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Necessary Air Change Rate in a Danish Passive House

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1 Introduction

In Denmark the concept of Passive House is rather new. Introducing a new building concept means among other things changing the "normal way of doing things". One of the things that are different compared to traditional Danish architectural tradition is the recirculation of air from the exhaust hood and the air change rate of the dwelling.

The demanded air change rate for dwellings given in the Danish building regulation is 0.5 h^{-1} and recirculation of air from the exhaust hood is not allowed. The demand regarding air change rate is to ensure a good indoor air quality and the prohibition of recirculation of air from the exhaust hood is to insure an adequately low level of moisture.

In this paper result of the moisture level in a Danish Passive House is reported. The results are produce using a detailed building simulation program; BSim [Wittchen et al. 2005].

2 Moisture in dwellings

There are two main reasons why the relative humidity in dwellings (and other buildings) should not be to high. The first is to insure that mould fungus can not grow. Mould fungus can cause both decomposition of the constructions and illness. The other is to keep the number of house dust mite under control. To avoid mould fungus the relative humidity (RH) should not exceed 70% RH except for short periods [Gunnarsen 2001]. At RH levels below 40 - 45% house dust mite will dry up and die [Gunnarsen 2001]. Therefore the RH should be below this boundary for a period of time - preferably more than one month. This can only be achieved in wintertime due to the high contents of water in the outdoor air in summertime.

There are many sources that are giving off moisture to the indoor environment. In Figure 1 the contribution of the different moisture sources are shown. "People" constitutes more than 40% of the total contribution and are by far the largest. In this context however the contribution from "Cooking" and "Cloth washing and drying" are investigated. In Danish dwellings it is a reasonably assumption that the moisture from "cooking" is removed by the exhaust hood which is not the case when recirculating the air. An other large contribution comes from "Cloth washing and drying". There are many was of drying cloth; outdoor, indoor, tumble drier and a combination of these. In this study all the cloth is dried indoor and therefore all the moisture are released in to the building.

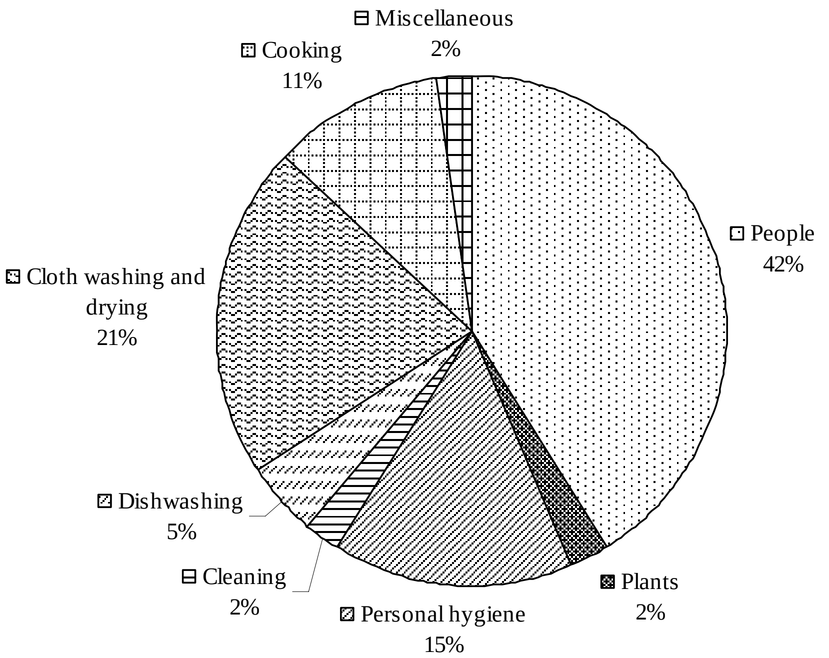

Figure 1 Moisture sources in dwellings [Koch et al. 1987]

The exact amount of moisture produce by a typical family is difficult to asses. In Table 1 the estimated contribution from the different categories are shown. The total amount of moisture produced dependent on the number of people agrees well with several field measurements conducted in Danish buildings [Bergsøe 1991], [Bergsøe 1994].

Moisture produced/number of people	1	2	3	4	5	6
People	0.88	1.75	2.63	3.50	4.38	5.25
Plants	0.20	0.20	0.20	0.20	0.20	0.20
Personal hygiene	0.33	0.65	0.98	1.30	1.63	1.95
Cleaning	0.20	0.20	0.20	0.20	0.20	0.20
Dishwashing	0.40	0.40	0.40	0.40	0.40	0.40
Cloth washing and drying	0.40	0.90	1.30	1.80	2.10	2.60
Cooking	0.90	0.90	0.90	0.90	0.90	0.90
Miscellaneous	0.00	0.10	0.20	0.20	0.40	0.50

Table 1 Estimated moisture produce by 1 to 6 people based on [Koch et al. 1987]

3 Simulations

The simulations are based on a square dwelling of 169 m^2 (gross) inhabited by a family of five people. The layout of the dwelling can be seen on Figure 2 as well the three ventilation zones. Zone 1 consists of three bedrooms and an office. Zone 2 consists of a hall and a corridor. Zone 3a consists of a living room and a kitchen combined. Zone 3b consists of a bathroom, a toilet and a utility room (only divided into two rooms on the figure).

The air enters into Zone 1. From there it passes through Zone 2 and is finally extracted from Zone 3a and 3b. The amount of air extracted per square metre from Zone 3a and 3b are the same.

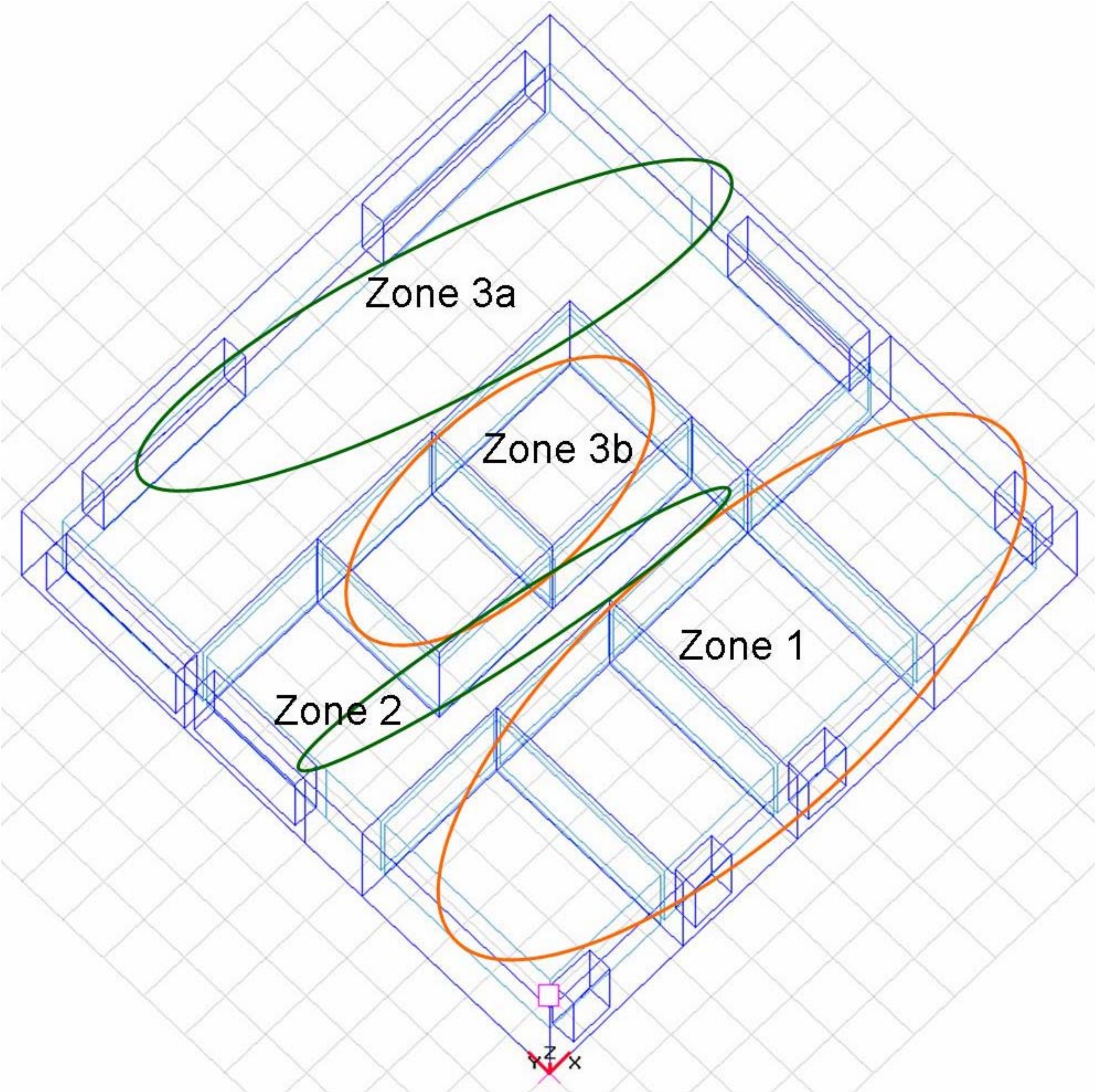

Figure 2 Layout of the dwelling and location of the three ventilation zones

Moisture

The moisture loads are distributed between the zones in different ways. Plants, Cleaning and Miscellaneous are evenly distributed according to floor area. Personal hygiene and Cloth washing and drying are distributed only to Zone 3b whereas Dishwashing and Cooking are distributed only to Zone 3a.

People

Since people are the largest source in relation to moisture special care has been devoted to the distribution and numbers of hour's people spend in there home. According to [Keiding et al. 2003] Danish people between the age of 16 and 74 spend in average 16.3 h in there home. The dwelling is according to [Bergsøe 1994] empty 5.4 h a day on weekdays. Based on this a distribution of the five people are shown in Table 1 fore a week. This week is used through out the simulated year knowing that there are times where there are more and less people. It is assumed that the people are a sleep from 23 to 7 (hour 1-7 and 24). Fore these hours they are placed in Zone 1 and in the rest of the hours they are placed in Zone 3.

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	5	5	5	5	5	5	5
2	5	5	5	5	5	5	5
3	5	5	5	5	5	5	5
4	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5
8	5	5	5	5	5	5	5
9						5	5
10						5	5
11						5	5
12						3	3
13						3	3
14						3	3
15					3	3	3
16					3	3	3
17	3	3	3	3	3	3	3
18	3	3	3	3	3	3	3
19	3	3	3	3	3	3	3
20	3	3	3	3	3	3	3
21	5	5	5	5	5	5	5
22	5	5	5	5	5	5	5
23	5	5	5	5	5	5	5
24	5	5	5	5	5	5	5

Table 2 Number of people present during a week. Hour 1 is from 0:00 - 1:00 and so on.

Infiltration

The infiltration rate are calculated based on n_{50}=0.6 h^{-1}. The maximum limit was chosen since demands regarding airtightness of buildings have only recently been introduced in Denmark and therefore only little experience in making buildings tight exits. According to the Danish building regulations an air change n_{50} of 0.6 h^{-1} corresponds to an average air change of 0.08 h^{-1}.

Ventilation

Simulations are carried out at four different air change rates. 0.5 h^{-1} as required by the Danish building regulations. Reduced air change rates of 0.4 and 0.3 h^{-1} and finally 0.36 h^{-1} calculated according to [Krause 2007] based on both the number of people and the number and types of rooms in the building.

4 Results

All the simulations where carried out using the Danish Design Reference Year [Jensen et al. 1995] and the results are given in grams of water per kilogram of air. In Table 3 the corresponding relative humidity at 22°C can be found. 22°C is chosen since it is the normal comfort temperature during the heating season.

RH at 22°C	20	30	40	45	50	60	70	80
Humidity ratio g/kg	3,2	4,8	6,6	7,4	8,3	9,9	11,6	13,2

Table 3 Water contents at different relative humidity at 22°C

In Figure 1 the monthly average humidity level calculated at an air change of 0.5 h^{-1} can be seen. During all three winter month the corresponding RH is below 45% for all the zones, giving no problems in connections with to high levels of humidity.

In Table 4 the water contents in the four zones at the four different air change rates are shown for both the three winter month and the heating season. The maximum humidity level in winter time (air change rate of 0.3 h^{-1}) is 8.2 g/kg (Zone 3b) corresponding to a RH of less than 50%. In addition to that the humidity level in Zone 3a is significant lower than that of Zone 3b. Extracting more air from Zone 3b will lower the RH even further in this zone. The increasing in Zone 3a due to this is not a problem.

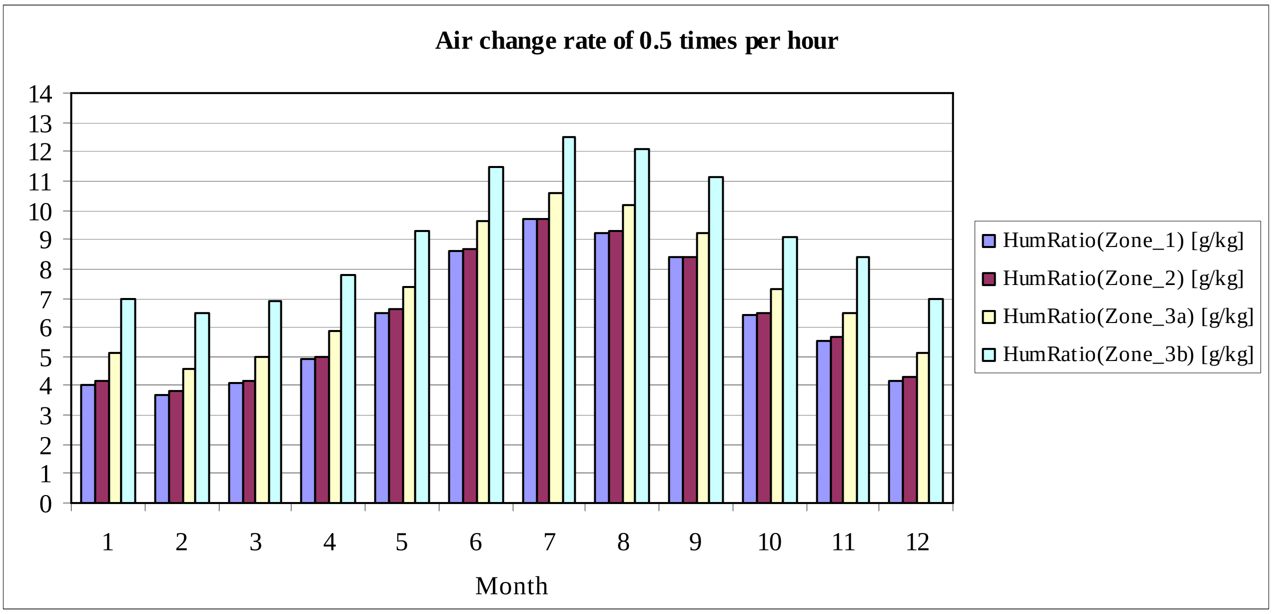

Figure 3 Monthly average humidity level.

Air change rate	0.5		0.4		0.36		0.3	
Time of the year	Winter	Heating season	Winter	Heating season	Winter	Heating season	Winter	Heating season
HumRatio(Zone_1) [g/kg]	4,0	4,7	4,1	4,8	4,3	4,9	4,4	5,0
HumRatio(Zone_2) [g/kg]	4,1	4,8	4,3	5,0	4,5	5,2	4,7	5,3
HumRatio(Zone_3a) [g/kg]	4,9	5,6	5,4	6,1	5,7	6,3	6,1	6,7
HumRatio(Zone_3b) [g/kg]	6,8	7,5	7,0	7,7	7,7	8,3	8,2	8,8

Table 4 Water contents in the zones at different air change rate. Heating season is defined as October to April

5 Conclusions

The results presented in this paper shows that recirculation of air from the kitchen exhaust hood and drying of clothes indoor dose not lead to moisture problems even at a very low air change rate of 0.3 h^{-1}.

The calculations are based on a qualified estimation of the average production of moisture released in Danish dwellings. However the values used are subject to a significant uncertainty due to the large variations of habits and use of dwellings. Therefore introducing air change rates below the required 0.5 h^{-1} to save energy, demands more of the residents to avoid problems with house dust mite and mould fungus.

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