Knowledge E
Engaging minds

Conference Paper

Carbon Footprint Inventory of Buildings in Isabela State University: Benchmark for Future Design Alternatives

Geraldine J. Paguigan[1] and Daniel C. Jacinto[2]

[1]Assistant Professor I, Isabela State University, Ilagan, Isabela
United Architects of the Philippines
[2]Professor V, Associate Dean Institute of Business Management, Isabela State University, Cabagan, Isabela
Philippine Institute of Civil Engineers

Abstract

Energy consumption of buildings was accounted for forty percent (40%) in the burning of fossil fuels that contributed to global warming. Climate change will continuously increase the global temperature in the coming years and this has resulted to the increased demand for energy consumption for cooling and ventilation for the indoor temperature in buildings. The study aimed to determine the carbon footprints of the buildings using the carbon footprint calculator to serve as a benchmark for future design of buildings at Isabela State University in Garita, Cabagan, Isabela. As revealed in the study, the rise in temperature, number of electrical fixtures used for cooling and ventilation, number of floor levels and number of occupants are the factors which influences the increase in the energy consumption of the buildings. Generally, the electrical fixtures used for cooling and ventilation were proven to be with the highest carbon footprint contribution. Hence the researchers recommend to adapt green building technology for future designs of buildings in the campus.

Keywords: carbon footprint, energy consumption

Corresponding Author:
Geraldine J. Paguigan
archjpaguigan@yahoo.com

Received: 23 April 2018
Accepted: 8 May 2018
Published: 4 June 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the IRCHE 2017 Conference Committee.

OPEN ACCESS

1. Introduction

Climate Change is a global concern and as a result to this was the creation of Climate Change Act 2009, under Republic Act 9729 in the Philippines which is the an act mainstreaming climate change into government policy formulations, establishing the framework strategy and program on climate change. Scientific evidences show that our climate is changing and the average temperatures will increase by several degrees over the coming century. Greenhouse gas (GHG) emissions, released into

How to cite this article: Geraldine J. Paguigan and Daniel C. Jacinto, (2018), "Carbon Footprint Inventory of Buildings in Isabela State University: Benchmark for Future Design Alternatives" in *4th International Research Conference on Higher Education*, KnE Social Sciences, pages 506–521. DOI 10.18502/kss.v3i6.2401

the atmosphere in ever rapidly growing volumes are responsible for this change. (G. Magatti,C.Bellantoni, M. Cavallotti, R. Benocci, M. Gualtieri, M. Camatini *2013).*

The Carbon footprint (CF) is defined by JRC (2007) as the overall amount of carbon dioxide (CO_2) and other GHG emissions (e.g., methane, laughing gas, etc.) associated with a product (goods or services) along its supply-chain. CF is therefore a useful indicator to calculate the emission as a baseline information to determine the priority for impact reduction.

Buildings are the biggest source of emissions and energy consumption. Buildings are responsible for more than 40 percent of global energy use and one third of global greenhouse gas emissions, both in developed and developing countries.

Energy consumption is said to be the number one contributor to global warming. Solutions on how to mitigate climate change is to design low or no-energy use in buildings. To design for climate change is to optimize the features of a specific site and minimizes the potential extreme energy use (Evans, 2002).

The Isabela State University is an institution which serves a population of students, faculty and personnel which require in maintaining and growing their own facilities. The growing population in the university will need additional buildings to support the various activity of the university in terms of instruction, research, extension, production and administration. The very main objective of the university to offer quality education would necessitate buildings that will provide quality environment both on the outdoor and indoor.

2. Objectives of the Study

The study analysed the Carbon Footprint emission of the academic buildings in the campus. It specifically aims to determine the annual level of total carbon footprint of the five academic buildings in five years. The study seeks to determine what year has the highest and least value of carbon footprint emission and determine the significant difference between buildings as regards to their carbon footprint emission.

3. Significance of the Study

This study aims to evaluate the carbon footprint emission of the buildings in order to establish a baseline data that could help the university management in coming up with new design alternatives for the future buildings of the campus at the same time to establish new policies on energy conservation practices in the campus.

4. Scope and Limitations

Carbon Footprint has a very wide scope and definition. For this particular study, the researcher specifically focus on the Carbon Dioxide (CO2) emission produced through the energy consumption of the buildings.

5. Methodology

Five academic buildings were evaluated in this study. The carbon footprint emission of the buildings were computed using the carbon footprint calculator which was downloaded from the website of timeforchange.org The secondary data on energy consumption of the buildings were sourced out from Isabela Electric Cooperative (ISELCO) II in Ilagan, Isabela which is the agency in charge of monitoring in the energy consumption of buildings in Isabela. The monthly energy consumption of the buildings from CY 2011 to 2015 were considered and computed. The total annual energy consumption of the five buildings were computed and converted the carbon footprint emission. Table I below shows the composition of electricity and conversion factor for Carbon Dioxide with the formula as shown below:

Formula:

Carbon Footprint = kilowatt hour x weighted factor

Where:

Kilowatt Hour = total energy consumption in kilowatt hour

Weighted factor = Composition of electricity x Conversion Factor for CO_2

Figures, tables and graphical presentation was made to compare the carbon footprint emission by each building. Analysis of variance was used to determine the significant difference of the carbon footprint emission of the buildings on the five(5) year trend.

6. Results and Discussion

The study site was conducted in Luzon, Region II which is the northern part of the Philippines. It is specifically located in Isabela State University, Cabagan, Isabela. The site is under Type III Climate wherein there is no very pronounce maximum rain period

Table 1: Composition of Electricity and Conversion Factor for Carbon Dioxide.

Composition of Electricity	% share	Unit	Qty. in SI Unit	Conversion Factor for CO2	Kg. of CO2 Produce
coal	26%	kWh	26	0.9	23.4
oil	30%	kWh	30	0.7	21.0
natural gas	20%	kWh	20	0.36	7.2
nuclear energy	20%	kWh	20	0.02	0.4
hydroelectric	2%	kWh	2	0	0
PV solar	0%	kWh	0	0.05	0
wind	0%	kWh	0	0.01	0
geothermal	0%	kWh	0	0.03	0
wood	0%	kWh	0	0	0
waste	2%	kWh		0	0
Sum	100.00%			Weighted factor	**.5200**

Source: http:timeforchange.org

with a dry season lasting only about one to three months, either during the months from December to February or during the months from March to May.

The municipality of Cabagan is a first class municipality in the province of Isabela. It is bounded by the municipality of Sta. Maria and San Pablo in the North, by the municipality of Tumauini and Sto. Tomas in the South, secured by the Sierra Madre Mountains in the East; and bounded by the municipality of Quezon and Kalinga in the West. According to the 2015 census, it has a population of 50,174 people. It is locally known for its "Pancit Cabagan". Its people are called Ybanags.

The five buildings in the study is specifically located in Isabela State University in Garita campus, Cabagan, Isabela is situated at 17°24′45″ latitude and 121°49′15″ longitude and with a total land area of 254 hectares. The campus is about five (5) kilometers away from the poblacion of Cabagan, Isabela. The College of Teachers Education (CTE) Building, College of Forestry and Environmental Management (CFEM) Building, College of Development Communication and Arts and Sciences (CDCAS) Building, Department of Social Sciences (DSS) Building and Provincial Technical Institute of Agriculture (PTIA) Building are the buildings that were evaluated in this study. Figure 1 shows the location of Cabagan, Isabela in the Northern Luzon.

Figure 1: Map of Cabagan Isabela showing the location of ISU Cabagan.

7. Characteristics of the Buildings

The PTIA building has the biggest floor area with 1,488 sq.m. Second is the CTE building with 1,400 sq.m. Third, are the buildings with typical plan and design namely CDCAS, CFEM and DSS building with 1272 sq. m. All the five (5) buildings have the same building materials with concrete foundations, plastered concrete hollow blocks on walls, steel windows and wooden doors and corrugated galvanized iron sheets on roofing. Four (4) out of the five (5) building are two-story buildings which are the CDCAS, CFEM, DSS and PTIA building while the CTE building is a one-story building. The CTE building has the most number of electrical fixtures installed in the building for lighting fixtures and equipment used for cooling and ventilation while CFEM building has the least number. Based from the Energy Consumption in CY 2015, the CTE building is the highest consumer of energy with an annual energy consumption of 29,549 kwhr, PTIA building with 15,559 kwhr, DSS building with 10,632 kwhr, CDCAS building with 8,633 kw and CFEM building with 4,324 kwhr. Figures 2 to 6 shows the facade of the buildings included in this study. Table 2 shows the Characteristics of the Buildings. Table 3. shows the Annual Energy Consumption of the Buildings from 2011 to 2015 is shown in Table 3.

Figure 2: College of Forestry and Environmental Management Building.

Figure 3: College of Development Communication and Arts and Science Building.

7.1. Total carbon footprint emission by month and year

Table 4 shows the total carbon footprint of the five(5) buildings by month and year for the five-year period (2011-2015). Obviously, Table 4 revealed the increasing carbon footprint emission of the five(5) buildings for the duration of five years. The total carbon footprint emission of the buildings was recorded to have about 19,367.92 in 2011 and 35,722.44 in 2015 an increasing rate of about 60% increase in the last five(5) years. The table shows that the highest (5036.72) carbon footprint was obtained in 2015 in the month of September and (801.32) being the lowest carbon footprint and was obtained during the year of 2011 in the month of January. The table shows that

Figure 4: Department of Social Sciences Building.

Figure 5: Provincial Technical Institute of Agriculture Building.

the highest carbon footprint emission is usually recorded during the months of June, July, August and September while the lowest was consistently recorded during the month of January. However, the significant variation can be explained by the varying energy consumption of the buildings which is influence by the number of occupants and number of electrical fixtures and equipment used for cooling and ventilation inside the buildings for each month and year. The temperature during the month of January is usually very low as compared to any other months which also influenced the lower energy consumption of the buildings. Based on the ANOVA Table 4a, evidently, the results show that there is indeed an annual increase of Carbon Footprint in the campus. Figure 7 below is the Annual Estimated Marginal Means of Carbon Footprint from 2011

Figure 6: Teachers College Education Building.

Table 2: Characteristics of the Buildings.

Name of Buildings	No. of Lighting Fixtures	No. of Electric Fans	No. of Air-conditioned Units	No. of Story	floor Area (sq. M)	No. of Occupants*	Elevation from the Sea Level
CFEM Building	34	13	5	2	1272	290	45
CDCAS Building	81	12	5	2	1272	148	45
DSS Building	40	14	5	2	1272	865	45
PTIA Building	85	12	11	2	1488	561	45
CTE Building	95	28	12	1	1400	955	45

Sources: ISELCO II; ISUC Planning Office; ISUC Registrar Office

to 2015. As can be glean on the figure, there is indeed increasing trend of carbon footprint emission. However, as shown in Table 2b which is the multiple comparisons on the annual carbon footprint of the buildings from 2011 to 2015 the 1 percent level of significance is observed between the year of 2011 and 2015.

7.2. Carbon emission by building in 2015

Table 5 shows the total carbon footprint emission by building (CTE, PTIA, DSS, CDCAS and CFEM). As shown, having the highest total of 15,365.48 CO_2 was obtained from CTE building and the lowest 2,248.48 CO_2 was obtained from CFEM building while the

Table 3: Annual Energy Consumption (Kw/Hr) 2011 to 2015.

Month	Annual Energy Consumption (kw/hr)				
	2011	2012	2013	2014	2015
January	1541	1807	1968	1748	2287
February	1977	2912	3398	3194	2704
March	2557	3512	4348	4511	5576
April	1743	2021	3301	2893	3070
May	3493	3392	3535	3239	4025
June	4392	3506	4333	5771	7816
July	4486	6884	6194	8078	8778
August	4691	4976	4696	7847	9458
September	3579	6564	6545	7120	9686
October	3590	4748	5510	5999	5827
November	3114	3223	4210	4187	5195
December	2083	2933	2235	4180	4275

Table 4: Characteristics of the Buildings.

Name of Buildings	No. of Lighting Fixtures	No. of Electric Fans	No. of Air-conditioned Units	No. of Story	floor Area (sq. M)	No. of Occupants*	Elevation from the Sea Level
CFEM Building	34	13	5	2	1272	290	45
CDCAS Building	81	12	5	2	1272	148	45
DSS Building	40	14	5	2	1272	865	45
PTIA Building	85	12	11	2	1488	561	45
CTE Building	95	28	12	1	1400	955	45

Sources: ISELCO II; ISUC Planning Office; ISUC Registrar Office

month of June was recorded with the highest 1,928.68 CO_2 from CTE building and least is 84.24 CO_2 from CFEM building which was computed from the month of April. The significant variation can be explained by the differences of each building in terms of energy consumption which was influenced by the varying number of occupants and number of electrical fixtures, appliances and equipment used by the occupants for ventilation and cooling the indoors of the buildings. The CTE building also has the most number of electrical fixtures and appliances installed in the building utilized for

Table 5: Annual Energy Consumption (Kw/Hr) of the Five Buildings in 2011 to 2015.

Month	**Annual Energy Consumption (kw/hr)**				
	2011	**2012**	**2013**	**2014**	**2015**
January	1541	1807	1968	1748	2287
February	1977	2912	3398	3194	2704
March	2557	3512	4348	4511	5576
April	1743	2021	3301	2893	3070
May	3493	3392	3535	3239	4025
June	4392	3506	4333	5771	7816
July	4486	6884	6194	8078	8778
August	4691	4976	4696	7847	9458
September	3579	6564	6545	7120	9686
October	3590	4748	5510	5999	5827
November	3114	3223	4210	4187	5195
December	2083	2933	2235	4180	4275
TOTAL	39257	48490	52286	60781	70712
Sources: ISELCO II					

cooling and ventilation as shown in Table 1 above. It has also has the most number of occupants (students, faculty and staff) while CFEM has the least number. Based on the ANOVA Table 3a, the carbon footprint emission during the period varied significantly. This means that carbon footprint emission varied by building.

It can be observed that during the months of June, July, August and September when the CO^2 is usually high which is the first semester wherein the buildings is utilized by many occupants (faculty, student and staff) hence the high demand for the energy consumption and increase in the Carbon footprint emission of the buildings. Figure 8 shows the 2015 Estimated Annual Marginal Means of Carbon Footprint of the buildings. It can be observed on the figure that the CTE building has the highest estimated marginal carbon footprint.

Table 6: Annual Carbon Footprint Emission of the Buildings.

Month	**2011**	**2012**	**2013**	**2014**	**2015**
January	801.32	939.64	1023.36	908.96	1189.24
February	1,028.04	1514.24	1766.96	1660.88	1406.08
March	1,329.64	1826.24	2260.96	2345.72	2899.52
April	906.36	1050.92	1716.52	1504.36	1596.4
May	1,816.36	1763.84	1838.2	1684.28	2093
June	2,283.84	1823.12	2253.16	3000.92	4064.32
July	2,332.72	3579.68	3220.88	4200.56	4564.56
August	2,439.32	2587.52	2441.92	4080.44	4918.16
September	1,861.08	3413.28	3403.4	3702.4	5036.72
October	1,866.80	2468.96	2865.2	3119.48	3030.04
November	1,619.28	1675.96	2189.2	2177.24	2701.4
December	1,083.16	1525.16	1162.2	2173.6	2223
Total	19,367.92	24,168.56	26,141.96	30,558.84	35,722.44

Table 7: Analysis of Variance of the Total Carbon Footprint per year for the five year period 2011-2015.

SV	df	SS	MS	F	Sig.
Year	4	12,963,404.46	3,240,851.12	3.51	0.01
Error	55	50,742,893.27	922,598.06		
Total	60	371,779,149.54			
**significant at the 0.01 level (2-tailed)*					

7.3. Carbon footprint emission and monthly temperature

The monthly carbon footprint emission of the buildings over the monthly average temperature shows their significant relationship. This is supported by the result of correlation analysis result as shown in Table 4b.

8. Conclusion and Recommendation

The study analysed the Carbon Footprint emission of the academic buildings in the campus. The study was conducted in Isabela State University in Cabagan, Isabela. Five(5) academic buildings were considered in the study.

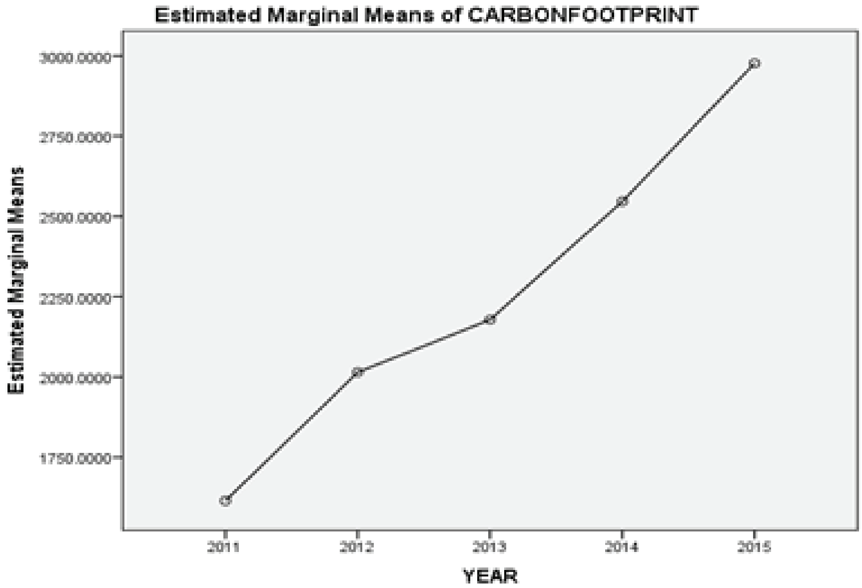

Figure 7: Estimated Marginal Means of Carbon Footprint from 2011 to 2015.

Estimated Marginal Means of Carbon Footprint of Buildings

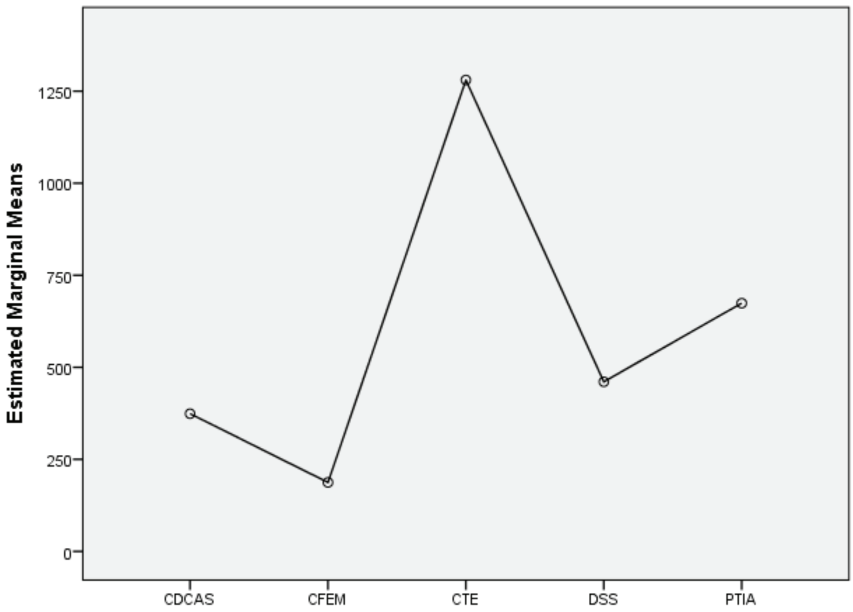

Figure 8: 2015 Estimated Annual Marginal Means of Carbon Footprint of the buildings.

It specifically aims to determine the annual level of total carbon footprint of the five(5) academic buildings, determine what year has the highest and least value and determine the significant difference between buildings as regards to their carbon footprint emission.

The carbon footprint equivalent was computed using the downloaded carbon footprint calculator from the internet.

Table 8: Multiple Comparison on the Carbon Footprint of Buildings from 2011 to 2015.

(I) YEAR	(J) YEAR	Mean Difference (I-J)	Std. Error	Sig.
2011	2012	-400.146667	392.1305181	1
	2013	-564.48	392.1305181	1
	2014	-932.563333	392.1305181	0.209
	2015	-1362.896667*	392.1305181	0.01
2012	2011	400.146667	392.1305181	1
	2013	-164.333333	392.1305181	1
	2014	-532.416667	392.1305181	1
	2015	-962.75	392.1305181	0.173
2013	2011	564.48	392.1305181	1
	2012	164.333333	392.1305181	1
	2014	-368.083333	392.1305181	1
	2015	-798.416667	392.1305181	0.466
2014	2011	932.563333	392.1305181	0.209
	2012	532.416667	392.1305181	1
	2013	368.083333	392.1305181	1
	2015	-430.333333	392.1305181	1
2015	2011	1362.896667*	392.1305181	0.01
	2012	962.75	392.1305181	0.173
	2013	798.416667	392.1305181	0.466
	2014	430.333333	392.1305181	1

Energy consumption of the buildings was requested from the Isabela Electric Cooperative (ISELCO) in Ilagan, Isabela and the Meteorological condition such as temperature was gathered from the data of Philippine Atmospheric and Geographical Service Administration (PAGASA) CY 2011 to 2015.

The total carbon footprint by year, by month and by buildings for the five(5) year period (2011-2015) indicates that the carbon footprint emission varied significantly (1 percent level of significance) This means that carbon footprint emission increases and varied by month and by year.

The total carbon footprint emission of the buildings are found to have significant increase in the five year trend. With the result of this study, it is recommended that

Table 9: Carbon Footprint Emission By Building 2015.

2015 Annual Carbon Footprint Emission of the Buildings					
Month	CFEM	CDCAS	DSS	PTIA	CTE
January	102.96	164.32	251.68	229.84	440.44
February	114.4	192.92	250.12	257.4	591.24
March	215.28	395.72	460.72	681.2	1146.6
April	84.24	293.8	199.68	294.32	724.36
May	94.64	230.88	266.76	404.04	1096.68
June	260.52	506.48	565.24	803.4	1928.68
July	293.28	395.2	694.2	1085.76	2096.12
August	313.04	512.2	723.32	1185.6	2184
September	291.2	635.44	778.96	1094.6	2236.52
October	245.96	492.96	611	752.96	927.16
November	128.96	386.36	371.28	673.4	1141.4
December	104	282.88	355.68	628.16	852.28
Total	2,248.48	4,489.16	5,528.64	8,090.68	15,365.48

Table 10: Correlation Analysis showing Carbon Footprint dependency on Temperature.

Correlation Coefficient			
Variables		Average Temperature	Carbon Footprint
Average Temperature	Pearson Correlation		.655*
	Sig. (2-tailed)		0.021
Carbon Footprint	Pearson Correlation	.655*	
	Sig. (2-tailed)	0.021	

** Correlation is significant at the 0.05 level (2-tailed).*

continuous monitoring on the carbon footprint emission of buildings should be undertaken in order to come up with mitigating measures and control in the increasing carbon emission of the academic buildings. It is recommended to consider an efficient design for building energy consumption for the future buildings of the campus.

Acknowledgement

This study was realized through the financial support of Commission on Higher Education.

References

[1] Carbon Footprint Calculator http//timeforchange.org

[2] Committee on the Effect of Climate Change on the Indoor Air Quality and Public Health 2011. Climate Change, The Indoor Environment and Public Health

[3] Crump Derrick IEH 2011. Climate Change-Health Impacts due to changes in the indoor environment ISBN :978-1-899110-49-0

[4] Federspiel, C., et. al., 2002. Worker Performance and Ventilation: Analyses of Individual Data for Call-Center Workers.

[5] Garcia Rincón, Maria Fernanda; Virtucio, Jr. Felizardo K. 2008. Climate Change in the Philippines: A Contribution to the Country Environmental Analysis. Draft for discussion

[6] Green Architecture. Wikipedia Free Encyclopedia

[7] Ingersoll Robert G. 2011. Climate Change Impacts Indoor Environment

[8] Khalil Natasha, Husrul Nizam Husin, Lilawati Ab Wahab, Kamarul Syahril Kamal, Noorsaidi Mahat 2011. Performance Evaluation of Indoor Environment Towards Sustainability for Higher Educational Buildings

[9] Lemmet Sylvie. 2009 *United Nations Environment Programme,* Buildings and Climate Change-Summary for Decision Makers

[10] Levin Hal. 2008. Indoor climate and global climate change: Exploring connections Building Ecology Research Group, Santa Cruz, California USA

[11] Mazria Edward 2009. Architects and Climate Change

[12] Mudarri, David, Ph. D. 2010. Public Health Consequences and Cost of Climate Change Impacts on Indoor Environment

[13] National Academy of Sciences 2011. Climate Change, The Indoor Environment and Health

[14] Nazaroff William W. 2013. Exploring the consequences of climate change for indoor air quality

[15] Preethi Prakash 2005. Effects of Indoor Environmental Quality on Occupants Performance: A Comparative Study. Graduate Thesis, University of florida.

[16] Ruparel Archana 2009. Environment in Tall Residential Buildings, Mumbai

[17] Rincón Maria Fernanda Garcia;. Virtucio Felizardo K Jr. 2008

[18] Climate Change in the Philippines: A Contribution to the Country Environmental Analysis

[19] Technical Primer on Climate Change in the Philippines 2010. By the Manila Observatory for the Congressional Commission on Science & Technology and Engineering (COMSTE) COMSTE Conference Engineering Resilience, Confronting Risk Beyond Adaptation 15 & 16 March 2010 * Sofitel Philippine Plaza Manila Visit http://resilience.comste.gov.ph

[20] Zhun Yu, Benjamin C. M. Fung, Fariborz Haghighat1, Hiroshi Yoshino3, Edward Morofsky 2011. A Systematic Procedure to Study the Influence of Occupant Behavior on Building Energy Consumption