

# Environmental Comfort Perception in the Alvorada Sustainable Low Cost House: Second Post Occupancy Evaluation

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**ABSTRACT:** This paper describes part of a larger study, developed by NORIE, that deals with the urban and architectural design, construction and post occupancy assessment of CETHS – Experimental Center of Sustainable Housing Technologies, started in 1999. This is a housing settlement located in the city of Nova Hartz/RS, where eight one-floor single-family low-cost houses have been occupied. After a first post occupancy evaluation, made in 2003, CETHS was submitted to a second post occupancy evaluation, in March 2005, on several features included in the design stage, such as: local food growth, income generation, environmental comfort, building functionality, spaces appropriation, among others. These studies intended to evaluate the efficacy of the sustainability strategies included in the design stage, by verifying the residents' satisfaction after three years occupancy and its comparison with the previous assessment. The tools used in the survey were interviews and questionnaires carried out with the residents of six of the settlement houses. In a general context, inhabitants are satisfied with their homes, including construction and landscape. The comparison of the results of the two post occupancy assessments, allows to conclude that the major part of obtained results were similar to the ones found in the previous study, performed in 2003, and that all users approve CETHS houses as conceived in the design.

**Keywords:** low-income house, post occupancy evaluation, environmental sustainability

## 1 INTRODUCTION

NORIE has been developing, since 1997, studies on low cost housing, that were designed in accordance with principles of environmental, social and economical sustainability.

Some of these studies include the urban and architectural design, construction and evaluation of the Centro Experimental de Tecnologias Habitacionais Sustentáveis (CETHS), which was started in 1999, in Nova Hartz [1, 2]. Nova Hartz is a small town in the metropolitan region of Porto Alegre, capital city of the southernmost State of Brazil. The design of CETHS aimed at the implementation of an urban settlement with 49 houses, based on sustainability principles and technologies applicable to low-income housing, including: local food production, jobs and income generation, passive and low energy strategies, use of low environmental impact materials, among others. CETHS has, so far, eight one-floor single-family houses, already occupied by residents. It was built by the municipality, with funds supplemented by a Brazilian public bank (Caixa Econômica Federal) [5].

In 2003 CETHS was submitted to a post occupancy evaluation on several issues that were considered in the design phase, such as: environmental comfort, building functionality and spaces appropriation by users [4]. This study intended to verify the efficacy of the sustainable strategies adopted in the design stage. However, at the time the houses were occupied for just 6 months, not long enough to allow the users to know about the building's performance during all seasons of the year.

The study presented in this paper was developed in July of 2005 and approached the same subjects of the previous research. Among the objectives, we aimed at comparing how, after 3 years of occupancy, the residents' opinion would match that of the previous study. Other topics of interest were related to materials durability and to the quality of the adopted technical solutions.

The tools used in the survey were interviews and questionnaires carried out with the residents of seven settlement houses. The questionnaires, besides resident's profile, collected information about formal and functional aspects of constructions. Visual, thermal and acoustical performances were also investigated. Results of this research are expected to

allow adapting the original design for future implementations.

## 2 CHARACTERIZATION

Nova Hartz is a small city with approximately 15,000 inhabitants. Its territorial area is around 60 km<sup>2</sup>.

CETHS has been implemented in a 2,3 ha area located in the urban perimeter of the municipal district, about 2 km far from its city centre, in an area that is still not totally urbanized. Eight houses were built according do NORIE's design and users moved in on July 2002. Six of these houses have the characteristic of being oriented with their main façade to the North direction and two of them oriented to South (Fig. 1 and 2).



Figure 1: Location of the houses (in darker shade) in the settlement.



Figure 2: General view of CETHS.

The previous study evaluated the houses having their façade oriented to North (4). The present study has also evaluated the two South oriented houses, having a floor area of 46,50m<sup>2</sup>. The other six North oriented houses have each a floor area of around 48 m<sup>2</sup>. Each house has four usable spaces: two bedrooms, a living room/kitchen and a bathroom, as can be visualised in Figure 3.

The constructional system employed ceramic bricks masonry. The walls are rendered only where a higher value for thermal or humidity insulation is justified or incident radiation and/or light reflectance requires it (mainly external south and west walls).

Foundations were made using the locally available sandstone, topped with reinforced concrete beams

(using fly ash cement). The house floor simply sits on the ground, having a layer of cement mortar topping a layer of construction rubble mixed with clay.

The roof has a structure in timber, covered with ceramic tiles, with an intermediary layer of recycled aluminum offset sheets, to minimize long wave radiation transmission. As far as possible, the timber structure was made up of recycled wood used in the formwork, being the wood from sustainable managed forests, with no toxic treatment. The same principles of minimum toxicity were also applied to the windows, made from eucalyptus and treated with linseed oil, for controlling humidity, and natural essences, for the control of termites (4).

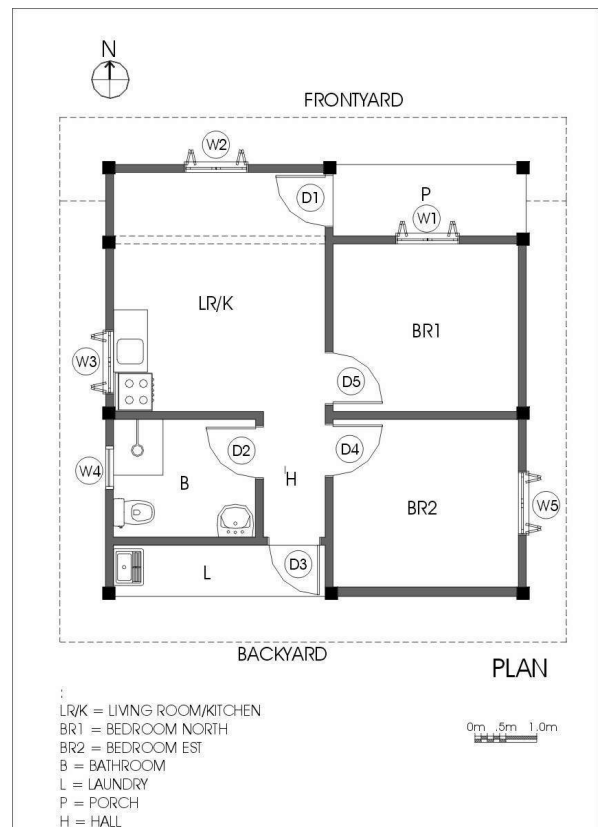


Figure 3: Plan of the house (North orientation)

## 3 RESULTS

### 3.1 Building Design

In order to assess the perception of the residents on building design, the following topics were included in the interviews:

- |  |   |
|--|---|
| 1: satisfaction with the house             | 10: aesthetic modifications (desired)                               |
| 2: satisfaction with the size of the house | 11: changes (made)  |
| 3: satisfaction with the number of rooms   | 12: changes (desired)   |
| 4: satisfaction with the kitchen           | 13: satisfaction with the windows handling                          |
| 5: satisfaction with the bathroom          | 14: satisfaction with the easiness of cleaning                      |
| 6: room too much big                       | 15: satisfaction with the artificial lighting                       |
| 7: room too much small                     | 16: satisfaction with the number of electrical switches and outlets |
| 8: space for professional work             | 17: satisfaction with easiness of access to switches and outlets    |
| 9: satisfaction about aesthetics           |   |

Table 1, below, presents the answers obtained from the interviews:

**Table 1:** Users' perception and satisfaction with the design of the house.

	HOUSE NR.						
	A39	A63	A83	B20	A20	A51	A73
1	yes	yes	yes	yes	yes	yes	yes
2	no	no	no	no	yes	yes	no
3	no	yes	yes	no	yes	yes	no
4	no	no	no	no	yes	yes	no
5	yes	yes	yes	yes	yes	yes	no
6	B	B	B	no	no	B	B
7	BR1	LR/K	LR/K	BR1/ BR2	no	LR/K	no
8	no	no	no	no	yes	yes	no
9	yes	yes	yes	yes	yes	yes	yes
10	yes	yes	no	no	no	no	no
11	yes	yes	yes	no	yes	no	yes
12	yes	yes	yes	yes	yes	yes	yes
13	yes	yes	yes	yes	no	yes	yes
14	yes	yes	yes	yes	no	yes	yes
15	yes	yes	yes	yes	yes	yes	yes
16	no	yes	yes	yes	yes	yes	no
17	yes	yes	yes	yes	yes	no	no

After the analysis of the collected data, it was verified, in relation to design's aspects, that most of the users were satisfied with the houses. However, it's important to note that they have a low income and have received of Nova Hartz's municipality the concession to use the buildings. So, a great majority comes from precarious dwellings, which increases the tolerance degree with any problem found in the given houses.

When they were asked about the housings size, 70% of the users considered the house small, since 60% of the families are constituted of more than five persons, a couple and three children, sharing an area of 48m<sup>2</sup>. The number of rooms was considered insufficient for 40% of the interviewed householders. The users suggested the addition of one more room or the enlargement of the bachelor's room.

Another two references were made regarding the house size. The kitchen is the room identified with the highest degree of dissatisfaction. Most of the users think it is small and would like to have the living room and the kitchen in separate spaces. It is interesting to point out that the opposite happens with the bathroom: 70% of the interviewees considered it larger than necessary (it was designed for universal accessibility).

The homeowners of the house A20 were the only ones totally satisfied with the house size. This dwelling, as well as B20, has a living room and a kitchen bigger than the others, and is occupied by a couple without children. They also are the only ones that think to be possible to carry out professional work at home, probably because they have a unoccupied room, available for these activities.

All homeowners considered their house aesthetically nice, and when they were asked about improvements, the only desired modification was the house enlargement.

Among the seven families, five have already made some sort of change in their house, and all of them would like to do some refurbishment. The modifications already made include the construction of a storage space/garage and the application of ceramic tiles on the floor, since the homeowners received the houses the just a cimented floor, with no floor tiles. Half of the interviewees agreed that these implementations are desirable, as well as the construction of a new bedroom and of a new kitchen, separated from the living room. A few users would like to close the laundry to avoid robberies.

The windows were considered of good quality, though 45% of the users mentioned problems with their hardware, making difficult the handling and reducing their useful life. Regarding easiness of cleaning, there was a complaint regarding the higher ventilation windows, which were considered difficult to clean, by one of the users.

All homeowners considered the number and location of lamps, switches and outlets satisfactory, but they complained about the difficulty to change lamps in the living room and kitchen, due the ceiling's height. Another complaint was regarding the electrical systems. They are apparent and were considered unsafe for a family with children.

Although issues regarding buildings' constructional problems were not included in the questionnaires, they have become obvious. It was verified that all inhabitants, in one way or other, complained about problems related to the used constructional system (determining small gaps and humidity in the walls, loose tiles, etc), as well as to poor finishing (doors and windows, floor and walls).

### 3.2 Plot

In order to evaluate the inhabitants' perception and satisfaction in relation to the plot and to the implementation of the houses, the following topics were analyzed:

- |                                     |   |
|-------------------------------------|---|
| 1: yard area size;                  | 6: changes in yard (desired);           |
| 2: backyard content;                | 7: type of plants, in backyard;         |
| 3: front yard content;              | 7: type of plants, in front yard;       |
| 4: what could there be in the yard; | 8: type of plants, in the yard;         |
| 3: activities in the front yard;    | 9: plants (desired);                    |
| 4: activities in the backyard;      | 10: characteristics of plants (desired) |
| 5: children preferred place;        |   |

Table 2, below, presents the answers obtained:

**Table 2:** The users' perception and satisfaction in relation to the plot and to the implementation of the studied houses.

	HOUSE NR.						
	A39	A63	A83	B20	A20	A51	A73
1	P	M	M	M	G	G	M
2	yes	yes	yes	yes	yes	yes	yes
3	no	-	vegetables	-	leisure	leisure	leisure
4	no	-	leisure	-	leisure	leisure	-
5	no	front back	-	front	front back	front	front back
6	vegetables	-	-	wall	vegetables	fruits	vegetables
7	yes	no	no	no	yes	yes	yes
8	yes	yes	yes	yes	yes	yes	yes
9	herbs fruits	herbs	herbs flowers	herbs	herbs	flowers	herbs flowers
10	teas spice fruits	teas flowers fruits shade	teas herbs spice fruits	teas flowers spice fruits	teas flowers spice fruits shade	teas flowers spice fruits shade	teas flowers spice fruits shade

The inhabitants' origin was a determinant factor to their perception in relation to the yard size. More than 50% of the interviewees consider it enough for an urban area. Those who consider the yard big (28%) come from urban areas or, even those coming from rural areas, had not enough space for vegetables cultivation before.

All inhabitants consider that the distance between the houses is enough, not prejudicing the residents' privacy.

Most of the inhabitants (57%) use the yard (front and backyard) for leisure activities. One of the residents has built a garage and a barbecue place (typical "gaucho's" habit). Only 43% do not have any activity in the open areas, but these yards are the preferred playing spaces for the children.

More than 50% of the inhabitants grow spices, herbs and trees. And when they were asked what else they would like to plant in the garden, all have mentioned teas, herbs and fruits, and most of them have said flowers and trees, "those which offer shade and fruits".

### 3.3 Thermal Performance Issues

In relation to the residents' perception and satisfaction with thermal performance, the following information was obtained:

- |  |   |
|--|---|
| <ol style="list-style-type: none"> <li>1. hottest room in the summer, during the day;</li> <li>2. hottest room in the summer, during the night;</li> <li>3. coldest room in the winter, during the day;</li> <li>4. coldest room in the winter, during the night.</li> <li>5. preferred place in very hot days;</li> <li>6. response action to very hot days;</li> <li>7. response action to very</li> </ol> | <ol style="list-style-type: none"> <li>10. presence of draughts inside the house;</li> <li>11. spots where draughts were noticed;</li> <li>12. presence of excessive humidity inside the house;</li> <li>13. spots where excessive humidity was noticed (mould);</li> <li>14. period of the year when excessive humidity was noticed (summer or winter);</li> </ol> |
|--|---|

8. house thermal performance, in relation to the outdoor temperature (summer);
9. house thermal performance, in relation to the outdoor temperature (winter);

15. presence of window gaps;
16. spots where window gaps were noticed;
17. condensation noticed on internal surfaces;

**Table 3:** Perception and satisfaction of the residents on thermal performance issues.

	HOUSE NR.						
	A39	A63	A83	B20	A20	A51	A73
1	LR/K	BR2	same	ind	ind	same	BR1 BR2
2	LR/K	BR1	same	ind	same	same	BR1 BR2
3	same	ind	LR/K B	LR/K B	ind	ind	LR/K
4	same	ind	LR/K B	LR/K B	ind	ind	LR/K
5	outside	outside	G	MT	outside	outside	LR/K
6	vent ext	open window	open window fan	open window fan	outside	fan	open window fan
7	close the window	close the window	close the window	windows and heater	blanked	blanked	close the window
8	5	3	4	4	5	5	4
9	4	4	5	4	5	5	5
10	yes	yes	yes	yes	yes	no	no
11	LR/K	LR/K	LR/K	LR/K	LR/K	-	-
12	yes	yes	no	no	no	yes	yes
13	B	BR2	-	-	-	roof	whole house
14	always	-	-	-	-	-	winter
15	no	no	no	yes	yes	no	no
16	-	-	-	W3 W2	W3 W2	-	-
17	no	no	yes	no	yes	no	no

The interviewees pointed out many spaces as being the hottest spaces of the house, both at night as during the day. Comparing to the first evaluation, when the hottest spaces were the bedrooms, it is possible that something has occurred, either on the tolerance of on the inhabitants perception.

Most residents, in both evaluations, prefer to stay outdoors in hot days. It reveals that the building thermal conditions are not satisfactory in the hot days of summer. Besides, sometimes the residents need to use fans. In this study, it was detected that the householders open the windows in order to improve thermal comfort indoors.

In winter, similarly to what was observed in the first evaluation, the simple act of keeping the openings shut seems to supply the residents' comfort needs. It has to do with controlling ventilation and keeping warm the inside.

In relation to the house's temperature in relation to the outdoor, in summer, six residents feel their

houses less hot than the outside. From these six, five turn on the fan, which increases their tolerance to the hot indoor conditions in summer, as it was observed in the first study. Only one declared the house to be as hot as the temperature outside.

Four interviewees pointed out the existence of excessive humidity in the house. The identified points were located in the bathroom (B), in bedroom east (BR2), in the roof. One resident identified humidity points everywhere inside the house.

In relation to the presence of window gaps through the external windows, two users identified it in the living room windows. In relation to the existence of condensation inside, one resident pointed out in the living room walls and another one identified in the roof.

The living room/kitchen (LR/K) was considered the coldest room in winter. As identified in the first study, the presence of small gaps through the external windows and doors (due to construction flaws), leads to air infiltration and causes heat losses, in winter, even when the windows and doors are shut.

In winter, all interviewees declared the houses to be less hot than outdoors. Four residents close their houses in order to protect themselves from the cold temperatures outdoors. It is possible to say that houses present favorable conditions in winter.

One reason for that, could be that in the region where the houses were built, summer is harder to stand than winter and the houses North orientation improves the solar heat gains during the winter.

As pointed out by the interviewees in both studies, it can be concluded that the houses present more favourable conditions in winter than in summer, but it is possible that small changes in the plots, like the introduction of vegetation have enhanced the summer conditions (shade and the lowering of the air temperature).

### 3.4 Luminous Comfort

Residents have considered natural illumination levels adequate to develop their daily tasks requiring good visibility. The houses were considered as offering (natural) visual comfort when user needn't have to turn on the electric lights for developing these tasks, during day period (just needing to open the louvers of the windows).

For assessing luminous comfort, the following topics were considered in the interviews:

- |  |   |
|--|---|
| <ol style="list-style-type: none"> <li>1. Need to turn on the lights, during the day, in summer;</li> <li>2. Need to turn on the lights, during the day, in winter;</li> <li>3. Rooms that need shading devices;</li> <li>4. Clearest room in summer;</li> <li>5. Darkest room in winter; 6. Clearest room in summer;</li> </ol> | <ol style="list-style-type: none"> <li>7. Darkest room in winter;</li> <li>8. Room where the interviewee accomplishes tasks that require a higher illumination level;</li> <li>9. Type of activity requiring higher illumination level;</li> <li>10. Room where children use to accomplish their homework.</li> <li>11. Why?</li> </ol> |
|--|---|

Table 4 presents the results obtained in this topic:

**Table 4:** Users perception regarding luminous comfort.

	CASA N°.						
	A39	A63	A83	B20	A20	A51	A73
1	no	no	BR2	no	no	no	no
2	LR/K	no	BR2 BR1	LR/K	no	all	all
3	no	LR/K BR2 BR1	LR/K BR2 BR1	no	no	BR2	no
4	LR/K	LR/K BR1	LR/K	LR/K	all	LR/K BR1	LR/K
5	BR2	BR2	BR2	-	no	BR2 B	BR2
6	LR/K	LR/K BR1	LR/K	LR/K	all	LR/K BR1	-
7	BR2	BR2	BR2	-	no	BR2 B	-
8	LR/K	-	-	-	BR2	LR/K	LR/K BR1
9	Shoe making	-	-	sewing	reading	-	coking reading
10	no	-	BR2	-	no	LR/K	BR2

As could be seen in table 4, six interviewees declared not necessary to turn on the lights during summer days. Only one answers that it is necessary to turn on the light in the east bedroom (BR2). Comparing with previous study, it's possible to state that results haven't changed.

Contrasting previous study, in the winter season, only two interviewees need not to turn on the lights during the day.

Curtains, or shading devices, when they are needed, are mostly so in the bedrooms, as it can be seen in table 4. Three of the interviewees have stated that a curtain was need in the living room and kitchen (LR/K), what could be explained by the high light incidence in this room. After all, six of the interviewees have pointed this room as the clearest room, even in winter as in summer. Also it is observed in answers that the preferred room, in which tasks requiring high illumination levels are performed, such as shoe making, sewing, reading and cooking, is the living room and kitchen (LR/K). However, it's not possible to conclude that these tasks are accomplished in this room only because it is the clearest.

On the other hand, the darkest perceived room was, in most of the interviews, the east bedroom (BR2), in winter and summer. Maybe it is because the window is east oriented and, consequently, oriented to neighbour house. It is possible to say, regarding visual comfort, that both this and previous studies shows very similar results.

### 3.5 Acoustical Comfort

Some potential noise sources oriented the formulation of questionnaires to evaluate residents' acoustical comfort, both outdoors as indoors. Interviewees were questioned on issues like the noise produced by traffic in the nearby road, noise produced by neighbours and also on noise generated inside the houses and their interference in the daily activities. The following topics were included in the questionnaires to assess acoustical performance:

- |  |   |
|--|---|
| <p>1. discomfort due to traffic noise (nearby road);<br/>2. discomfort due to neighbourhood noise;</p> | <p>3. discomfort due to traffic noise (local street) during the night;<br/>4. discomfort due to indoor noise;</p> |
|--|---|

Table 5 shows the obtained results regarding the users' acoustical comfort.

**Table 5:** Users' perception on acoustical comfort

	HOUSE NR.						
	A39	A63	A83	B20	A20	A51	A73
1	no	yes	no	no	no	no	no
2	yes	no	no	no	no	no	no
3	no	yes	no	yes	yes	no	no
4	no	no	no	no	no	no	yes

According to the answers, as it could be seen in table 5, only one of the interviewees has felt bothered by local traffic noises. Only one has declared uncomfortable due to neighbourhood noise. This is something different from the previous study, where half of interviewees were bothered by neighbourhood noises. A possible explanation is living-together time may cause some influence in neighbourhood acceptance. Also might be due to mutual respect.

Regarding local street noises, three interviewees have complained about car noises, a little different from the four from six who were bothered by this noise in the previous study.

Six of interviewees said to be not bothered with the noises caused indoors (radio, television, talking). This is similar to the previous results. Acoustics is quite well perceived by users, so that it is possible to say that the houses are perform well in this feature. A few complaints may be due to openings on existing gaps between the door and window frames and the surrounding masonry.

#### 4 CONCLUSIONS

By means of this second evaluation study, aimed at in this paper, it was possible to conclude that the major part of obtained results were similar to the ones found in the previous study, performed in 2003. A probable explanation is that a proposed modification in that study was not implemented. Obviously, some changes are in a planning/design level, but some could have been executed, as, for instance, mezzanines in living room/kitchen (LR/K) and in north oriented bedroom, reconsidered after first study.

In general, considering only the results of this study, inhabitants are satisfied with their houses, in relation to the building and to the plot. It is probable that some changes have been made on the building surround area, as vegetation insertion or its own growth. It is possible to infer that vegetation growth or insertion result in an increase in the users indoor summer conditions satisfaction, considering thermal comfort.

On the basis of the results obtained in interviews with CETHS houses inhabitants and with next houses

inhabitants (study performed in parallel to this, that aimed to study neighbour's houses users perception – this houses were self built by their users), there were similar opinions that can be a reference for future social interest houses design concept. Both studies pointed out, as a problem. the size of the houses, considered small, besides the kitchen location, to be integrated to the living room.

However, all users approve CETHS houses as conceived in project, as in the example of a neighbour female user who although possess a larger house previously, changed her house for a CETHS house. This user judges its current house a better residence than her previous one considering other requisites.

After all, six houses inhabitants (five were interviewed) commented that the other two houses rooms' disposal is better: the living room separated from the kitchen and the smaller bathroom, considered excessively big.

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