Energy Impact of Ventilation and Air Infiltration
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1 SYNOPSIS

This paper reports results from the ventilation and air tightness measurements in Swedish dwellings as part of the 1992 Swedish Energy and Indoor Climate Survey (the ELIB-study). The indoor climate in a random sample of 1200 single- and multi-family houses from the Swedish housing stock were investigated. Among different parameters the ventilation and the air-tightness of the houses were measured. The ventilation measurements were performed during one month in each house/flat by means of the so called PFT-method and the air tightness of a sub-sample of 90 buildings were measured by means of pressurisation technique. Main results are that the ventilation rate is lower than 0.35 $l/(s,m^2)$ or 0.5 ACH in more than 80 % of all the single-family houses and more than 50 % of all the multi-family houses. Expressed in l/(s,inhabitant) around 50 % of all, both single- and multi-family houses, have a ventilation rate higher than 10 l/(s,inhabitant). The influence of age, construction year, ventilation system, renovation staatus and geographical region can be traced by means of a scheme of relative-differences correction factors. The investigation of the air tightness of the houses showed mainly that newer houses are less leaky than older ones and that the prescribed maximum n50-leakage value, as stated in the Swedish Building Code, is reached only by the newest multi-family houses.

2 BACKGROUND

A nation-wide energy and indoor climate survey, the ELIB-study (Norlén and Andersson (1993) and (1993b)), has been carried out in Sweden. A number of indoor air quality parameters, among them ventilation rate, were measured in a random sample of 1200 single- and multi-family houses from the Swedish housing stock. A sub-sample of 90 single- and multi-family houses were investigated more in detail, Boman and Sundberg (1993). In these houses the air tightness levels were measured by means of pressurisation technique.

3 VENTILATION RATES

3.1 Measurement technique

Measurements by means of a "passive" constant emission tracer gas technique were used, the so called PFT-method (perfluorcarbon tracers). The further development of the method for this investigation, which was performed at the Swedish Institute for Building Research, is described in Stymne and Boman (1993). In this investigation the method has been applied as a single- or (mainly in two-storey houses) two zone model.

3.2 Results

The results of the long-term PFT-measurements are summarized in figures 1 and 2. The method used for estimation of the distribution functions is described in Waller and Högberg (1993). For each dwelling the measurement was performed during approximately one month in the period November 1991 to April 1992.

In figures 3 and 4 the average ventilation rates in the Swedish housing stock are presented for different types and ages of residential buildings.

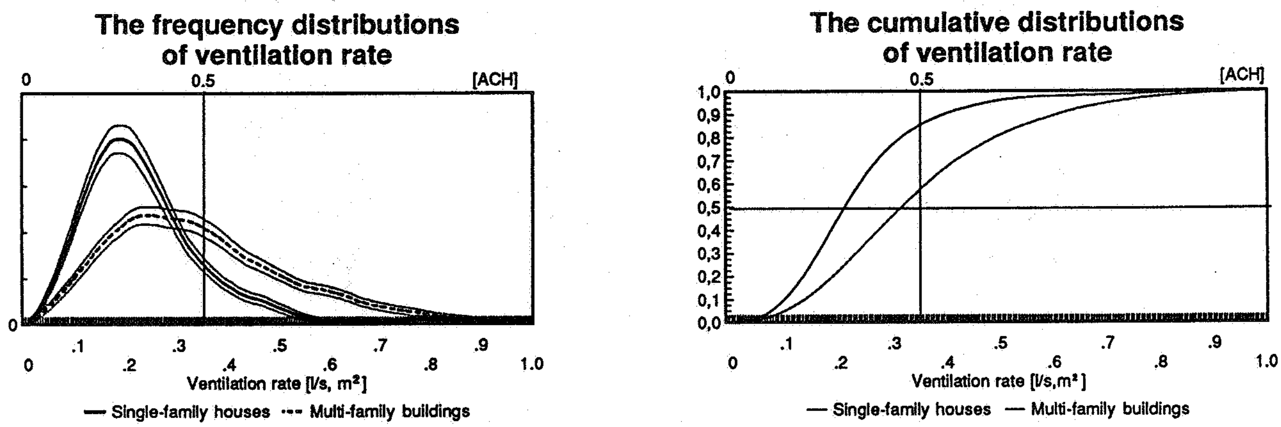

Figure 1. The frequency (left) and cumulative (right) distributions of the ventilation rate expressed as ventilation flow rate per square metre of the floor area and air change rate (ACH) for single-family houses (solid line) and multi-family houses (dotted line). Thin lines for the frequency functions show the upper and lower limits for the statistical uncertainty

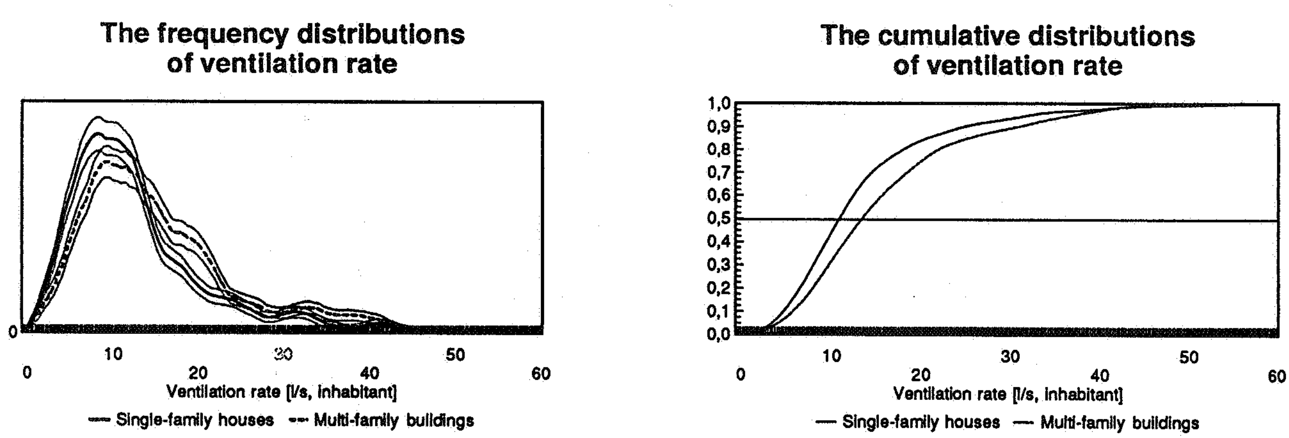

Figure 2. The frequency (left) and cumulative (right) distributions of the ventilation rate expressed as ventilation flow rate per inhabitant for single-family houses (solid line) and multi-family houses (dotted line). Thin lines for the frequency functions show the upper and lower limits for the statistical uncertainty

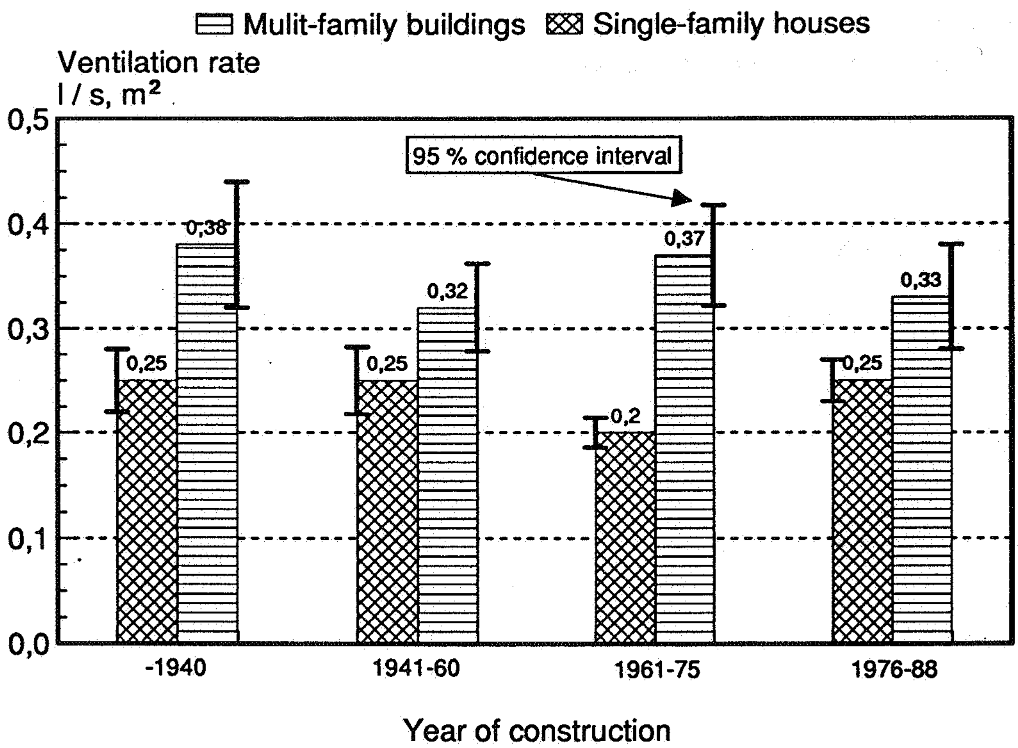

Figure 3. Average ventilation rate ($l/(s,m^2)$) in the Swedish housing stock by type of building and year of construction. 95%-confidence intervals of the averages are indicated.

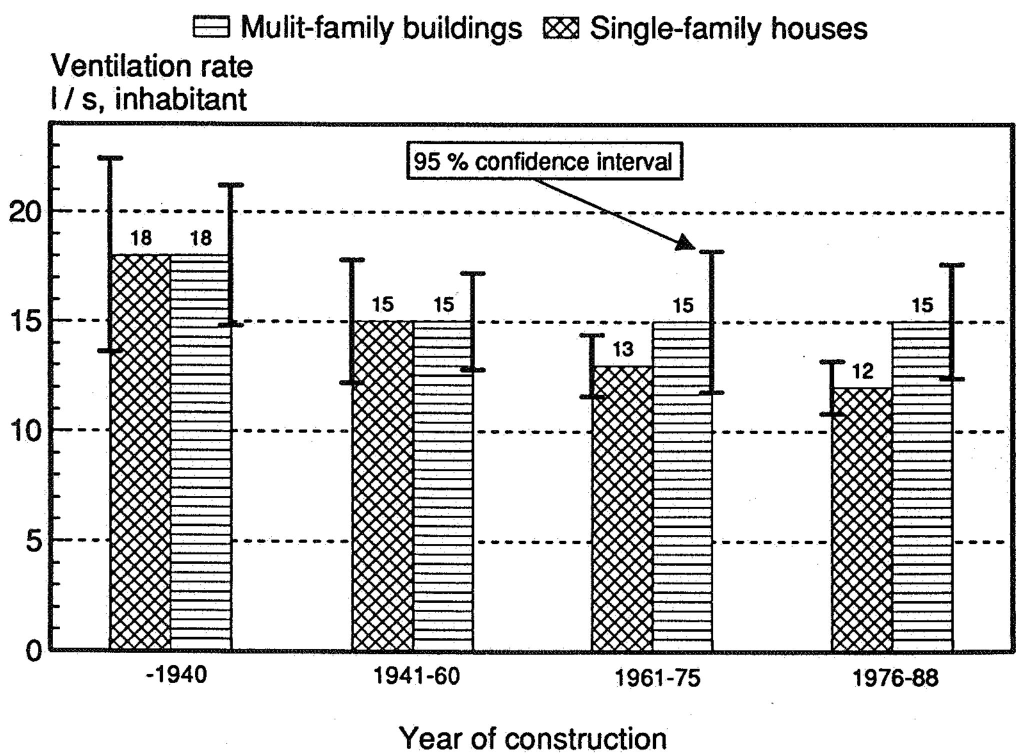

Figure 4. Average ventilation rate (l/(s,inhabitant)) in the Swedish housing stock by type of building and year of construction. 95%-confidence intervals of the averages are indicated.

Based on these diagrams, some obvious observations are:

- The variation in average ventilation rates (expressed in $l/(s,m^2)$ is very large. It ranges from an average value of 0.20 for single-family houses built in 1961-1975 up to a value close to twice as large (0.38) for multi-family houses built up to 1940.

- Compared to prescribed ventilation rate for dwellings of 0.35 $l/(s,m^2)$, as stated in the Swedish Building Regulations from 1975 and onwards, the average for all single-family houses of all ages fall below. This is the case for most multi-family houses too, except for the group with the oldest houses and the group built in 1961-1975.

- Generally the average ventilation rates in multi-family houses are higher than in single-family houses. There is no exception in any age-group.

- When the average ventilation rate based on number of inhabitants, (l/(s,inhabitant)), is considered, the variation is small, both between different age-groups of the same type of house and between different types of houses.

In order to analyse the extent to which specific factors, such as age, ventilation system, renovation status and geographical region influence the average ventilation rate of dwellings , loglinear regression analyses were performed. The results are summarized in figures 5 and 6, quoted from Norlén and Andersson (1993 b).

Here we assume that the average ventilation in a group of residential buildings can be written as a product of a reference value and factors of age, renovation, ventilation and geographical region.

Thus, the average ventilation in a group of buildings can be roughly estimated by multiplying the reference value by the actual relative differences. Consider for example the group comprising all naturally ventilated, not renovated single-family houses built in or before 1960 in central Sweden: Figure 5 can supply the following estimate of its average ventilation in litres per second and person: 12 * 1.10 * 1.02 * 1.04 = 14.

a) Ventilation in ***litres per second and square metre***

Average relative difference (**reference value=0.22**) according to:

Construction year		Ventilation system		Renovation status		Geographical region	
- 1960	1.04	(Natural vent 1.00)		Not renovated	1.05	Southern Sweden	**1.01**
1961-	0.96	Natural vent	**0.78**	Renovated	0.95	Central Sweden	**1.07**
		Exhaust vent	**0.99**				
		Supply-and-exhaust vent	**1.23**			Northern Sweden	**0.91**

b) Ventilation in ***litres per second and person***

Average relative difference (**reference value=12**) according to:

Construction year		Ventilation system		Renovation status		Geographical region	
- 1960	1.10	(Natural vent 1.00)		Not renovated	1.02	Southern Sweden	**1.04**
1961-	0.90	Natural vent	**0.92**	Renovated	0.98	Central Sweden	**1.04**
		Exhaust vent	**0.98**				
		Supply-and-exhaust vent	**1.11**			Northern Sweden	**0.92**

Figure 5. Ventilation in single-family houses by construction year, renovation status, ventilation system and geographical region. Relative differences for significant factors are given in semi-bold. Single-family houses from or before 1960 with mechanical ventilation are not included in the analysis because of too few observations made.

a) Ventilation in ***litres per second and square metre***

Average relative difference (**reference value=0.30**) according to:

Construction year		Ventilation system		Renovation status		Geographical region	
- 1960	1.04	Natural vent	**0.95**	Not renovated	1.06	Southern Sweden	**1.09**
		Exhaust vent	**1.05**				
1961-	0.96	Natural vent	**0.86**	Renovated	0.94	Central Sweden	**1.05**
		Exhaust vent	**1.01**				
		Supply-and-exhaust vent	**1.13**			Northern Sweden	**0.86**

b) Ventilation in ***litres per second and person***

Average relative difference (**reference value=13**) according to:

Construction year		Ventilation system		Renovation status		Geographical region	
- 1960	1.07	Natural vent	**0.95**	Not renovated	1.03	Southern Sweden	**1.07**
		Exhaust vent	**1.05**				
1961-	0.93	Natural vent	**0.86**	Renovated	0.97	Central Sweden	**1.06**
		Exhaust vent	**0.99**				
		Supply-and-exhaust vent	**1.15**			Northern Sweden	**0.87**

Figure 6. Ventilation in multi-family houses by construction year, renovation status, ventilation system and geographical region. Relative differences for significant factors are given in semi-bold. Multi-family houses from or before 1960 with supply-and-exhaust ventilation are not included in the analysis because of too few observations made.

4 AIR TIGHTNESS

4.1 Sample and measurement technique

The sub-sample of 90 single- and multifamily houses was drawn from the main random sample of 1200 houses, used for the main investigation. The sub-sample is identical to the sample chosen for the Institute's quality control performance regarding the sub-contractors that were hired by the Swedish Institute for Building Research for performing the inspections of the houses in the main investigation. Practical aspects, such as availabilty, travel optimisation etc may have influenced the choise of houses for the sub-sample, which means that the sub-sample is not a correct random sample. Anyhow, the houses in the sample represents a wide variety of bulidings in different geographical regions.

The air tightness performance of the houses tested was carried out by means of standard pressurisation technique, as described in the current Swedish standard. The result of the test is expressed in leakage rate at 50 Pa (average of leakage at over- and under-pressure) divided by house or flat volume (Unit: 1/h). It should be noted that the figures regarding multi-family houses refer to flats, not the whole building. Due to limitations in the capacity of the measurement equipment, results from 5 single- and 5 multi-family houses are lacking.

4.2 Results

The results of the air tightness measurements are summarized in figure 7.

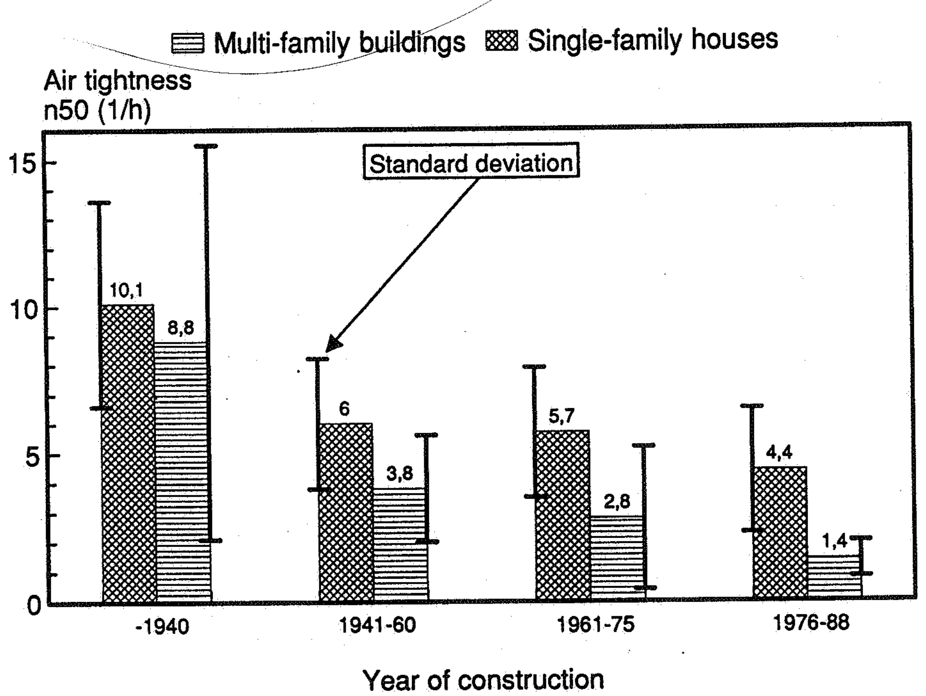

Figure 7. Air tightness of a sample of 50 single-family houses and 30 flats in multi-family houses of different ages in Sweden.

It could be seen from figure 7 that:

- The standard deviations are rather large, due to the relatively small number of houses in each age-group.

- There is a clear tendency that newer houses are less leaky than older ones.

- Multi-family houses have lower n50-values than single-family houses; this is due to higher volume-to-leaking area relationship.

- Compared to the prescribed maximum values of n50 as stated in the Swedish Building Code of 1980 (3.0 for single-family houses and 1.0 - 2.0 for multi-family houses), only the newest multi-family houses (on average) seem to meet the prescribed level.

5 ACKNOWLEDGEMENTS

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