DESIGN CHANGES FOR ENERGY EFFICIENCY OF SOLAR DECATHLON HOUSE IN BRAZIL: A CASE STUDY "EKÒ HOUSE"

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ABSTRACT

In September 2012 the contest Solar Decathlon was held in Madrid, for the second time. One Brazilian team with its own project called the "Ekó House" was there, too. The "Ekó House" project was in development for the weather conditions in Madrid during September. Considering that the Brazilian's territory is divided in a 8 bioclimatic territory, What can we learn from the Solar Decathlon experience in order to apply it to the Brazilian case?

The objective of this paper is to modify the "Ekó House" project for achieving the best energetic behaviour in Brazil. In order to do so, the behaviour of the house will be tested by using the simulation program "Energy Plus 7.1".

INTRODUCTION

In Brazil 46.9% of electricity consumption is used by buildings: 23.8% of that in residential sector, 15% in commercial and 8.1% in public buildings (BEN, 2011). The consumption of electric energy in Brazil has grown considerably over the last twenty years. The higest increase was recorded in the residential sector.

For this reason, the use of innovative integrated technologies with the use of solar energy and passive strategies aimed at a reduction in residential consumption appears to be fundamental to modern architecture.

Founded in 2002 by the U.S. Department of Energy (DOE), the Solar Decathlon is a contest among universities of the whole world to design and build self-sufficient houses that operate using only solar energy. Since 2010, after the great success of the American edition in Washington DC, for the first time the contest was held in Madrid and took the name of Solar Decathlon Europe (SDE). During the two weeks of the competition, the participating houses are evaluated on different categories, including one of the most important: the energy efficiency (Solar Decathlon Europe, 2012). The past year, in September, the contest was held in Madrid. For the first time, among the 18 participating universities, Brazil was represented by "Ekó House", the house designed by the Federal University of Santa Catarina and the Federal University of Sao Paulo (Team Brazil, 2012).

Brazil, with its 8.5 millions Km^2 of territory, is the fifth largest country in the world. The climate conditions are very different in this territory. For this reason the country was divided in 8 climatic zones.

What will be the energy behaviour of the house in Brazil? And What possible design changes can be used to improve the behaviour of the House?

The answers to these questions are the reason of this paper.

EKÓ HOUSE

The name "Ekó House" connects "Ekó" - a native Indian word that means "way of living" and is also related to ecology - with house. For this reason natural materials and techniques of bioclimatic architecture are the base of the house project.

"Ekó House" is a rectangular small home, about 48 m^2. The house has been designed as a single large room, having no interior wall divisions. The project includes a living area with a kitchen, a study area, a bedroom and a bathroom. The house has a main south-north direction that allows a higher solar energy gaining (Figure 1).

Figure 1 Ekó House

The materials used are mostly sustainable materials, such as wood and bamboo. Several passive systems have been used in order to increase the thermal comfort of inhabitants, such as:

- Automated blinds located on the southern facade;
- Thermal insulation walls;
- Windows with double-glazed low emissivity;
- Bamboo vertical solar shadings on the eastern and western facades;
- Cross ventilation.

Besides the passive systems, the solar systems make the house self-sufficient for the electric energy and hot water production. 48 photovoltaic panels were installed on the roof for meeting the electricity needs of the house. The area of the panels is 66,65 m^2. The panels are placed at an angle of 15°. This is the maximum inclination allowed by rule of the contest.
Again on the roof, 4 solar collectors were installed, which allow hot water production.
A HVAC air-conditioned system was installed for cooling and heating the house.

Finally, the rainwater harvesting is carried out through the wetland system. All electronic and domestic appliances inside the house are low energy consuming, such as lighting that uses LED lamps.

"Ekó House", at the end of the contest, was clasified in fourteenth position.

METODOLOGY

The methodology used for the energy analysis of "Ekó House" starts from the definition of some basic parameters.

At first, the type of use of the house had to be considered. Due to its small sizes, the house has been set up to be used for a family of 2 adults (Table 1). According to the habits of this representative couple, it is possible to create an annual occupation schedule and use of various appliances in the house.

Table 1
Use of the "Ekó House"

	WEEK	WEEK-AND
HOURS	*N° of people*	*N° of people*
1 hs- 8 hs	2	2
9 hs	1	0
10 hs-16 hs	0	0
17 hs- 18 hs	1	0
19 hs-24hs	2	2
6 hs	2	2
7 hs	2	2
8 hs	2	2
9 hs	1	2
10 hs	0	0
11 hs	0	0
12 hs	0	0
13 hs	0	0
14 hs	0	0
15 hs	0	0
16 hs	0	0
17 hs	1	0
18 hs	1	0
19 hs	2	2
20 hs	2	2
21 hs	2	2
22 hs	2	2
23 hs	2	2
24 hs	2	2

For the next step, some Brazilian cities were chosen to be used as a place for testing the energetic behaviour in the house.

These cities were selected according to two factors:
- Bioclimatic zones (NBR 15220)(Figure 2);
- Solar Energy Generation (Figure 3)

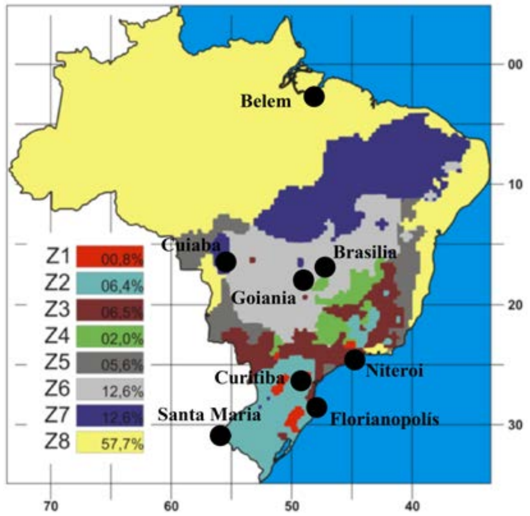

Figure 2 Brazilian bioclimatic zones

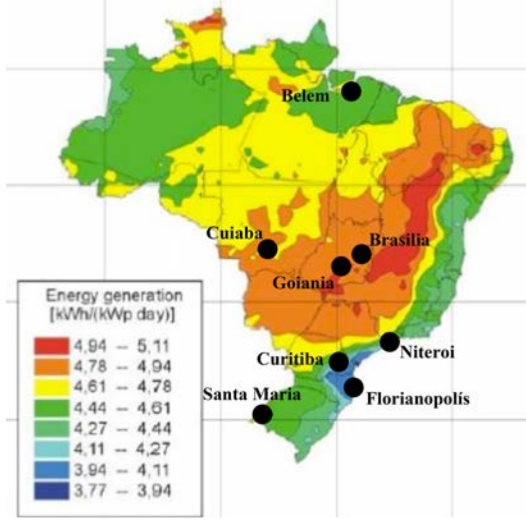

Figure 3 Solar energy generation

According to these 2 parameters, the 8 cities were chosen:
- Curitiba, Bioclimatic Zone 1, global radiation from 4.11 to 4.27 kWh / day;
- Santa Maria, Bioclimatic Zone 2, global radiation from 4.44 to 4.61 kWh / day;
- Florianopolis, Bioclimatic Zone 3, global radiation from 3.94 to 4.11 kWh / day.
- Brasilia, Bioclimatic Zone 4, global radiation from 4.78 to 4.94 kWh / day;
- Niteroi, Bioclimatic Zone 5, global radiation from 4.27 to 4.44 kWh / day;
- Goiania, Bioclimatic Zone 6, global radiation from 4.78 to 4.94 kWh / day;
- Cuiaba, Bioclimatic Zone 7, global radiation from 4.78 to 4.94 kWh / day;
- Belem, Bioclimatic Zone 8, global radiation from 4.44 to 4.61 kWh / day.

Finally, the last parameter required to start the analysis of the house was to define the indoor thermal comfort during the staying of residents. For this reason the ASHRAE Standard 55-2010 norm was used for establishing what temperature comfort must be within a range defined by the local external temperature. Then for each city a specific temperature of comfort was defined (Table 2).

Table 2
Example of Comfort Temperature in the city of Brasilia

COMFORT TEMPERATURE °C

	J	F	M	A	M	J	J	A	S	O	N	D
Max	27.1	27.2	27	27.1	26.7	26.5	26.5	27.1	27.2	27.1	27.1	26.9
Min	22.1	22.2	22	22.1	21.7	21.5	21.5	22.1	22.2	22.1	22.1	21.9

After choosing the Brazilian cities and having defined the comfort temperature for the same cities, the methodology used can be divided in 4 basic points:

- Construction of a simplified model of the "Ekó House", with your design features;

- Simulation of the Energy Balance of the house, in the 8 Brazilian cities;

- Chosen the correct design changes with the help of the Brazilians norms in energy efficiency of building and the bioclimatic study;

- Simulation of the Energy Balance of the house with the design changes, and compares the results before and after the changes.

SIMULATION

As previously mentioned, the program used to obtain the results of this research, is Energy Plus 7.1.

"Ekó House" energy model

To get to simulate the energy performance of the house, the first step was created the building geometry of the house, presented in Figure 4. This was made with the program Open Studio plugin for Goolgle SketchUp.

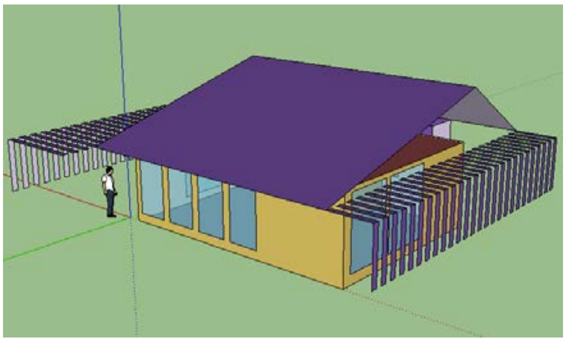

Figure 4 Geometry of "Ekó House" in Open Studio

The geometry of the "Ekó House" was created with the same characteristics of the home:

- Roof with an inclination of 15°;

- Solar shading elements in the façade have been simplified;

- Floor is not in contact with the ground, being up to 60 cm.

- The house, inside, was created as a single room, where the only interior walls are of the bathroom. For this, the home is composed of two thermal zones: the bathroom and open space room.

Another element of the sunscreen, is the blinds located on the southern façade, was created with the object "window material blind" in the program energy plus, and used when the external temperature is over of the heating temperature comfort.

The materials used have been reported in the model according to the sizes and their thermal characteristics; Table 3 contains the U-values for each layer used in the building.

Table 3
U-values for each component of the building

LAYER	U-VALUE (W/m^2K)
External walls	0,22
Internal partitions	1,73
Roof	0,22
Floor	0,22
Glazing	1,331

Created the model of the house, the next step was recreated the hypothetical use of the house. At first it represented the activity of the couple in the home. The activity- based heat gain of occupants was derived from the ASHRAE metabolic heat gain (ASHRAE, 2001). As shown the Table 4, the activity was divided in 3 different typologies:

Table 4
Metabolic heat gain

ACTIVITY	HEAT GENERATION ($W\ m^{-2}$)
Sleeping	40
Working	115
Seated,quiet	60

In agreement with the use of the house of the household (Table 1), there were created 11 schedules used for each different appliance presents in the house (Table 5):

Table 5
Appliances "Ekó House"

APPLIANCE	POWER (W)	TIME OF USE/DAY (h)
TV	92	3
Sound bar	150	0,5
Laptop	95	2
Cooktop	1000	1,5
Hood	400	0,5
Oven	3500	0,5
Refrigerator	67	24
Dishwasher	1050	0,25
Blender	400	0,25
Clothes washer	1220	0,5
Clothes dryer	2000	0,5

The same thing was done to the interior and exterior lighting; for the all lighting present in the house, LED technology was used, because it delivers both lower energy consumption with lower heat emission compared with other commercially available lighting technologies (Table 6).

Table 6

Lighting "Ekó House"

LIGHTING	ROOM	POWER (W)	TIME OF USE/DAY (h)
Interior		277	
	Kitchen	*48*	1
	Dinning room	*45*	1,5
	Work space	*56*	0,5
	Living room	*40,5*	1
	Bedroom	*65*	1
	Bathroom	*22,5*	0,5
Exterior		140	3

To conclude the section on consumption of the "Ekó House", it was created with the simulation program, the air conditioner system present in the home. The use of the air conditionar system is made to maintain the temperature comfort in the house. The air conditioner will be turned on, when the household will be at home. The air conditionar system presents the following features in Table 7:

Table 7

Air conditionar system "Ekó House"

AIR CONDITIONER	POWER (W)	COP	Btu/h
Heating	4440	3,7	15153,72
Cooling	4820	3,49	16450,66
Compressor	3500	-	11945,50

Completed the section on consumption of the house, the last step, before starting the simulate performance of the house, was creating the solar systems in the home.

The power production capability of "Ekó House" is provided with 48 photovoltaic panels model SPR 230 WHT provided by Sun Power Corporation. The modules occupy an overall area of the roof of 66,65 m^2, for a total power installed of 11,04 kWp. The modules face south with a zero azimuth (for Madrid). The inclination of the panels is 15° for the best disengagement in the competition. To reproduce the photovoltaic system in the Energy Plus, program use the object "*photovoltaic performance simple"*.

In order was created the solar collector system which allow hot water production. This is composted of 4 collector Solterm-PU200/5. The modules occupy an overall area of the roof of 3,97 m^2. The hot water tank has a capacity of 300 litres. The daily consumption of hot water by the couple is 150 litres. To verify the energy saved with the use of solar collectors, it's simulated the consumption of an electric shower with the power of 5500 W, to produce the some amount of water (150 litres/day). This study is interesting because 70% of the Brazilian population use electric shower for hot water (Rüther, 2010).

Completed the creation of the simplified model of the "Eko House" was started the first step of simulation.

"Ekó House" was simulated first for the climatic conditions of Madrid with the same orientation of the house in the contest, that is, with the main facade oriented to southward. In the Brazilian cities the house was simulated on all the four orientations.

"Ekó House" energy model with the design changes

Obtained the energy balance of the house in the analyzed Brazilian cities, the next step was changed the "Ekó House" to get a better performance in the 8 climatic zones of Brazil.

To obtain a better energy balance of the home 2 different methodologies were used:

- Brazilian Norm of residential buildings:
  - NBR 15575 that defines parameters of thermal construction of material for residential buildings (Figure 5);
  - NBR 15569 that defines the correct use and installation of solar collector;
  - NBR 10899 that defines the correct use and installation of photovoltaic panels model.
- Bioclimatic analysis of Brazilian cities object of study, with the program Climate Consultant 5.3 (Figure 6).

EXTERNAL WALL			ROOF		WINDOW FOR VENTILATION	
Zone	**U min**	**CT min**	**U min**	**α**	**A(% area of floor)**	***Shading Elements***
ZB1: CURITIBA	≤ 2,5	≥ 130	≤ 2,3	-	8%	Yes
ZB2: SANTA MARIA	≤ 2,5	≥ 130	≤ 2,3	-	8%	Yes
ZB3: FLORIANOPOLIS	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	≥ 130	≤ 2,3 ≤ 1,5	α ≤ 0,6 α > 0,6	8%	Yes
ZB4: BRASILIA	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	≥ 130	≤ 2,3 ≤ 1,5	α ≤ 0,6 α > 0,6	8%	Yes
ZB5: NITEROI	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	≥ 130	≤ 2,3 ≤ 1,5	α ≤ 0,6 α > 0,6	8%	Yes
ZB6: GOIANIA	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	≥ 130	≤ 2,3 ≤ 1,5	α ≤ 0,6 α > 0,6	8%	Yes
ZB7: CUIABA	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	≥ 130	≤ 2,3 ≤ 1,5	α ≤ 0,4 α > 0,6	5%	Yes
ZB8: BELEM	≤ 3,7 α ≤ 0,6 ≤ 2,5 α > 0,6	-	≤ 2,3 ≤ 1,5	α ≤ 0,4 α > 0,6	15%	Yes

Figure 5 *Norm NBR 15575*

With the norms and the bioclimatic analysis of the Brazilian cities, it was possible to meet the correct design changes for the best energy balance for the 8 different cities of Brazil.

The design changes were reported in the new model of the "Ekó House" created for the second part of the research. In this way it was possible to simulate the Energy Balance of the house with the design changes, and compare the results before and after the changes.

To run the all simulations of the house in the different cities, were used climate archives format EPW.

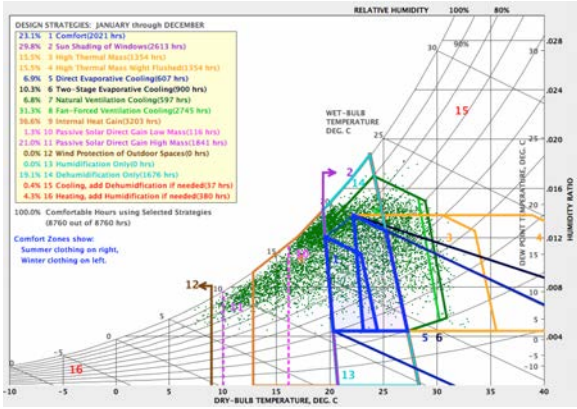

Figure 6 Example of bioclimatic study of the city of Brasilia

DISCUSSION AND RESULT ANALYSIS

The simulations performed show the results related to "Ekó House"' s performances (Figure 7).

The first step will simulate the energy balance of the house with the project of competition (Solar Decathlon) in Brazilian territory, for understanding the behaviour of the "Ekó House" project. Then will be evaluated the performances of the home with the changes design.

		CONSUMPTION	PHOTOVOLTAIC PRODUCTION	ENERGY SAVED	ENERGY BALANCE
		[kWh/Year]	[kWh/Year]	[kWh/Year]	[kWh/Year]
MADRID	S	4107	18720		***13433***
ZB1 CURITIBA	N	3725	16075	1022	***11170***
	E	3645	14900		***10075***
	S	3793	14188		***9215***
	W	4054	15475		***10241***
ZB2 SANTA MARIA	N	3929	16692	909	***11583***
	E	3805	15354		***10269***
	S	3928	14017		***8909***
	W	3958	15480		***10342***
ZB3 FLORIANOPOLIS	N	3866	13925	862	***8879***
	E	3762	13103		***8161***
	S	3841	12134		***7113***
	W	3745	13049		***8124***
ZB4 BRASILIA	N	4230	18970	868	***13560***
	E	4106	18320		***13034***
	S	4196	17450		***12074***
	W	4183	18450		***13087***
ZB5 NITEROI	N	3458	16498	821	***11860***
	E	3396	15862		***11286***
	S	3377	15211		***10654***
	W	3417	15854		***11257***
ZB6 GOIANIA	N	4291	18829	758	***13358***
	E	4226	18560		***13154***
	S	4272	18012		***12560***
	W	4305	18400		***12915***
ZB7 CUIABA	N	4859	18654	540	***12615***
	E	4732	17955		***12043***
	S	4728	17421		***11513***
	W	4782	18144		***12182***
ZB8 BELEM	N	5626	17730	552	***10924***
	E	5628	17875		***11067***
	S	5695	17551		***10676***
	W	5584	17545		***10781***

Figure 7 "Ekó House" performances

"Ekó House" of Solar Decathlon

First of all, the house was evaluated according to the conditions of Madrid, location of the contest. The annual consumption of the house lived by 2 people has been verified. As already mentioned, the temperature of comfort required for the staying of people within "Ekó House" has been determined by norm ASHRAE Standard 55-2010.

The results obtained for Madrid, show that the house have a positive energy balance: 13433 kWh per year. This is possible with a photovoltaic power generation at 18720 kWh per year. The annual consumption is 5287 kWh.

Once the results for Madrid were collected, it was then possible to analyze the results for the cities in Brazil. The house has been analyzed by orienting it at all 4 different orientations (in Madrid only the southern orientation was considered). This allows evaluating the behaviour of "Ekó House" in a more complete form.

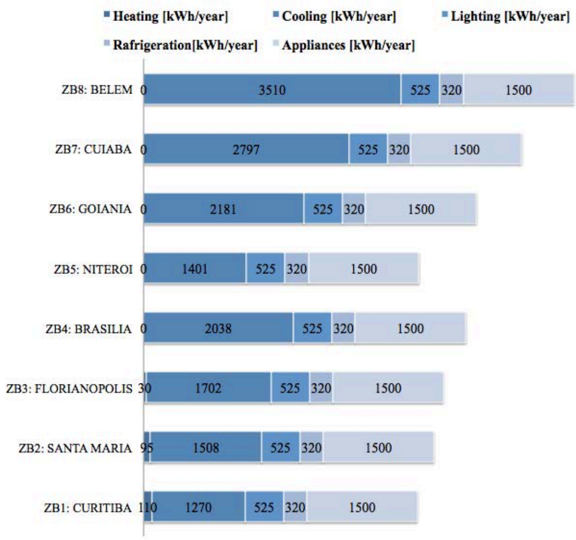

Figure 8 Total consumption in the 8 bioclimatic zones of Brazil.

Consumptions

Concerning the consumptions, the results show that the house has a very different behaviour for all different cities.

As show in Table 9, "Ekó House" in the hotter bioclimatic zone (Belem, Cuiaba and Goiania), the total annual consumption is higher. This is because the higher consumptions required for cooling and maintaining the indoor comfort temperature. In the cities of Belem and Cuiaba, more of 50% of consumption is caused for cooling. The consumption due to household appliances and refrigeration are the second and the third headings of the global consumption (Figure 8).

The energy consumption due to the use of air conditioner is the main cause for these big differences for each city. Where the climate is milder, like in the cities of Curitiba, Santa Maria and Florianopolis, consumption appears to be much lower. The different orientation of the house does not show great differences from the point of view of consumption. In general, the house oriented towards north and west presents a higher consumption in all cities (Figure 7).

Photovoltaic Production

The photovoltaic energy produced by "Ekó House" in the different cities widely varies according to the different orientation of the house. By analyzing the simulation results, it is evident that the production of photovoltaic energy is bigger in cities with northern orientation. This is more evident for the cities of Curitiba, Santa Maria, Florianópolis, Brasilia and Niteroi while in the other 3 cities the difference is less marked. In general, the higher generation of photovoltaic production there is when the house oriented towards north; the only case in which this not happen is for the city of Belem where the higher generation is for the east orientation (Figure 7).

Solar collectors

In the Figure 7 is represented also the energy saved with the solar collectors use. Given that the 4 solar collectors provide the daily consumption of hot water in all cities, the energy saved it's greater in the cooler bioclimatic zones. For example, the energy that would been used with the electric shower with power of 5500 W for hot water, in the city of Curitiba (1022 kWh/year) is almost double the energy of Belem (540 kWh/year). This proves that the importance of use of solar collectors is more in the "cooler cities" of Brazil.

Energy Balance

The results concerning the energy balance of the house are the outcome given by the difference between the energy produced and the energy consumed. It is evident, therefore, that where the production of photovoltaic energy was higher and the consumption lower, then a better energy balance was obtained. In general, the northern and eastern orientations gave the best results in almost all cities.

Overall, the best energy balance was registered in the city of Brasilia (13350 kWh/year), while the worst one was in the city of Florianópolis (8879 kWh/year).

Looking at the performance of the house in other Brazilian cities, it is possible to notice that in hot climates (Belem, Cuiaba) consumptions are very high due to high amount of energy requested for cooling the House; in a more temperate climate (Curitiba, Florianopolis and Niteroi) consumptions are relatively lower. It is interesting to analyse the production of photovoltaic energy: as previously mentioned, the energy/power produced by the house is higher in the cities of Brasilia, Goiania and Cuiaba as according to the map of solar power generation. The production of energy is much lower in the cities of Florianopolis and Curitiba.

"Ekó House" with design changes

The previous analysis has been made for understand the behaviour of "Ekó House" in Brazil. The results have shown that it is necessary to adapt the house to different Brazilian climatic conditions through design changes that improve its performance in different climatic zones.

To not change the project idea of "Ekó House", the design change will use the same materials of the house and will aim to maintain the original project. For the design changes, they were based on the Brazilian's norm and the bioclimatic study.

The first change was the mirror plan of the house. So the bedroom of the home will be found in the east orientation (also in the southern hemisphere). The other design changes were the house in contact with the ground.

Tabl

To decrease the cooling consumption was changed the composition of envelope of the house.

Table 8
Design changes "Ekó House"

Design Changes	***Cities***	Madrid	ZB1 CURITIBA	ZB2 SANTA MARIA	ZB3 FLORIANOPOLIS	ZB4 BRASILIA	ZB5 NITEROI	ZB6 GOIANIA	ZB7 CUIABA	ZB8 BELEM
Photovoltaic panels	*Number*	48	48	48	48	48	48	48	48	48
	Inclination (°)	15	25	29	27	15	22.5	16.5	15.5	1
Solar Colector	*Number*	4	3	2	2	2	2	2	1	1
	Inclination (°)	15	25	29	27	15	22.5	16.5	15.5	1
Thermal Characteristics U-value (W/m^2K)	*External Walls*	0,22	0,8	0,8	0,95	1,1	1,7	1,7	2,6	2,6
	Roof	0,22	0,8	0,8	0,95	1,1	1,7	1,7	2,6	2,6
	Floor	0,22	0,8	0,8	0,95	1,1	1,7	1,7	2,6	2,6
	Glazing	1,331	1,7	1,7	1,7	2,6	5,9	5,9	5,9	5,9
Architectural	*Layout*	-	Plant Mirrored	Plant Mirrored	Plant Mirrored	Plant Mirrored	Plant Mirrored	Plant Mirrored	Plant Mirrored	Plant Mirrored
	Floor	Up 60 cm	Contact Ground	Contact Ground	Contact Ground	Contact Ground	Contact Ground	Contact Ground	Contact Ground	Contact Ground
	Equipment	-	2 Roof Fans	2 Roof Fans	2 Roof Fans	2 Roof Fans	2 Roof Fans	2 Roof Fans	2 Roof Fans	2 Roof Fans
	Area of Window(m^2)	25,5	25,5	25,5	25,5	25,5	25,5	25,5	14,5	35,5

As shown the Table 8, for the different cities of Brazil was used a different thermal characteristics of envelope, according to Norm NBR 15575. Another design change in the bioclimatic zone 7 and 8 was modifying the windows area of the house.

For a better photovoltaic production was changed the inclination of the roof according to the latitude of the city. The inclination of the solar collector is the same of the photovoltaic panels. For the second part of simulations occurred the required number of solar collector for the hot water production of the house.

The last design change was the installation of the 2 roof fans: one in the living room and one in the bedroom. The roof fans were used to increase the ventilation and decrease the use of air condition. In the hot bioclimatic zones (ZB6, ZB7 and ZB8) the use of 2 roof fans will be turned on when the household will be at home during the year.

Reported the design changes of the house in the simplified model, the simulation was starts for the all Brazilians cities. "Ekó House", in this case, was evaluated only the best performance orientation of the past simulation.

Consumption

The Figure 9 shows the results of energy performance of "Ekó House" with the design changes.

The consumption was reduced due the design changes in all Brazilian's cities. In the hottest cities, the consumption was reducing by more than the cities in the cooler bioclimatic zones.

In the cities of Belem and Cuiaba the annual consumption was reduced by 25 %. This is due to change in the thermal characteristics of envelope of the house, allow decrease the consumption for cooling of "Ekó House" (Figure 10).

CITY DESIGN CHANGES		CONSUMPTION	PHOTOVOLTAIC PRODUCTION	ENERGY BALANCE
CITY SOLAR DECATHLON		[kWh/Year]	[kWh/Year]	[kWh/Year]
ZB1: CURITIBA	N	***3570***	***16220***	**12650**
ZB1: CURITIBA		*3725*	*16075*	12350
ZB2: SANTA MARIA	N	***3640***	***16950***	**13310**
ZB2: SANTA MARIA		*3929*	*16692*	12763
ZB3:FLORIANOPOLIS	N	***3400***	***14220***	**10820**
ZB3:FLORIANOPOLIS		*3866*	*13925*	10059
ZB4: BRASILIA	N	***3407***	***18970***	**15563**
ZB4: BRASILIA		*4240*	*18970*	14730
ZB5: NITEROI	N	***2905***	***16620***	**13715**
ZB5: NITEROI		*3458*	*16498*	13040
ZB6:GOIANIA	N	***3365***	***18925***	**15560**
ZB6:GOIANIA		*4291*	*18829*	14538
ZB7: CUIABA	N	***3640***	***18732***	**15092**
ZB7: CUIABA		*4858*	*18654*	13796
ZB8: BELEM	E	***4021***	***17990***	**13969**
ZB8: BELEM		*5628*	*17875*	12247

Figure 9 *"Ekó House" performances with design changes*

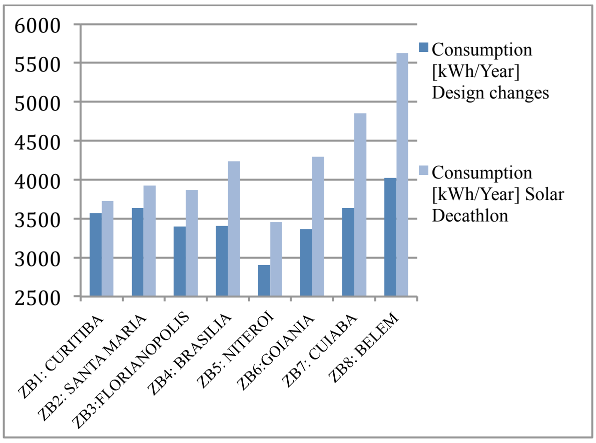

Figure 10 Consumption before and after design changes of "Ekó House"

Photovoltaic Production

The photovoltaic energy production, with the change of correct inclination of the roof, has not provided significant changes. The improvement of energy generation with the photovoltaic panels is more evident in the cities of Santa Maria, Curitiba and Florianopolis; however the annual energy production increased around 2% (Figure 11).

Solar collectors

The results concerning the solar collectors have demonstrated that the installation of 4 solar collectors in the "Ekó House" is disproportionate for the use made for the family of two people in all cities of Brazil. That shows the table 10: for hotter bioclimatic zones it's sufficient 1 solar collector. Already in the city of Curitiba, are necessary 3 solar collectors for satisfying the annual hot water demand.

Energy Balance

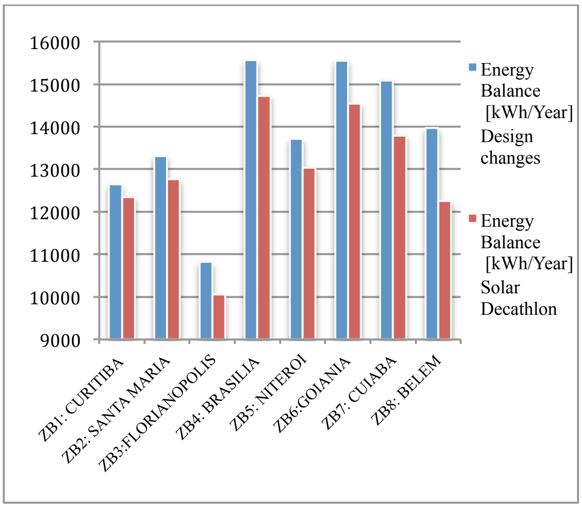

Figure 11 Energy Balance before and after design changes of "Ekó House"

In all the cities analyzed, through the design changes, the energy performances are improve (Figure 12).

In the cities where the energy consumption is more reduced, the energy balance had a greater improvement. Belem, Cuiaba and Goiania are the cities with the higher greater energy balance.

Overall, the best energy balance continues to be for the city of Brasilia (14383 kWh/year), while the worst continues to be for the city of Florianópolis (9640kWh/year).

CONCLUSION

The objective of this work is to demonstrate how "Ekó House", a self-sufficient house, designed for the city of Madrid shows different behaviours, if placed in Brazil. For this reason, through design changes of the house, it's possible to improve the energy performance and the thermal comfort of this home.

The energy performance data for this house has shown that the "Ekò House" is the home designed for colder and drier climate. Looking at the performance of the house in all Brazilian cities, it is possible to notice that in hot climates (Belem and Cuiaba) consumptions are very high due to high amount of energy requested for cooling the house; in a more temperate climate (Curitiba, Florianopolis) consumptions are relatively lower. For this reason the design changes of envelope of the house together the other design changes (floor in contact with the ground, modify of area of windows, and increase of mechanical ventilation) are fundamentally for the best energy performances and for a high levels of thermal comfort.

The modify of correct inclination of the roof for the all Brazilian cities hasn't more increase the energy produce with the photovoltaic system.

Very important was the analyses of the solar collector system. It was demonstrated the importance for the energy saved with the use of solar collectors in Brazil. It was also verified that 4 solar collectors installed for the use of "Ekó House" are not essential.

This research has shown that for the correct use of "Ekó House" in the different bioclimatic zones of Brazil are required some design changes, that don't change the original project of the house, but allow an improve the energy performance and the thermal comfort of the home.

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