ORIGINAL RESEARCH PAPER
VOLUME-6 | ISSUE-6 | JUNE-2017 | ISSN No 2277 - 8179 | IF : 4.176 | IC Value : 78.46
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

LIFE CYCLE ASSESSMENT OF BUILDING MATERIALS

Engineering

Rajeev Sharda Post Graduate student, Department Of Civil Engineering DAV Institute Of Engineering & Technology, Jalandhar

Dr. Sanjeev Naval Associate Professor ,Department Of Civil Engineering DAV Institute Of Engineering & Technology, Jalandhar.

ABSTRACT

Life cycle energy of the low rise residential building accounts for all energy inputs to the buildings during their intended service life. Buildings need to be constructed in such a way that energy consumption in their life cycle is minimal. Life Cycle Energy (LCE) consumption data of buildings is not available in public domain or with government departments which is essentially required for building designers and policy makers to formulate strategies for reduction in LCE of buildings. As per LCA of present building it is reported in different case studies available in the literature that operating energy of the buildings has largest share (80% - 90%) and embodied energy constitutes 10% - 20% in its life cycle energy distribution. Thus, the most important aspect for the design of buildings which demand less energy throughout their life cycle (low energy buildings) is the reduction in operating energy. LCE of the buildings is varying from 160 - 380 kWh/m2 year depending on the type (geometry) of the building and climatic conditions. With insulation on wall and roof along with double pane glass for windows, reduction in LCE of the buildings is about 5% - 30%.

KEYWORDS:

1. INTRODUCTION

Since LCA is an environmental management tool EMT for analyzing and assessing and research the main environmental impacts caused through production, use and disposal of products used in construction industry these days. Hence to make maximum use of the LCA tool all those concerned with construction must be familiar with its manner of application, its potential and its limitations. Amritsar buildings study highlights the guidelines within frame work of ISO-14040 series for the uniform application of LCA for construction industry especially for conducting inventory analysis in the building material industry.

Since LCA is being used as an environmental management tool in India so the work of standardization of LCA has been started recently. It will take some time to get maturity and stabilized, however Ministry of Environment and Forests (MoEF), Govt. of India has taken initiatives to carry out LCA studies in different major sectors like Steel, Coal, Paper, Power and Cement industry. All the studies have been completed. The MoEF had sponsored the project entitled LCA Study for Cement Sector to National Council for Cement & Building Materials (NCB). The study encompassed mining of limestone to dispatch of cement i.e. Cradle – to – Gate. NCB has made a sincere effort to evaluate not only input & output in terms of thermal & electrical energy, raw material & emission, but also its impact, independent of its geographical boundaries for cement plants.

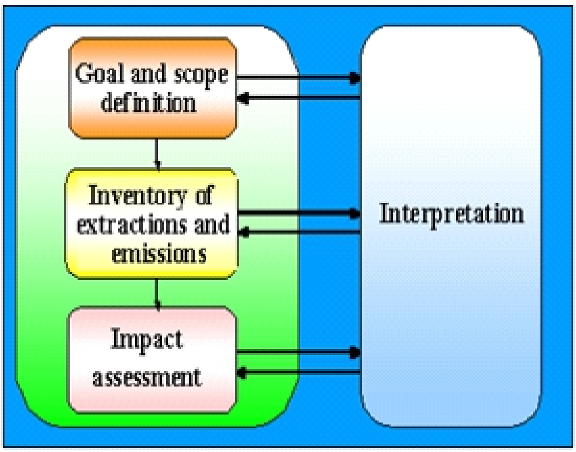

Fig-1: Framework of LCA

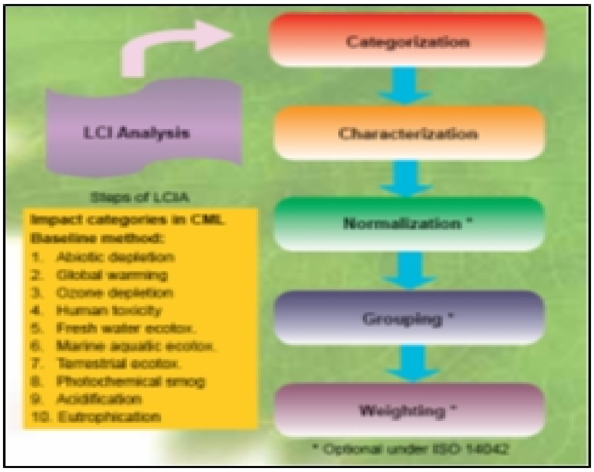

Fig-2 Characterization & Impact Categories

2. LIFE CYCLE ENERGY OF LOW RISE RESIDENTIAL BUILDINGS IN PUNJAB

Fig-3 Building of Amritsar under case study

Life cycle energy of the low rise residential building accounts for all energy inputs to the buildings during their intended service life. Buildings need to be constructed in such a way that energy consumption in their life cycle is minimal. Life Cycle Energy (LCE) consumption data of buildings is not available in public domain or with government departments which is essentially required for building designers and policy makers to formulate strategies for reduction in LCE of buildings. LCE of the studied buildings is varying from 165 - 385 kWh/m2 year . Based on the LCE data of studied buildings, an equation is proposed to readily reckon LCE of a new building. Keywords Life Cycle Energy, Residential Buildings, Embodied Energy, Operating Energy. Building construction sector is experiencing a fast-paced growth in developing countries, like India, due to growth of economy and rapid urbanization. A large number of buildings are being built for residential, commercial and office purposes every year. In India, 24% of primary energy and 30% of electrical energy is consumed in buildings. The use of electricity in this sector is growing at the rate of 11% - 12% annually, which is 100% more than the average growth rate of 5% - 6% in the economy. Besides the depletion of non-renewable energy sources, this energy use contributes greenhouse gases to the atmosphere, with consequent detrimental effects. In order to reduce the detrimental environment impacts of the buildings, new buildings need to be planned in such a way that energy consumption in their life cycle is minimal. Life cycle energy of the present study building accounts for all energy inputs to the buildings during their intended service life. It includes direct energy inputs during construction, operation and demolition phases of the buildings, and indirect energy inputs through the production of components and materials used in construction called embodied energy.

As per LCA of present building it is reported in different case studies available in the literature that operating energy of the buildings has largest share (80% - 90%) and embodied energy constitutes 10% - 20% in its life cycle energy distribution. Thus, the most important aspect for the design of buildings which demand less energy throughout their life cycle (low energy buildings) is the reduction in operating energy. In order to reduce operational energy demand of the buildings, passive and active measures such as providing higher insulation on external walls and roof, using gas filled multiple pane windows with low emissivity coatings, ventilation air heat recovery from exhaust air, heat pumps coupled with air or ground/water heat sources, solar thermal collectors and building integrated solar photovoltaic modules, etc. can be used. Reduction in operating energy is generally accompanied by increase in embodied energy of the buildings due to energy intensive materials used in the energy saving measures and on-site power generating equipment integrated with building. Though embodied energy constitutes only 10% - 20% to life cycle energy, opportunity for its reduction should not be ignored. There is a potential for reducing embodied energy requirements through use of materials in the construction that requires less energy during manufacturing. While using low energy materials, attention must be focused on their thermal properties and longevity as they have impact on energy use in operating phase of a building's life cycle. Thus, energy saving measures aimed at reducing one phase of energy use (operating) has impact on other phase of energy use (embodied energy) of the building. Hence, holistic evaluation of the buildings covering all phases of energy use is required to assess energy performance of the buildings.

3. METHODOLOGY

LCE demand of the building is taken as the sum of the embodied energy of materials used in the construction (EBE) and operating energy (OPE) on an assumed lifespan of 75 years using following relation

LCE = + ∑mM E L i i Ab

where mi = Quantity of building material (i),
Mi = Embodied energy of material (i) per unit quantity ,
EA = Annual Operating Energy (primary),
Lb = Lifespan of the building (75 years).

Unit for LCE is chosen as kWh (thermal). However, normalized LCE per unit floor area and per year is useful for quick comparison of energy performance of buildings of different sizes or different design versions of a building. Hence, LCE and other energy entities (OPE and EBE) of the building are normalized to kWh/m2 year based on their floor area and assumed lifespan of 75 years. Quantity of materials is estimated from the technical drawings of the buildings. The embodied energy of PV modules, for initial installation and replacement, is included in calculation of EBE of the building. Number of times the PV modules are replaced is calculated using following relation:

N = (Lb/Li – 1)
where N = No of times the PV modules are replaced in life span of building,
Lb = Lifespan of the building,
Li = Lifespan of PV modules

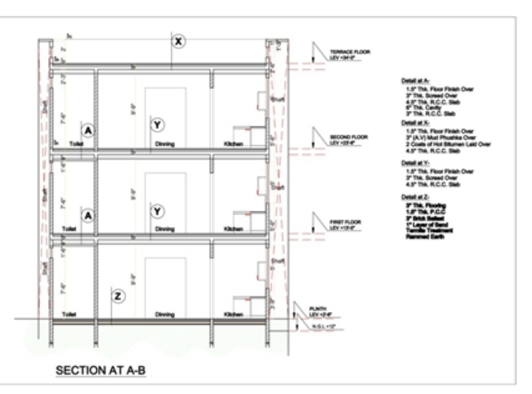

Fig-4 Elevation of Amritsar Building G+2

CONSTRUCTION OF (120 FLOORS) G+2 AT ALPHA INTERNATIONAL CITY – AMRITSAR

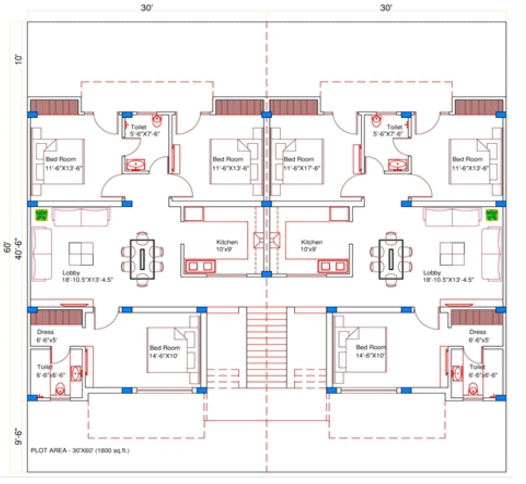

Fig-5 Plan of Amritsar Building G+2

Table No. 1 Quantities of material 6 buildings of 1250 sft – 7500 sft total

Sr.No	Description of material	Quantity in cum	Quantity in KG
1	EARTH	150	247500
2	PCC, RCC, Mortar & Plaster		
	Cement	50	80000
	Sand Coarse	150	217500
	Stone Aggregate 10mm 20mm	312	686400
3	Bricks and bricks bats	135	229500
4	Stone	30	51000
5	Tor Steel	4.39	34500
6	WINDOWS		
	MS GRILLS etc	0.28	2200
	GLASS	6.5	16900
	Aluminum	0.008	20.19
7	DOORS		
	Wood Red Marandee	5.25	3465
	Mica & Plywood	44	23320
8	PLASTER	68	122400

	Mortar		
9	FLOORING		
	Vitrified Tiles	35	61250
	Ceramic tiles	9	15750
	Paver block	15	26250
10	Paints	8	9600

4. EMBODIED ENERGY

These embodied energy values have been taken from Auroville earth institute, embodied energy of various materials and technologies (2008). These values are subjected to changes according to the processes involved i.e. energy, electricity and transportation of material at present locations.

Table No. 2 Standard Embodied Energy of Various Building Materials

Sr.No	material	Embodied energy kg CO2 /kg
1	EARTH	0.053
2	PCC, RCC, Mortar & Plaster	
	Cement	0.412
	Sand Coarse	0.0028
	Stone Aggregate 10m 20mmm	0.25
3	Bricks and bricks bats	0.24
4	Stone	197.89
5	Tor Steel	4.116
6	WINDOWS	
	MS GRILLS etc	4.116
	GLASS	2.528
	Aluminum	25.48
7	DOORS	
	Wood Red Marandee	0.49
	Mica & Plywood	1.019
8	PLASTER	
	Mortar	0.552
9	FLOORING	
	Vitrified Tiles	0.116
	Ceramic tiles	0.245
	Paver block	0.073
	Mosaic tile	0.073
10	Paints	6.1

5. TO CALCULATE CO2 - CARBON EMISSION

The total CO2 emission of a building is important to access the emission from each material independently. Initially all the quantities of the building are evaluated by marking each wall starting from its foundation till the slab, similarly for all the other components of the building such as doors, windows, lintels, beams, columns are marked and the quantities are found out. And later volume of CO2 emission from each material is estimated by using the formula given below as under in formula shape :-

Formula to Calculate of CO2 emission (Kg)= VxDxC
V= Volume of Building Material Used (m3)
D=Density of Building Materials (Kg/m3)
C= Embodied Carbon Emission (Kg CO2 /Kg)

Building materials

Table below describes the amount of carbon dioxide emitted by various materials used in the building. It is observed that the highest amount of carbon dioxide is releasing from, Steel, Aluminum, Stone, Glass and cement according to the quantity used. The CO2 emission of Brick according to the quantity is high, wood and plywood are emitting less. Between all of the used materials just ceramic tile and mosaic tiles and stone have the minimum level of carbon dioxide emission. Having a look at the total CO2 released gas, it will be perceived that a considerable amount of carbon dioxide is emitting from this building during its construction period, and the total CO2 emission comes to around 999.00 MT, which is 0.133 T/SFT (Total area is 7500 sft)

Table No.3 Co2 Carbon Emission of Materials as Per Density

Sr.No	Material	Embodied energy kg CO2 /kg	Density KG per M3	CO2 Emissions in KG
1	EARTH	0.053	1700	13515
2	PCC, RCC, Mortar & Plaster			
	Cement	0.412	1570.37	32349.62
	Sand Coarse	0.0028	1450	609
	Stone Aggregate 10mm 20mm	0.25	2600	202800
3	Bricks and bricks bats	0.24	1700	55080
4	Stone	197.89	2570	15188.7
5	Tor Steel	4.116	7860	142024
6	WINDOWS			
	MS GRILLS etc	4.116	7860	9058.49
	GLASS	2.528	2600	427232
	Aluminum	25.48	2600	529.98
7	DOORS			
	Wood Red Marandee	0.49	630	1620.68
	Mica & Plywood	1.019	540	24211.44
8	PLASTER			
	Mortar	0.552	1450	276.08
9	FLOORING			
	Vitrified Tiles	0.116	2500	10150
	Ceramic tiles	0.245	1750	3858.75
	Paver block	0.073	1450	1587.75
	Mosaic tile	0.073	1750	428
10	Paints	6.1	1200	58560

6. EMISSION Co2 FROM ELECTRIC CONSUMPTION

The amount of CO2 emission by electricity consumption at all seasons by the appliances used in the house which has been measured seasonally: 5 months summer,3 months rainy and 4 months winter. and it is seen that electricity consumption in the summer season is a little more as compared to the other seasons. There are no air-conditions used in the house since the house has been designed according to the climate the house is properly lighted up during the day and is well ventilated, that's why the CO2 emission level by electricity tends to be low, the total CO2 emission comes to around 21.48 Tones for 6 Floors of 7500 sft, 12.66 Tones in winter and 16.2 Tones in rainy season.

Table No. 4 Carbon Emission from Electricity Consumption - 1. Summer Season for One Floor

Electric Equipment used in house	Quantity of equipments	Number of total hours Used /24 Hr	Unit Power Consumption "ON" (Watts)	Number Of Working Days	Electricity Consumed Watts/ Hr	Total Consumption one year Watt	Gross Consumption
Rod Lights	8	15	40	150	600	90000	90
Ceiling Fan	4	18	60	150	1080	162000	162
CFL	12	15	25	150	375	56250	56.25
TV	1	10	100	150	1000	150000	150
MUSIC	1	6	50	150	300	45000	45
PRESS	1	1	1000	150	1000	150000	150
W/Machines	1	2	500	150	1000	150000	150
Refrigerator	1	24	700	150	16800	2520000	2520

Microwav	1	1	1000	150	1000	150000	150
Blender	1	0.6	300	150	180	27000	27
Grinder Mc	1	0.7	300	150	210	31500	31.5
Toaster	1	2	800	150	1600	240000	240
Wall Mounted Fan	2	3	25	150	75	11250	11.25
Exhaust Fan	2	2	48	150	96	14400	14.4
Total Consumption							3797.4
Co2 Emission Factor In India Grams Co2/Kwh							943.36
Total Co2 Emission In Grams							3582315
Co2 Emission In M Tones For One Unit							3.58

Table No. 5 Carbon Emission from Electricity Consumption - 2. Rainy Season for One Floor

Electric Equipment used in house	Quantity of equipments	Number of total hours Used /24 Hr	Unit Power Consumption "ON" (Watts)	Number Of Working Days	Electricity Consumed Watts/ Hr	Total Consumption one year Watt	Gross Consumption
Rod Lights	8	16	40	150	640	96000	96
Ceiling Fan	4	13	60	150	780	117000	117
CFL	10	8	25	150	200	30000	30
TV	1	8	100	150	800	120000	120
MUSIC	1	6	50	150	300	45000	45
PRESS	1	1	1000	150	1000	150000	150
W/Machines	1	1	500	150	500	75000	75
Refrigerator	1	18	700	150	12600	1890000	1890
Microwave	1	1	1000	150	1000	150000	150
Blender	1	0.5	300	150	150	22500	22.5
Grinder Mc	1	0.5	300	150	150	22500	22.5
Toaster	1	1	800	150	800	120000	120
Wall Mounted Fan	2	4	25	150	100	15000	15
Exhaust Fan	2	2	48	150	96	14400	14.4
Total Consumption							2867.4
Co2 Emission Factor In India Grams Co2/Kwh							943.36
Total Co2 Emission In Grams							2704990
Co2 Emission In M Tones For One Unit							2.70

Table No. 6 Carbon Emission from Electricity Consumption - 1. Winter Season for One Floor

Electric Equipment used in house	Quantity of equipments	Number of total hours Used /24 Hr	Unit Power Consumption "ON" (Watts)	Number Of Working Days	Electricity Consumed Watts/ Hr	Total Consumption one year Watt	Gross Consumption
Rod Lights	10	15	40	150	600	90000	90
Ceiling Fan	1	1	60	150	60	9000	9
CFL	8	10	25	150	250	37500	37.5
TV	1	12	100	150	1200	180000	180
MUSIC	1	3	50	150	150	22500	22.5
PRESS	1	2	1000	150	2000	300000	300
W/Machines	1	3	500	150	1500	225000	225
Refrigerator	1	10	700	150	7000	1050000	1050
Microwave	1	1	1000	150	1000	150000	150
Blender	1	0.2	300	150	60	9000	9
Grinder Mc	1	0.5	300	150	150	22500	22.5
Toaster	1	1	800	150	800	120000	120
Wall Mounted Fan	1	1	25	150	25	3750	3.75
Exhaust Fan	2	2	48	150	96	14400	14.4
Total Consumption							2233.65
Co2 Emission Factor In India Grams Co2/Kwh							943.36
Total Co2 Emission In Grams							2107136
Co2 Emission In M Tones For One Unit							2.11

Table No 7 Co2 Carbon Emissions due to Fuel through Transportation of Material

MATERIAL USED	QTY IN CUM	TRIPS TOTAL	DISTANCE OF ONE TRIP	TOTAL DISTANCE	AVERAGE DISTANCE	POL CONSUMED	FUEL emission C02/LITRE	Total Co2 Emissions
CEMENT	50	8	25	200	5	40	2.9	116
SAND	150	22	100	2200	5	440	2.9	1276
AGG	312	69	100	6900	5	1380	2.9	4002
BRICK & brick bat	150	9	25	225	5	45	2.9	130.5
Fine sand	30	7	6	42	5	8.4	2.9	24.36
STEEL	4.39	1	4	25	5	5	2.9	14.5
MILD S	0.28	1	1	25	5	5	2.9	14.5
GLASS	6.5	1	2	100	5	20	2.9	58
WOOD	5.25	1	100	100	5	20	2.9	58
MICA/PLY	44	3	120	360	5	72	2.9	208.8
LIME/SD	68	1	13	13	5	2.6	2.9	7.54
FLOORING	50	1	9	9	5	1.8	2.9	5.22

Quantity of CO2 emission by transportation of materials is the distance and has been calculated from the source of the material i.e. from where the material has been manufactured till the site. the CO2 emission for which is coming up to 6Tones. In this case study the main focus has been given on the building materials used in construction and not on the functions of the building Initially volume of each building material is estimated and later carbon dioxide emission due to each material is evaluated. Calculations were also done for electricity consumption by the building which was considerably less and emissions due to the transportation of materials were also calculated. Since main material which has been used for the construction is rammed earth, it is estimated that RE structures consume 30-50% less energy in some cases than conventional houses. This may be attributed to better thermal properties of raw earth and their greater wall mass and thermal inertia.

In three different ways we can categorize the reimbursement of sustainable building like 1. Environmental benefits 2. Economic benefits 3. Social benefits. The complete idea behind sustainable building is to preserve our environment and avoid the depletion of the earth's natural resources. When sustainable substitutions are used in any design project development it allows to: Protect the Ecosystem, Reduce Emissions, Improve Air and Water Quality, Conserve Water, Reduce Waste Streams, Conserve and Restore Natural Resources, Waste reduction, and Temperature control. The economic benefits of using sustainable materials are: it helps to aid the expansion of green market, reduces operating costs, optimizes the Life Cycle of the Building, increases Property Value and improves Occupants Attendance and Productivity. The social benefits are it helps to Improve Occupants Comfort and Health, create an Aesthetically Pleasing Environment, minimizes Strain on Local Infrastructure, increases Occupants Overall Morale, and improves Worker Productivity Suggestions Many of the carbon emissions from buildings can be reduced by using environmental engineering techniques such as passive design of buildings so that the carbon emitted during their 'use' phase is dramatically reduced.

CONCLUSIONS

LCE of the buildings is varying from 160 - 380 kWh/m2 year depending on the type (geometry) of the building and climatic conditions. With insulation on wall and roof along with double pane glass for windows, reduction in LCE of the buildings is about 5% - 30%. LCE of the buildings can be further reduced by on-site power generation from PV system (30 to 70%). A polynomial equation is proposed to readily reckon LCE of the ongoing buildings. Hence it becomes necessary when large number of LCE data is available in future. Research of the present study are useful for building designers involved in design and construction of the energy efficient buildings and for policy makers to set meaningful targets. Some other cooling techniques like free cooling, evaporative cooling, solar air conditioning etc., may be tested to bring down LCE of the buildings. Use of energy efficient cooling/heating equipment and appliances would also reduce LCE of the buildings considerably.

Mainly by minimizing the embodied carbon in buildings by using sustainable or alternative building materials is another way to contribute to this carbon reduction.

1. Use recyclable materials as much as possible to minimize CO2.

2. Preferably bring into action locally available materials to minimize fuel used for transporting of materials in order to reduce Co2 gas emission.

3. Vernacular architecture drawings to be used.

4. Eco friendly building materials to encourage for its usage.

5. Drawings of the buildings to made with respect to the nature for having better ventilation and using natural day light.

REFERENCES

1. . . Cole, Raymond J., and Paul C. Kernan. “Life-Cycle Energy Use in Office Buildings.” Building and Environment 31.4 (1996): 307-317. Science Direct. Web. 28 March 2010.
2. . . Eaton, K.J., and A. Amato. “A Comparative Life Cycle Assessment of Steel and Concrete Framed Office Buildings.” Journal of Constructional Steel Research 46.1-3 (1998). CD-ROM.
3. . . Guangli Du1, Raid Karoumi2 , et al (2010) “Environmental life cycle assessment comparison between two bridge types: reinforced concrete bridge and steel composite bridge”
4. . . Guggemos, Angela Acree, and Arpad Horvath. “Comparison of Environmental Effects of Steel- and Concrete-Framed Buildings.” Journal of Infrastructure Systems 11.2 (2005): 93-101. Web. 16 February 2010.
5. . . Jönsson, Asa, Thomas Björklund, and Anne-Marie Tillman. “LCA of Concrete and Steel Building Frames.” International Journal of Life Cycle Assessment 3.4 (1998): 216-224. SpringerLink. Web. 17 February 2010.
6. . . Junnila, Seppo, and Arpad Horvath. “Life-Cycle Environmental Effects of an Office Building.” Journal of Infrastructure Systems 9.4 (2003): 157-166. Print.
7. . . Johnson, Timothy Werner. Comparison of Environmental Impacts of Steel and Concrete as Building Materials Using the Life Cycle Assessment Method. Cambridge: Massachusetts Institute of Technology, 2006. Print.
8. . . Kato H., Osada M. (2005), “A life cycle assessment for evaluating environmental impact of inter regional high speed mass transit projects”, Journal of the Eastern Asia Society for Transportation Studies.
9. . . Kofoworola, Oyeshola F., and Shabbit H. Gheewala. “Life Cycle Energy Assessment of a Typical Office Building in Thailand.” Energy and Buildings 41.10 (2009): 1076-1083. ScienceDirect. Web. 20 February 2010