DETERMINATION OF ENERGY INDEX FOR HOTELS IN BRAZIL

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Abstract. *Due to the increasing concern regarding environmental impact. together with the advent of LEED certification (Leadership in Energy & Environmental Design). the simulation of energy building performance gained great importance. Also the need of energy performance reference became more and more important. Among the several simulation tools that are available. EnergyPlus® is validated as a tool for LEED certification due to its capabilities of simulating building using heat balance models with partial load for building systems (lighting. lifts. air conditioning. etc.). ASHRAE Standard 90.1 provides guidelines for defining parameters that provides benchmarks for energy consumption of building with different occupancy schedules (offices. hotels. malls. etc.) This paper presents the results obtained when the guidelines of Standard 90.1 are applied for a virtual hotel operating in five different Brazilian cities (São Paulo. Rio de Janeiro. Porto Alegre. Brasília and Belém). In order to evaluate the energy consumption profile of such hotel. EnergyPlus® were used to simulate the energy performance of the virtual hotel and the results were used to evaluate an energy index that might provide a benchmark for normalized energy consumption for hotels in Brazilian cities. The energy matrix obtained from the simulation shows that the largest part of the power consumption corresponds to the HVAC system. A sensibility analysis of some variables (occupancy. lightning power density. COP. etc.). was made and provided some insights for the energy behavior of such buildings. Finally. some indexes such as kWh/m².ºC .month and kWh/m².ºC .year were analyzed for five different climate regions of Brazil. One can verified that these indexes can provide a good forecast of the energy consumption for economic hotels in Brazilian climate conditions.*

Keywords. Energy index. building simulation. building performance.

1. Introduction

The increasing importance of sustainable design in human activities. according to Carlo (2008). is based on the growing energy consumption per capita. affecting developed countries such as USA. Australia. Japan and Germany. as well as developing countries such as Brazil. Most of the energy production in those countries is provided by non-renewable energy such as fossil fuels that has very negative effects for the environment.

According to ANEEL (2010) most of the electrical energy source provided from water has been already used in Brazil. The financial and environmental limits to building more power plants based on the water resources are pushing the Brazilian efforts in this area to use other non-renewable sources such as thermal plants that requires fossil fuels that imposes the dispersion of pollution in the environment.

According to Hernandez Neto (2009) there is a tendency in Brazil not only to use alternatives sources of energy but also an increasing concern to the development of policies for more alternatives to achieve higher efficiency levels in energy consumption. According to Guia Construir Fácil(2009) and INFRA (2009). there is an increase of the number of buildings projects that are requesting LEED certifications (*Leadership in Energy and Environmental Design*). developed by USGBC (*United States Green Building Council*).

According to Hernandez Neto (2009) Procel Edifica is a voluntary enrolment program developed by Brazilian government in order to promote more efficient building projects that it will become obligatory by 2012. Therefore. the Brazilian government has been introducing ways for the buidling projects become more and more efficient and sustainable.

This paper presents the evaluation of the energy performance of a virtual hotel which its occupancy schedules. materials and system efficiencies are based on the guidelines of the Standard ASHRAE 90.1-2007 (2007). The energy consumption profiles will be simulated using the toll EnergyPlus® for five different Brazilian cities (São Paulo. Rio de Janeiro. Porto Alegre. Brasília and Belém). Based on the simulations. an sensitivity analysis of an energy index are presented in order to provide a benchmark for the energy consumption of such buildings.

2. Literature review

According to Priyadarsini et al. (2009). the energy consumption index (kWh/year.m^2) of a hotel is closely related to the building type. hotel size and the luxury level provide to hotel occupants. Priyadarsini et al. (2009) classified hotels based on the number of rooms (Figure 1). i.e.:

- Small (less than 50 rooms)
- Medium (from 50 to 150 rooms)
- Large (more than 150 rooms)

Priyadarsini et al. (2009) also classified the hotels based on the level of luxury (Figure 2) which is directly related to the average size of the rooms:

- one and two stars: 22 m^2 per room
- three stars: 32 m^2 per room
- four and five stars: 42 m^2 per room

Hotel	Area (m2)	Year	Retro-fit	Rooms	Stars	Pools	Laundry	Emplo-yees	Electri-city (GWh)	Gas (MWh)	Die-sel (MWh)
1	42.483	1979	2000	439	5	1	1	280	12,6	1.546	5.136
2	20.799	1985	-	413	5	1	0	150	9,3	144	1.004
3	32.124	1992	-	254	5	1	1	270	15,7	2.120	-
4	27.829	1992	-	459	5	1	0	170	10,1	764	-
5	101.998	1969	2003	1200	5	1	0	500	31,8	2.848	8.402
6	37.809	1999	-	540	5	1	1	295	16,3	3.953	10
7	35.972	1969	2000	422	5	1	1	200	11,2	839	3.880
8	34.293	1982	2003	575	5	1	0	195	13,8	1.619	-
9	43.473	1993	-	509	5	1	0	200	17,5	690	-
10	50.470	1982	-	775	5	1	1	570	21,5	2.293	6.084
11	94.000	1977	2002	751	5	1	1	600	27,5	3.432	6.386
12	37.877	1995	-	476	4	1	1	100	11,5	2.158	-
13	19.206	1984	1997	354	4	1	0	161	9,0	1.054	915
14	25.916	1995	-	546	4	1	1	150	10,1	1.144	20
15	23.018	2000	-	539	4	1	0	195	10,8	611	-
16	17.194	2004	-	380	4	1	0	100	6,5	432	-
17	21.260	1996	-	299	4	1	0	70	6,3	452	-
18	27.291	1973	-	529	4	1	1	284	12,4	927	0,5
19	14.742	1998	2003	393	4	1	0	67	6,0	26	-
20	26.866	1969	1998	387	4	1	0	70	8,4	16	684
21	28.546	1980	-	402	4	1	0	120	10,1	444	5.188
22	19.410	1996	-	330	4	1	0	160	8,6	889	-
23	50.959	1980	-	653	4	1	1	320	25,3	3.096	-
24	49.424	1982	2002	380	4	1	1	270	15,5	1.209	1.184
25	28.112	1985	1993	440	3	1	0	85	6,9	826	-
26	18.133	1984	2001	272	3	1	0	125	4,8	49	754
27	20.591	1982	2002	229	3	1	0	90	5,3	276	482
28	1.648	1929	2002	32	3	1	0	12	0,4	116	-
29	24.394	1983	2002	472	3	1	0	80	5,4	1.062	-

Figure 1. Annual energy consumption index based on the number of rooms (adapted from Priyadarsini et al. 2009).

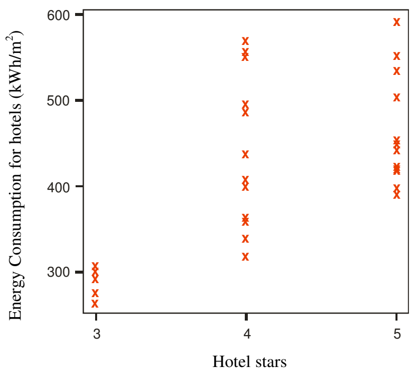

Figure 2. Annual energy consumption index based on hotel stars classification (adapted from Priyadarsini et al. 2009).

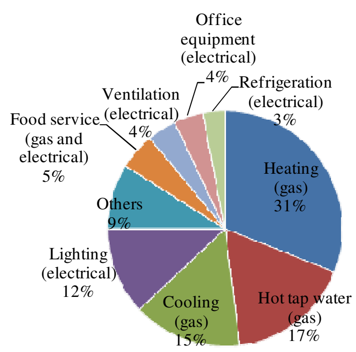

Figure 3. Electrical energy and gas distribution for a typical hotel (US EPA. 2008 apud HENDRIKX. 2008).

Based on Figure 3. one can observe that three stars hotels have a annual energy consumption from 250 to 300 kWh/m^2. For four and five stars hotels. one can notice a wider range for the annual energy consumption (from 300 kWh/m^2 to 600 kWh/m^2).

Priyadarsini (2009) proposed a division of the hotel into three zones : rooms. public area (lobby. restaurant. meeting rooms. pool. etc.) and service area (kitchen. offices. laundry. etc.). The division was made based on the different demands for each area where. for example. the thermal comfort (therefore energy consumption from the air conditioning) is different from service area.

Regarding the energy source. Hendrikx (2008) proposes that 40% of the energy used in a hotel is form electrical and the others 60% from natural and oil and the use for such energies are:

- Hot water or vapor for taps. showers and kitchen services. Central heating is distributed by radiators in the rooms or by the air conditioning system
- Chilled water for air conditioning systems and dehumidification system usually produced by vapor compression system.

The electrical source of energy is used for several purposes where the two main purposes are lightning and air conditioning and secondary ones are refrigeration cases. pumps for heated and cooled water (Figure 4). Hendrikx (2008) not only showed the distribution of energy use but also that . for small and medium hotels. the consumption of fossil fuel varies from 196 kWh/m^2.year to 286 kWh/m^2.year and the consumption of electricity varies from 71 kWh/m^2.year to 83 kWh/m^2.year. For large hotels. the consumption of fossil fuel varies from 220 kWh/m^2.year to 350 kWh/m^2.year and the consumption of electricityvaries from 100 kWh/m^2.year to 143 kWh/m^2.year.

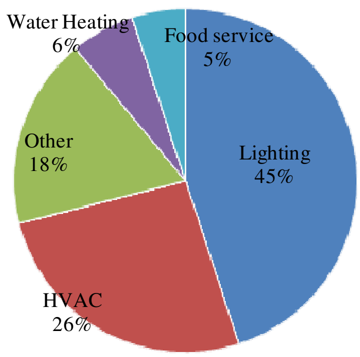

Figure 4. Electrical energy in a typical hotel (US EPA. 2008 apud HENDRIKX. 2008).

Carlo (2008) proposed that more standards should be created as a tool to achieve higher levels of energy efficiency. Lamberts (1997) proposed. based on the study of several standards for energy efficiency in different countries. a methodology that describes several actions in order to increase the effectiveness of the energy sector. Both authors draw our attention to the importance of the elaboration of standards for the reduction of energy consumption. They also mentioned that it should have more efforts in this direction to prevent future problems on the supply of electrical energy.

According to some benchmarking studies of the department of industry. tourism and resources of the Australian government (AUSTRALIAN GOVERNMENT. 1999). the best energy index for tourism and business hotels are 208 kWh/m^2.year e 292 kWh/m^2.year. respectively.

3. *Energy Plus®*

Energy Plus is a simulation tool that evaluates the thermal performance of buildings and its systems such as air conditioning. heating. lighting. etc. (U.S. DEPARTMENT OF ENERGY. 2010). The tool is developed by the USA Department of Energy and it is validated by the method BESTEST. described on Standard ASHRAE 140 (ASHRAE. 2001). Energy Plus is based on the method of the energy balance which is highly recommended by ASHRAE for energy analysis (STRAND et al.. 2001). The tool can simulate air conditioned and non air conditioned buildings for different climate and geographical locations.

4. Description of the virtual hotel

The geometry definition of the virtual hotel was based on the plans of a hotel classified as economic in the city of São Paulo. The building has 19 floors with 21 rooms each for the rooms and one ground floor for the lobby. restaurant and offices as well as for the parking area. All the rooms are supplied with chilled water for the air conditioning as well heated water for the taps and showers. The materials used to describe the walls and windows are based on the guidelines of ASHRAE 90.1 -2007. as shown in Table 1.

Table 1. Main thermal characteristics of the building envelope.

Surface	**Global Heat Transfer Coefficient [W/m^2.K]**
External walls	0.70
Roof	0.36
Floor	0.30
Windows	4.25 (SHGC=0.25)

Regarding the thermal zones division. the floor was divided into four zones as shown in Figure 5. This division was implemented based on the results of Mariana (2008) where it was found that this division for such hotel type provides the best simulation results comparing to an annual energy consumption of an existing economic hotel.

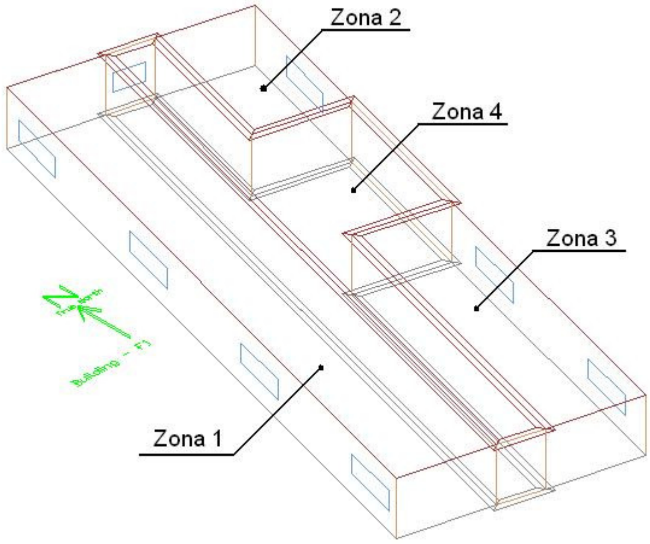

Figure 5. 3D Model of a typical of the virtual hotel.

The schedules of occupancy. lightning. electrical equipments and lifts were based on the guidelines of user´s manual of Standard 901.-2007 (ASHRAE. 2007). The maximum loads of each schedule were determined based on the studies made by Mariana (2008) where the author evaluate through technical visits in a typical economic hotel the nominal capacity of each load. The infiltration flow rate was determined based on the specifications of Standard NBR 16401 (ABNT. 2008) (see Table 2). Also. the users´s manual of Standard 90.1-2007 (ASHRAE.2007) provides a percentual hourly profile for a 24 hour typical day for a hotel for each load. as shown in Figure 6.

Table 2. Nominal values of internal loads and air renovation rate for each zone of the typical floor of a economic hotel.

Zone	**Occupancy [persons]**	**Lightning [W]**	**Equipments [W]**	**Infiltration [m^3/s]**
1	20.8	1488	402	0.1231
2	5.2	372	108	0.0305
3	10.4	744	216	0.0611
4	1.8	224	0	0.0921

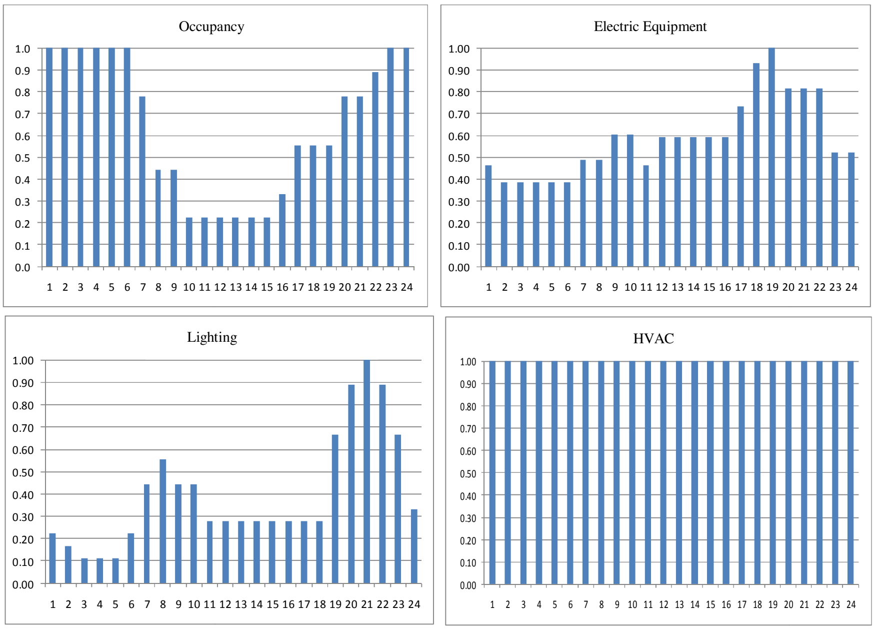

Figure 6. Hourly profile of occupancy. lightning. electrical equipments and HVAC systems in a typical day for an economic hotel (adapted from ASHRAE. 2007).

For the city of São Paulo. the design of the air conditioning was based on the simulation made by EnergyPlus® for a summer design day. The system that was chosen is a chilled water system with a reciprocating compressor with cooling tower as condensers. For such system. the COP of the chiller is determined as 4.45. based on the recommendations of Standard ASHRAE 90.1-2007 (ASHRAE. 2007).

5. Simulations result for São Paulo

After the definition of the building envelope and the internal loads. a first annual simulation was made using the climate data of São Paulo where the percentual distribution of each end-uses system is calculated and presented in figure 7. One can observe that the air conditioning system has the highest contribution followed by electrical equipments.

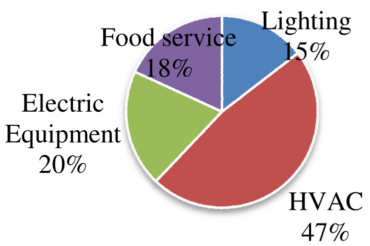

Figure 7. Percentual distribution of annual energy consumption of each end-uses for an economic hotel in São Paulo

6. Sensitivity analysis

In order to evaluate the impact of certain parameters in the evaluation of the energy consumption. a sensitivity analysis was carried out. For such evaluation. a ±20% variation was imposed to a group of parameters related to the building envelope. internal loads and air conditioning. For each parameters analysis. the others parameters were kept with the value initially imposed and an annual simulation was carried on. After finishing the simulation. the results are compared with the annual energy consumption without any variation (here it will be called reference). The parameters used for such analysis are: occupancy density. electrical equipment load. lightning power density. air infiltration rate. chiller COP and heater efficiency. heater electrical demand.

The results of those simulations are showed in Table 3 where one can observe that the most influential parameter is chiller COP (±6.7%) followed by the occupancy density (±6.4%). In third place. one will find the heating systems (±4.6%) with the electrical equipments being with the lower impact.

Table 3. Summary of the sensitivity analysis of the annual energy consumption of a hotel in the city of São Paulo.

Parameter	**Annual Energy consumption per building area (kWh/m²)**			**Variation**
	Min	Max	Reference	
Occupancy density	163.7	186	174.65	±6.4%
Electrical equipments	172.45	176.86	174.65	±1.3%
Ligthning	168.74	180.63	174.65	±3.4%
Air infiltration rate	170.9	178.8	174.65	±2.3%
Hot water efficiency	166.47	182.55	174.65	±4.6%
Chiller COP	165.3	188.7	174.65	±6.7%

7. Energy index for hotels

One of the goals of this study is to develop a energy index for hotels that can be used as a benchmarking for building with similar usage in Brazil. One can observe Figure 8 where a first attempt is presented and it was evaluated simulating the virtual hotel shown before for five different cities. in order to evaluate the impact of the climate data in such index. Based on those results. an average energy index was calculated (191.6 kWh/m^2.year) and comparisons with these indexes calculated for each city demonstrated that this index is not the most suitable definition for such type of building. A variation of ±9.8% was found when comparing the average index with the value evaluated found for each city. which can be considered quite high for such index.

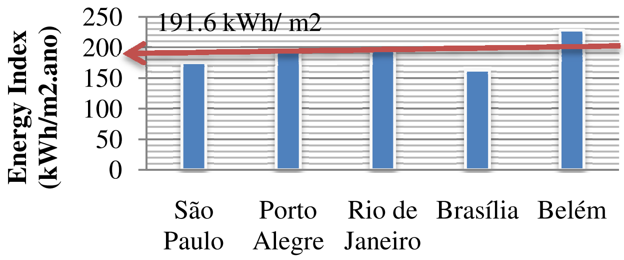

Figure 8. Energy index for 5 Brazilian cities.

Another attempt to develop a more suitable index was tried where the ratio between the monthly energy consumption and the building area was divided by the monthly average of the dry bulb temperature. Figure 9 shows the results provided by this new energy index and one can observe that no significant improvement was obtained. specially for the period between May and September.

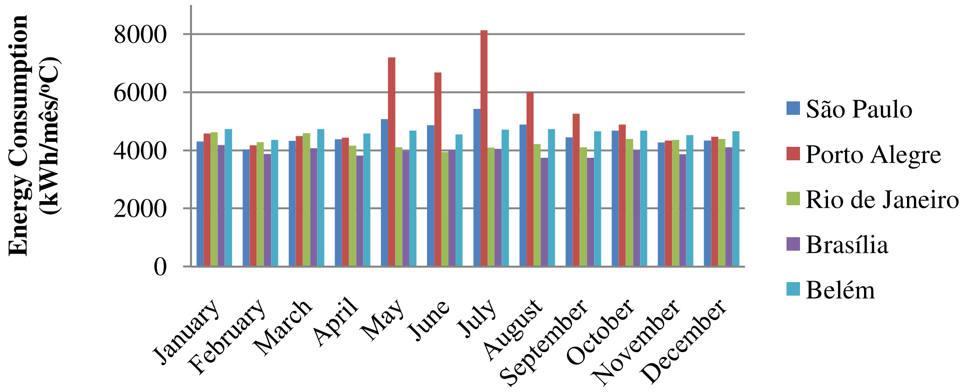

Figure 9. Energy index corrected by the monthly average dry bulb temperature.

Among the several systems used in a building. the air conditioning and heating systems are the most sensitive to climate changes and the air conditioning system has the highest energy consumption. Therefore. another attempt for evaluating an energy index was made where the energy consumption from the air conditioning system was separated from the building total energy consumption. Figure 10 shows the results of the annual energy consumption of the air conditioning system divided by total building area against the annual average dry bulb temperature. One can observe a good linear correlation was found and a variation of ±4.4% was found when comparing the average index with the value evaluated found for each city.

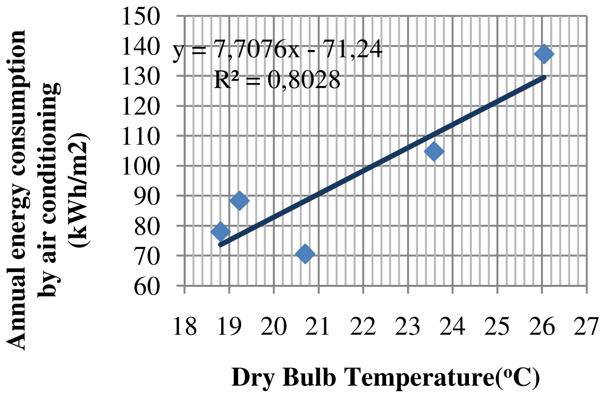

Figure 10. Comparison of the annual energy consumption of the air conditioning system and the annual average dry bulb temperature.

Using the linear regression equation shown in Figure 10 and adding the energy consumption of the lighting. electrical equipments (which are constant regarding the climate) and heating per total building area. an energy index was calculated and the results were compared to the annual energy consumption of the simulated virtual hotel in Table 4. One can observe that for the cities of São Paulo. Porto Alegre and Rio de Janeiro the difference is quite low (less than 2.5%) but it was found a difference of 11% for the cities of Brasília and Belém.

Table 4. Comparison of proposed and simulated energy index for each city.

City	Air conditioning annual energy consumption per total building area	Lightning & electrical equipments annual energy consumption per total building area	Heating system annual energy consumption per total building area	Proposed annual energy consumption per total building area	Simulated annual energy consumption per total building area	Percentual difference between proposed and simulated results
São Paulo	78.0	91.6	3.7	173.3	177.6	-2.4%
Porto Alegre	88.3	91.6	12.5	192.4	188.2	2.2%
Rio de Janeiro	104.8	91.6	0.0	196.4	194.7	0.9%
Brasília	70.6	91.6	0.0	162.2	182.2	-11.0%
Belém	137.2	91.6	0.0	228.8	205.5	11.3%

In order to improve the results for the cities for the Brasília and Belém. a regression based on quadratic equation was done correlating the monthly energy consumption of the air conditioning and heating systems per total building area with average dry bulb temperature of each month of each city climate data (see Fig. 11). One can observe that this regression did not quite improve the prediction of the building energy consumption with difference of ±11.8%.

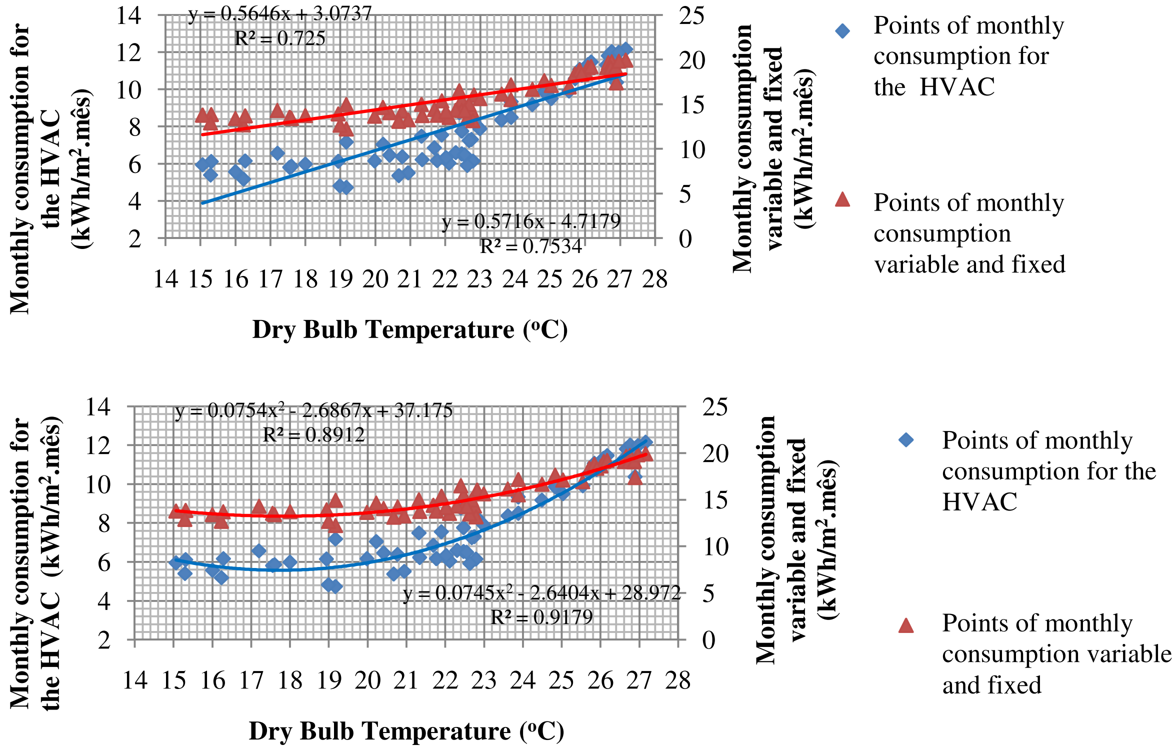

Figure 11. Regression of the monthly energy consumption for the air conditioning. the heating system and the whole building with the monthly average dry bulb temperature.

8. Conclusions

This paper proposes to analyze different possibilities for an energy consumption index for hotels located in 05 Brazilian cities. In order to evaluate the energy consumption of such hotels. a virtual hotel was simulated using the simulation tool EnergyPlus® for the cities of São Paulo. Rio de Janeiro. Porto Alegre. Brasília e Belém. A sensitivity analysis was carried in order to identify the more relevant parameters for the prediction of energy consumption of hotels. The results of such analysis showed that the performance of the air conditioning system and the level of occupancy are the most relevant parameters for the evaluation of the energy consumption index.

During the analysis. it was found that. by evaluating the energy consumption index separately for the air conditioning&heating energy consumption. a better prediction of the annual energy consumption index could be provided. This energy index provided a prediction for the total building energy consumption index within a range of ±11%. using the average dry bulb temperature as prediction variable. which is still quite high for benchmarking purposes. For future studies. the inclusion of the average COP of the air conditioning &heating should be included as a new parameter in the regression equations as well as the number of climate data should be increased in order to better predict the energy consumption of hotels in different climates in Brazil.

9. Acknowledgements

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