Analyzing Indoor Environmental Perception in 10 Active Houses

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Abstract

During a renovation of 92 homes in Montfoort (the Netherlands) it was decided to renovate 10 dwellings out of the 92 in line with the Active House specifications. These 10 dwellings have an even higher energy label, and the renovation ensured for an extra healthy and comfortable indoor climate for the residents.

The aim of the study was to develop a method to objectify the health and comfort performance and perception of the indoor environment in the Active Houses and compare the indoor environmental performance of the Active Houses to the reference dwellings (regular A-label dwellings).

A concept questionnaire was developed and conducted in 10 Active Houses and 7 adjacent regular A-label dwellings in Montfoort, The Netherlands. The residents were approached twice: once during the summer period and once during the heating season of 2015. The findings from the field study were analyzed and the questionnaire results were reported in the 'Active House Radar' format (perception variant).

The project showed that the questionnaire allows for systematic objectivation of end user perceptions of Active Houses. The outcomes of the pilot project show that in this specific case (Montfoort Active Houses) residents are most satisfied with the visual comfort in the houses and are least satisfied with the thermal environment, indoor air quality and the acoustic comfort in the houses.

Keywords - indoor climate, questionnaire, performance requirements, evaluation, Active House.

1. Introduction

After a renovation of 92 (rental) dwellings in Montfoort, the Netherlands, to an A energy label (reference dwellings) it was decided to bring 10 dwellings to an even better energy label and to ensure an extra healthy and comfortable indoor climate for the residents of those 10 dwellings. The 10 dwellings were renovated in line with the Active House specifications [1]. The concept focuses on the generation of solar energy, the use of passive solar energy and technology for energy- and climate control.

The Active Houses are equipped with a photovoltaic cells, solar water heater and a heat pump [2] which is connected to floor heating, instead of radiators in the reference houses.

By adding extra space in the attic, more openings in the roof and reconstructing the staircase, daylight has the possibilities to penetrate deeper into the Active House.

Both Active Houses and the reference dwellings are ventilated through vents and operable windows, with mechanic exhaust in the kitchen and the bathroom.

2. Objective

The objective of the study was to develop a method to objectify the health and comfort performance and perception of the indoor environment in the 10 dwellings developed in line with the Active Houses specifications and compare the indoor environmental performance of the Active Houses to the reference dwellings (regular A-label dwellings).

3. Methode

A questionnaire was developed based upon the results of previous projects that involved systematic evaluation of indoor environment perception and complaints like the HOPE project [3]. In the questionnaire for the study as described in this paper, relevant questions about the satisfaction of the residents on various aspects of the home were asked. These aspects are visual comfort, thermal environment, indoor air quality, acoustic comfort, perceived energy performance and perceived environmental performance. Each aspect is divided in 3 sub-questions (see Table 1).

A five-point scale is used, where 1 = very satisfied, 2 = satisfied, 3 = satisfied nor dissatisfied, 4 = dissatisfied and 5 = very

dissatisfied. The scale is derived from the 'Active House Radar' format [1].

Then the concept version of the questionnaire was tested in 10 Active Houses and 7 reference dwellings in Montfoort. The Active House residents and the residents form the reference dwellings were approached twice: once during the summer period (July 2015) and once during the heating season (November 2015).

The findings from the field study were analyzed and the questionnaire results were reported in the 'Active House Radar' format (perception variant). In the 'Active House Radar' format the results of the Active Houses are compared with the results of the adjacent reference dwellings.

Due to the low number of respondents no statistical analysis was conducted. When the difference between the score of the Active Houses and the reference dwellings is more than 0.5 on the five-point scale (1 = very satisfied to 5 = very dissatisfied), it is assumed to be a *significant* difference.

Table 1. Example of some questions asked in the questionnaire conducted in the Active Houses and reference dwellings.

General Experience

Generally speaking, how satisfied are you with your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	Satisfied	very satisfied

Light

Overall, how satisfied are you with the light in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	Satisfied	very satisfied

How satisfied are you with the daylight penetration in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

How satisfied are you with the availability of direct sunlight in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

Thermal Environment

Overall, how satisfied are you with the thermal environment in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

How satisfied are you with the thermal environment indoors during the summer months?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

How satisfied are you with the thermal environment indoors during the winter months?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

Indoor Air Quality

Overall, how satisfied are you with the indoor air quality in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

How satisfied are you with the fresh air supply in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

How often do you suffer from dry eyes?

5	4	3	2	1
O	O	O	O	O
always	often	sometimes (throughout the year)	sometimes (only in the winter months)	never

Energy

How satisfied are you with the energy consumption of your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

Other aspects

How satisfied are you with the overall environmental performance (apart from energy use) of your home? Think e.g. of fresh water consumption, use of green materials, support of local ecology.

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	Satisfied	very satisfied

How satisfied are you with noise and acoustics in your home?

5	4	3	2	1
O	O	O	O	O
very dissatisfied	dissatisfied	satisfied nor dissatisfied	satisfied	very satisfied

4. Results

The study showed that the questionnaire allows for systematic objectivation of end user perceptions of the Active Houses. The outcomes of the pilot project, the Active Houses in Montfoort, are shown in Fig. 1 and, Fig. 2.

The average score on the various comfort, energy and environmental aspects of the Active Houses and reference dwellings are about the same in the summer (score 2,5 Active Houses versus 2,2 reference dwellings on a five-point scale where 1 = very satisfied and 5 = very dissatisfied). In heating season the average score for both Active Houses and reference dwellings is 2,4. The average score of the Active Houses and reference dwellings are on all aspects better than neutral (<3 score).

The residents of the Active Houses evaluate their home *themselves* as less satisfied compared to the reference dwellings. In summer the Active House residents evaluate their home with an 2,4 (1 = very satisfied and 5 = very dissatisfied) compared to an 1,6 of the reference dwellings. This is in the heating season 2,3 compared to an 1,4.

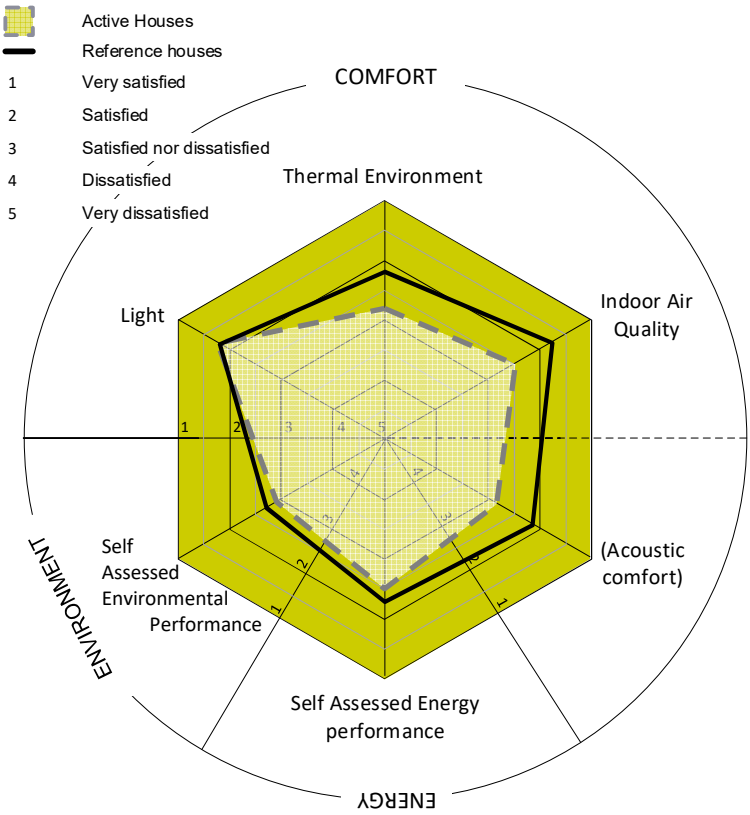

Fig. 1 Montfoort perceptions expressed in the 'Active House Radar' format in the SUMMER PERIOD.

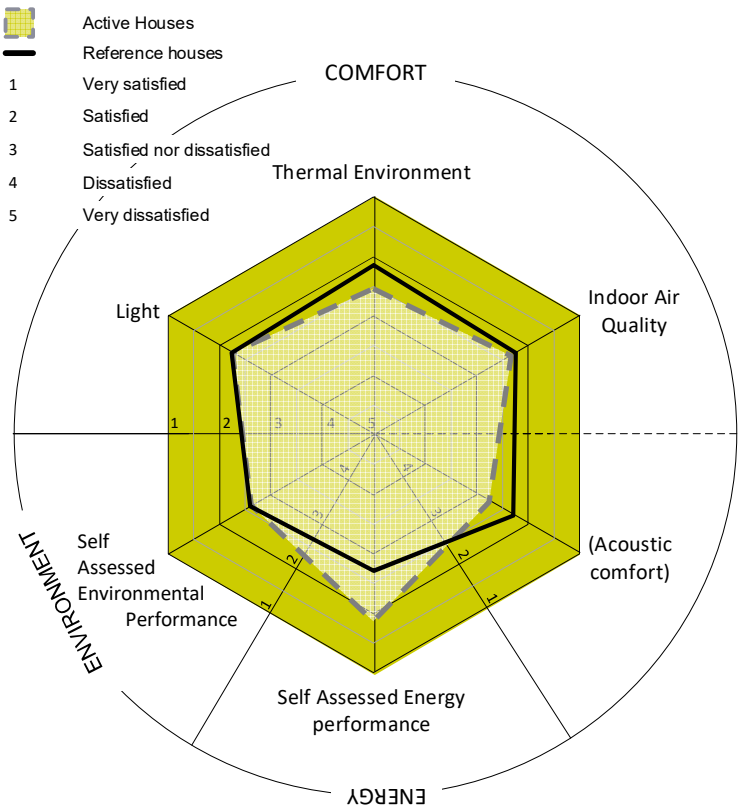

Fig. 2. Montfoort perceptions expressed in the 'Active House Radar' format in the HEATING SEASON.

The residents of the Active Houses are in the summer in particular less satisfied about the thermal environment, indoor air quality en acoustic comfort, see Table 2. In the heating season the Active Houses score more satisfied on the aspect self-assessed energy performance than the reference houses.

Table 2. Indoor environmental perception Active Houses versus reference dwellings in the summer and in the heating season. 1 = very satisfied, 2 = satisfied, 3 = satisfied nor dissatisfied, 4 = dissatisfied and 5 = very dissatisfied. A significant difference (score >0.5) is represented in bold.

		Summer			Heating season		
		Score Active Houses	Score ref. dwellings	Difference in score	Score Active Houses	Score ref. dwellings	Difference in score
Light	General	1.5	1.7	0.2	2.0	2.0	0.0
	Daylight penetration	1.7	2.0	0.3	2.4	2.3	0.1
	Availability of direct sunlight	2.1	1.7	0.4	2.4	2.4	0.0
	Average	1.8	1.8	0.0	2.3	2.2	0.1
Thermal Environment	General	2.9	2.1	**0.8**	2.9	2.3	**0.6**
	Summer	2.6	2.3	0.3	1.9	1.7	0.2
	Heating season	2.9	2.3	**0.6**	2.9	2.4	0.5
	Average	2.8	2.2	**0.6**	2.5	2.1	0.4
Indoor Air Quality	General	2.5	1.9	**0.6**	2.4	2.4	0.0
	Fresh air supply	2.5	1.7	**0.8**	2.4	2.6	0.2
	Dryness of the air	2.4	1.7	**0.6**	2.3	1.7	**0.6**
	Average	2.5	1.8	**0.7**	2.4	2.2	0.2
Acoustic comfort		2,8	2.1	**0.7**	2.8	2.3	0.5
Self-assessed energy performance		2,5	2.3	0.2	1.9	2.7	**0.8**
Self-assessed environmental performance		2,9	2.7	0.2	2.6	2.6	0.0
Average		2,5	2.2	0.3	2.4	2.4	0.0

With regards to the thermal environment, the Active Houses are most dissatisfied about the amount of control on the temperature in the home. The open questions showed that residents of the Active Houses indicate that the temperatures on the 1st and 2nd floor are too hot or too cold, while the temperature on the ground floor is as desired.

On follow-up question on the aspect indoor air quality the Active House residents indicate that they suffered from stuffy and / or damp and dry air in the house. Scientific research shows that complaints about 'dry air' in almost all cases are due to reduced air quality [e.g. 4] and not due to humidity of the air.

Several Active House residents indicate in the open questions that it is very noisy in the house because of the open staircase. Also, a few residents complain about the noise that the ventilation system creates outside. When the residents open the windows or the vent, the ventilation system (of the neighbors) creates noise disturbance. Inside the dwellings the own ventilation system is inaudible.

5. Conclusion and discussion

The project showed that the questionnaire allows for systematic objectivation of end user perceptions of Active Houses

The average scores on the various aspects of the Active Houses and the reference dwellings are about the same. Both dwellings score on average on all aspects better than neutral (score <3).

The residents of the Active Houses are in the summer in particular less satisfied about the thermal environment, indoor air quality en acoustic comfort. In the heating season the Active Houses score more satisfied on the aspect self-assessed energy performance than the reference houses.

A possible explanation for the lesser satisfaction of the Active House residents may be that the residents had a higher expectation level than the residents of the reference dwellings. E.g. due to promises like “one temperature level through the entire house”.

In addition, the large amount of glass in the attic and the open staircase of the Active Houses participate in the lesser satisfaction of the Active House residents. Despite the operable windows with solar shading in te attic, the large amount of glass allows it to be quite hot in the summer on the upper floors of the house. The open staircase does not only cause noise disturbance, but also allows the heat to rise to the attic and allows a downdraught from the (roof)windows in the attic. Insufficient use of the operable windows and the solar shading

by the residents due to inadequate instruction can also contribute to high temperatures in the attic.

Next to that, the Active Houses have floor heating in each room with one thermostat in the living room for all spaces in the dwelling, while the reference dwellings have radiators in each room. As a result, the temperature in the individual rooms in the Active Houses cannot be properly adjusted, while this is possible in the reference houses.

Acknowledgment

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