 1½-storey row houses without cellars. (Figure 1). In one of the houses, the "measurement house" three additional air outlets were installed in each bedroom (Figure 2). In all other respects, the ventilation system was a conventional exhaust air system. The additional cost of the modification to the system was 500 SEK, including the additional valves and air channels.

Measurements were carried out in the measurement house as well as in an adjacent referense house of the same type. Both houses were constructed with good air tightness (around 1,6 air changes per hour at 50 Pa). The reference house has a conventional exhaust air system with air outlets in all the wet rooms, in the clothes closet and in the kitchen.

In both houses there are air inlets - slot valves - in the windows of all the bedrooms, in the living room and in the hall.

The aim of the construction of the modified ventilation system was to enable a reduction of the total air change (including unintentional ventilation) to some 0,3 air changes per hour with maintained comfort. 0,3 air changes per hour corresponds to a total air change of 80 m^3/h, which is more than sufficient for the four persons living in the house, if the distribution of air flows is good.

The air outlets were adjusted to enable good ventilation in all the rooms - especially in those rooms where persons dwell for longer periods.

For the master bedroom this requires an air change of 25 m^3/h. The air change in the wet rooms was reduced slightly, in comparison to relevant standards.

In the reference house, the fan and the slot valve were pre-adjusted in the factory. The total air change - including unintentional ventilation - was around 0,6 air changes/hour (tracer gas measurement).

Table 4: Measured air change in master bedroom in the measurement house and in the reference house with fan at lowest speed and with the slot valve open or closed as much as possible (half closed). The bedroom door was closed.

Measurement conditions	Measurement house	Reference house
Measured air change in the entire house (air changes per hour)	0,3	0,6
Measured air change in master bedroom (slot valve fully opened) (m^3/h)	24	21
Measured air change in master bedroom with slot valve closed as much as possible (m^3/h)	20	14

The measurements indicate that, in spite of a very low total air change in the measurement house (0,3 air ch/h), the air change in the bedrooms is higher than in the reference house. Thus a great average air change in the house as a whole does not necessarily imply that all parts of the house get good ventilation.

Measurements of air humidity etc. have been carried out since October 1980, and are planned to continue for another year. The results and observations so far indicate that

- air humidity never exceeds 50% in any of the rooms (except, for very short periods, in wet rooms and kitchens)
- condensation has never appeared on the inside of the windows
- there has always been low pressure in the wet rooms
- on average the fan results in 2-5 Pa lower pressure in all the rooms than in the outdoor air.

Thus, through a "demand adjustment" of the ventilation system in such a way that good ventilation is obtained in those rooms where people spend longer periods, the total air change in the measurement house has been cut by around 50 %. The people living in the house have experienced a good indoor climate and have never had the feeling that the indoor air has been stuffy.

The energy losses due to ventilation have been estimated to around 3300 kWh/year which is to be compared to the losses in the reference house which amount to some 6600 kWh/year. With 0,5 air changes per hour (the stipulated value according to the Building Code) energy losses should have been around 5500 kWh/year.

Energy balance for a row house in Öringe, Tyresö

The calculations are made on the assumption of Stockholm's climate and an indoor temperature of 21°C.

Energy losses		Energy supply	
Transmission	8900 kWh/year	Heating system	7100 kWh/year
Ventilation (0,5 air ch/h)	6700	Domestic hot water production	5000
		Domestic elec- tricity	3500
Domestic elec- tricity	1000	Solar irradiation	3000
Drainage water	3500	Heat from persons etc.	1500
	20100		20100

Sum of billed energy	15600 kWh/year	(21°C)
Sum of billed energy	14200 kWh/year	(20°C)

Demand-adjusted ventilation with 0,3 air changes/hour

Sum of billed energy	12900 kWh/year	(21°C)
Sum of billed energy	11700 kWh/year	(20°C)

Actual energy consumption

for the period Sept 1, 1980 - Sept 1, 1981, 12600 kWh/year

for the period Sept 1, 1981 - Sept 1, 1982, 13000 kWh/year

The mean indoor temperature has been 21°C during the period.

Test of air tightness (at 50 Pa)

May 1980	1,6 air changes per hour
May 1981	1,6 air changes per hour

Low indoor pressure

The air pressure indoors has on average been 4-6 Pa lower than the outdoor air pressure, at an average air change (inclusive of unintentional ventilation) of 0,33 air changes per hour.

Other information

Window area 17,3 m^2.

Exhaust air fan in ventilation chimney. Air outlets in the wet rooms and in all the bedrooms.

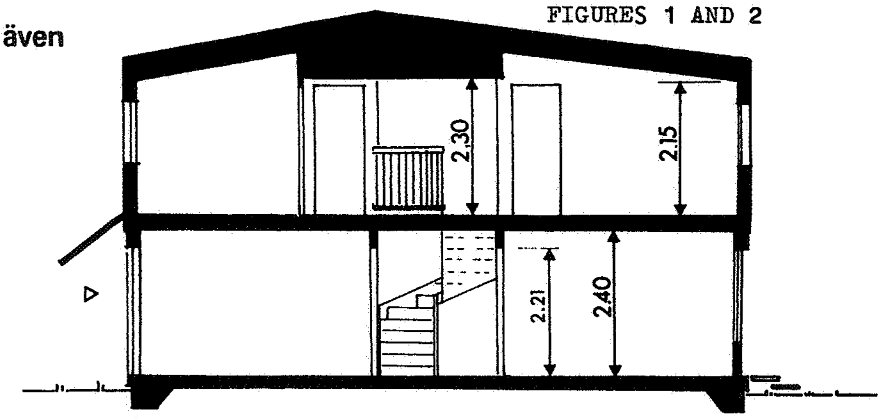
Air change in bedroom (master bedroom) 24 m^3, of which 5 m^3 through over-flow from adjacent rooms.

All measurements of air changes have been made through tracer gas measurement, thus also including unintentional ventilation.

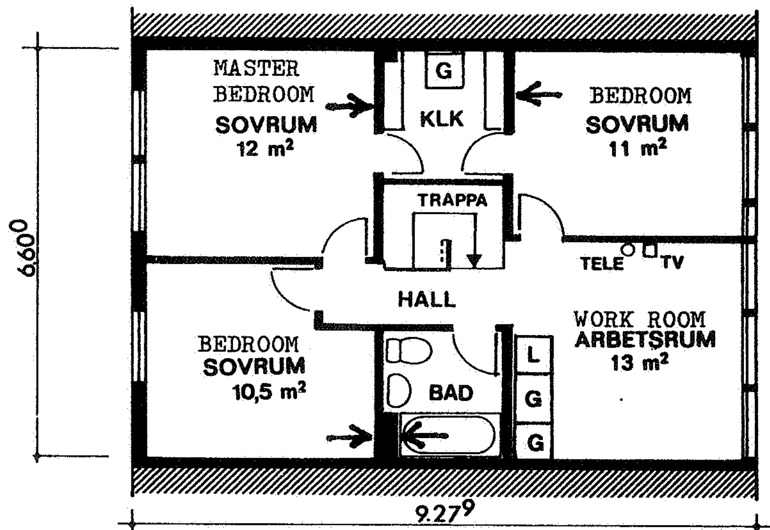
HUSTYP 6 A

Förekommer även spegelvänd.

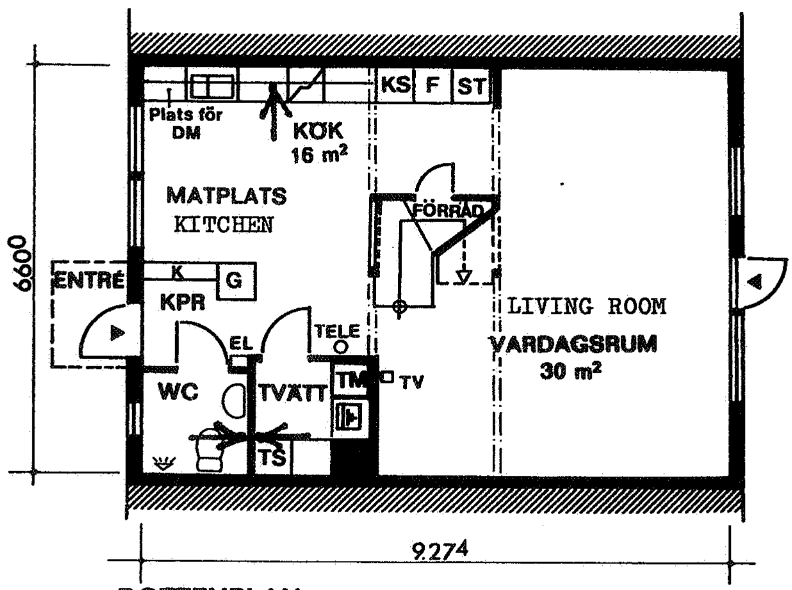
FIGURES 1 AND 2



SEKTION



ÖVERPLAN



BOTTENPLAN

Skala