Energy Assessment of Multi-Storied Apartments in Roorkee

Shailza Singh, P. S. Chani, and S. Y. Kulkarni

***Abstract*—This paper aims to identify the key energy predictors for multi-storied apartment development in composite climate of Roorkee. To achieve this, comprehensive energy assessment is carried out of an apartment building in Roorkee for a life cycle of 50 years. Manual estimation (using questionnaire survey) and simulations (using Design Builder's software) are done to estimate Operating Energy (OE).Embodied Energy (EE) is estimated by multiplying Embodied Energy Rates (EER) with the respective quantity of each Item of work. Internal gains through lighting, solar heat gain through glazing and roof insulation are found to be the three main energy predictors for OE and RCC & masonry work as the major determiner of the EE. The study reveals that the OE accounts for 80% of the total energy use, for a life span of 50 years. The changes made in the identified energy predictors have reduced OE per sq.mt to a significant figure of 18.9%. The same substitution also results in a reduction of 19.2 % in the EE and 18.6 % – 20 % in CO_2 emissions.**

***Index Terms*—Embodied energy, operating energy, energy predictors, simulation.**

I. Introduction

India ranks fifth, in terms of primary energy consumption and accounts for about 3.5% of the world commercial energy demand [1]. It is a well known fact, that economic development is directly associated with the energy consumption of any country. In India, to sustain the economic growth of 8-10%, it is necessary to ensure the energy supply with the growth rate of 5-6% [2]. Considering, the current status of real estate industry, construction is one of the core sectors of India's economy. Housing, in particular, is the focus of this study. It is estimated that the construction spending on residential buildings will increase from US$ 35 billion (2007) to US$ 63 billion (2013) in India [3]. Material consumption is also expected to double by the year 2020[4], out of which, 60% of building materials is used in housing[5].This shows a significant contribution of this sector to economy and the resultant energy demand, which is, presently,23% of the total energy consumption [2]. It is also noteworthy, that bulk of the energy loads (i.e. OE) in buildings depends on the thermal properties of the material used (which accounts for the EE), efficiency of services installed and finally on the design of the building. With this growing dependence on natural resources and the resultant CO_2 emissions (22% in India) [4], it becomes vital to find the key predictors of construction works for both EE and OE. This study focuses on multi-storied apartments in Roorkee, in which a conscious attempt is made to show variations in EE, OE and other related parameters to find the best energy predictors for such construction works.

II. Description of the Study

An existing apartment building called Hill View Apartments in IIT Roorkee (IITR) campus, has served as a base-case for the analysis (refer Fig. 1). It lies in 29^0 51'N latitude, 77^0 53' E longitude at an altitude of 274m , in a composite climatic zone, with temperatures ranging from above 40^0C in summer to below 5^0C in winter [6]. The apartments are occupied by the senior faculty members of the institute. It comprises of four blocks i.e. A, B, C & D (refer Fig. 1). The orientation of each block is along the East-West axis and floor to floor height is 3.5 m. In this study, only blocks A & B are studied in detail for estimation. The seven storied RCC framed structure of block A &B is connected with a bridge. The plinth area of block A & B is 925 sqm. Most families have 2 or 3 members per dwelling with at least one working member.

III. Methodology

The methodology used in the earlier studies have been thoroughly studied and accordingly applied to get the desired results. To estimate OE, two parallel approaches have been used. In the first one, manual estimation approach, similar to the Conditional Demand Analysis (CDA) [7], is followed. In this approach, household energy-use data is collected by carrying out a questionnaire survey describing the household's socio-economic status, no. of occupants, the appliances owned, monthly electricity units and the behaviour of the household. Though, occupant behavioural pattern was also analyzed but no significant results were drawn and, thus, not included in this paper. The second approach is the estimation using energy simulation software. For this, Design Builder's software (DB) v.1.6.9.003 has been used. Results obtained from manual estimation helped in validation of the base-case simulation model. Although many assessment methods and databases have been developed for EE estimation, the actual EE intensity for a given material is highly dependent on local technologies and transportation distances [8]. In North India, Bill of Quantities (BOQ) is an important document used for almost all types of construction, which gives a complete detail of the quantity of materials along with the breakups of the civil work. In this

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study, the Embodied Energy Rates (EER) is multiplied with the respective quantity of each Item of work (as they are presented in a BOQ) to get the Net Embodied Energy Cost (EEC_N) of a given project (refer Eq.1) Finally, Transport Energy Cost (TEC) of about 2.5% of EEC (as derived by Chani [5]) is added to get the Gross Embodied Energy Cost (EEC_G), refer Table I & Eq.2.

Fig. 1. Site plan of hill view apartments in IIT campus, Roorkee.

TABLE I: SAMPLE SHEET SHOWING THE APPLICATION OF EER TO ESTIMATE THE EECG OF BLOCK A& B (HILL VIEW APARTMENTS).

S.No.	Item of Work	Unit	IV. Quantity	EER (MJ/unit)	EEC (MJ)	Item Code No.
1.	Masonry Work 1st class brick work in super -structure in cement mortar 1:6	cum	1438.1	2641.75	3799048	2.2.15.
	EEC for Masonry Work (EEC_1)				4829329.68	
	EEC for Finishing (EEC_5)				255646.108	
	$EEC_N = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				15580794.96 MJ	
	Total EEC_G (includes 2.5 % of Total EEV)				**15970314.83MJ**	

Equation for EEC calculation:

$$EEC = EER \times \text{Quantity of each Item of rate} \quad (1)$$

$$EEC_N = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5 = (EEC_{Masonry} + EEC_{Concrete} + EEC_{RCC} + EEC_{Flooring} + EEC_{Finishing})$$

$$EEC_G = EEC_N + 2.5\% \text{ of } EEC_N \quad (2)$$

A. Simulation Arrangement

Design Builder's (DB) v.1.6.9.003 is employed to generate the geometric details of the building block which creates a simulated environment, where heating, cooling, and various other building systems are evaluated. The as-designed base-case model is established in accordance with the detailed drawings provided. The power densities of the lighting systems are assumed to be 10 W/m^2 for apartment units. An occupancy density of 0.019people/m^2 is assumed (i.e. 3 occupants per apartment with the floor area of 152 sqm.). As it was observed that simulation of both blocks i.e. A&B led to the slow processing of the system and was taking too much of time, only Block A is simulated. To identify the energy predictors in building, simulations are carried out for four types of models. First model is the base-case model, in which the existing construction materials and systems are used. In second model, wall and roof insulation is used with double glazed window. The third model is a retrofitted one with appropriate alterations in the lighting systems, window type and roof insulation. The fourth one is the recommended model with the wall infill of Aerated Concrete blocks (AAC) and other specifications followed as per ECBC (Energy Conservation Building Code).

The detailed specifications and energy-use performance of each model is given in Table II.

V. DISCUSSION OF RESULTS

A. Operating Energy

The results revealed that when ECBC is followed in the existing base-case model, annual energy consumption reduced from 180.6MWh to 146.43 MWh (refer Fig. 4, Table II). Internal gains through lighting, solar heat gain through glazing and roof insulation are found to be the three main energy predictors for OE(refer Table II). The changes made in the identified energy predictors has lead to a significant reduction of 18.9% in OE per.sqm.Wall infill is also observed to influence the heat transfer but the overall impact was insignificant. It can be explained by comparing Model 2 and Model 3 (refer Table II). On substitution of AAC in Model 3, hardly any decrease is observed in OE (although all the parameters are kept same except for the wall infill) but it effectively reduced EE by 19.2%. A remarkable reduction 44.24% is seen in internal heat gains through roof when insulation is provided in roof along with the few alterations in glazing type and lighting fixtures (refer Table II). Internal heat gain due to lighting is significantly reduced by 52.2% by using energy efficient fixtures (refer Table II). As CFLs uses only 20 to 33% of the power of equivalent incandescent lamps with the same output. Therefore, by installing energy efficient lighting two concurrent savings are achieved (reducing cooling load & energy load).Maximum drop is seen when window type is changed from singly glazed to double glazed, 57.3% reductions are achieved (refer Table II).

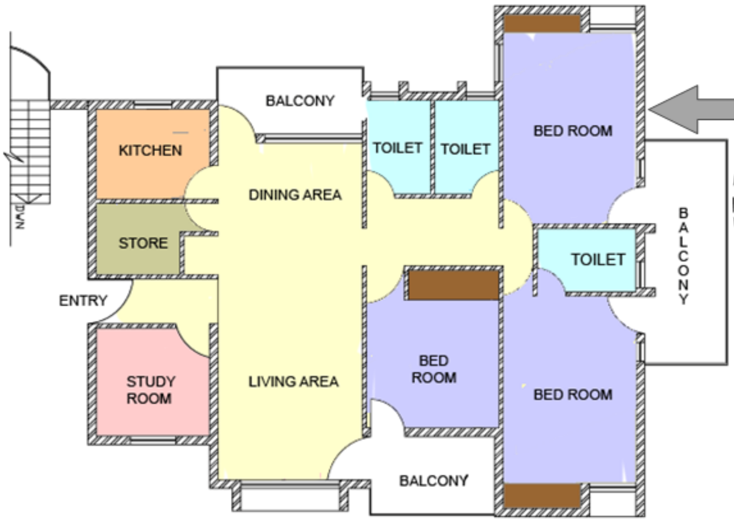


Fig. 2. Floor plan of dwelling unit.

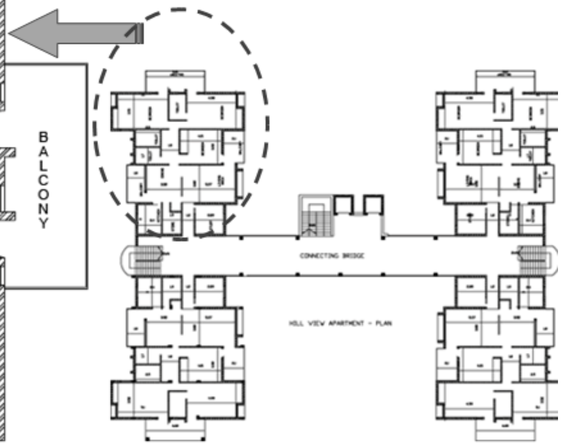
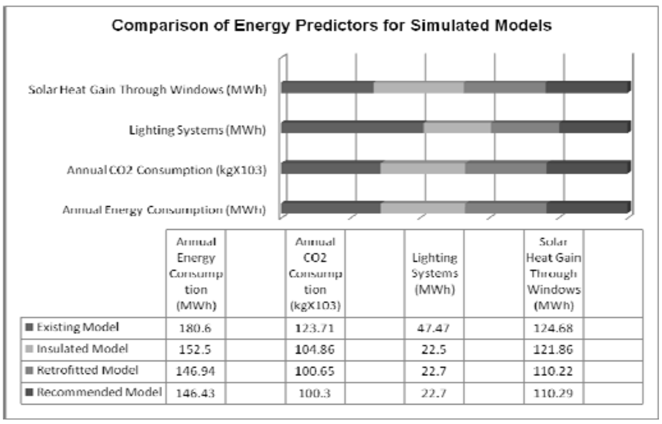


Fig. 3. Key plan of block A & B.

B. Embodied Energy

Results have revealed that the combined energy share of RCC and masonry work is the major determiner of the embodied energy. Aerated concrete blocks and Fal-G blocks give the best energy options; with the savings of 19.2% of EEC (refer Fig. 5). These are followed by solid concrete blocks, Clay Fly ash bricks, hollow concrete blocks and sand lime bricks. The overall reductions in EEC_G values for these materials are 13%-19.2%. Although, Embodied Energy Value (EEV) of aerated concrete block is more than traditional bricks, the EEC_G of the former in this study is less as compared to the later. This can be explained by the size of the blocks and reductions in the mortar volume. Use of large sized Aerated Concrete Blocks (40 cm x 20cm x 10cm) as oppose to traditional bricks (2.9cm x 11.4cm x 7.6cm) has reduced the number of blocks used per cum of masonry work (only 63 blocks instead of 494 blocks). With the reduced no. of blocks, the number of mortar joints has also reduced, which, further, reduced the volume of mortar used per cum of masonry work. This, as a whole, has effectively reduced the overall EEC of the building in this study.



	Annual Energy Consumption (MWh)	Annual CO2 Consumption (kgX103)	Lighting Systems (MWh)	Solar Heat Gain Through Windows (MWh)
Existing Model	180.6	123.71	47.47	124.68
Insulated Model	152.5	104.86	22.5	121.86
Retrofitted Model	146.94	100.65	22.7	110.22
Recommended Model	146.43	100.3	22.7	110.29

Fig. 4. Comparative analysis of simulated models.

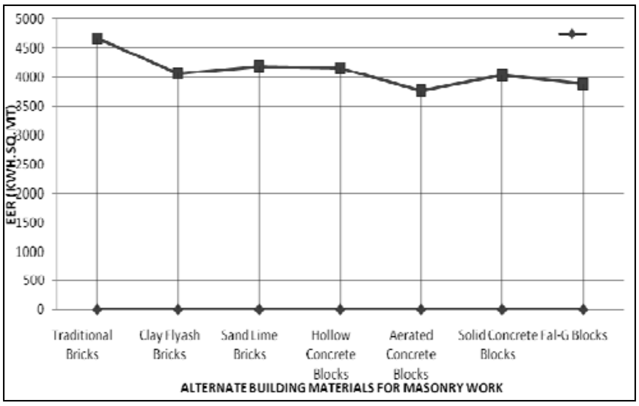
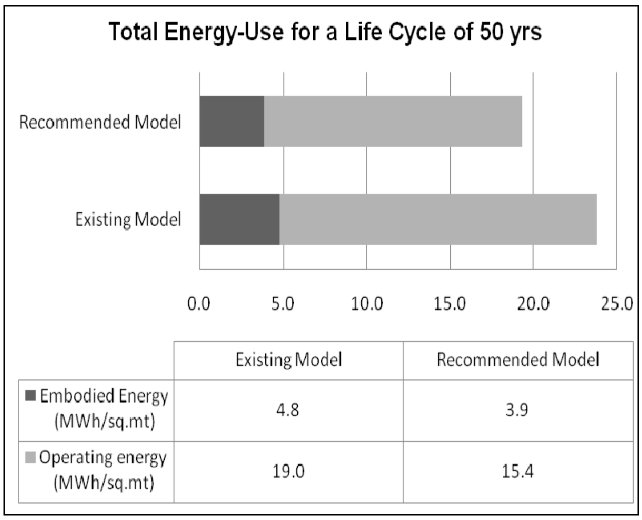


Fig. 5. Comparative analysis of EEC_G(kWh/sqm).



	Existing Model	Recommended Model
Embodied Energy (MWh/sq.mt)	4.8	3.9
Operating energy (MWh/sq.mt)	19.0	15.4

Fig. 6. Breakup of total energy-use (block A& B).

From the above result, a range of different materials is found, which fulfils the same function in a building, but since their energy-efficiency vary significantly, savings are achieved through substitution. When the relative impact of OE and EE are compared, OE has eclipsed the embodied energy and is over 80% of the total energy for a life cycle of 50- year period (refer Fig. 6). But the substitution of Aerated concrete block has reduced the embodied energy by 19.2% in addition to reductions made in OE (refer Model 3). Thus, Model 3 is proposed as the best alternative for apartments in composite climate, as it not only has optimised the energy usage but also the CO_2 emissions.CO_2 emissions have reduced from 123.71 (kg X10^3) to 100.3 (kg X10^3), in Model 3, which is 18.9% drop (refer Fig. 4).

TABLE II: COMPARATIVE ANALYSIS OF SIMULATED MODELS (BLOCK A, HILL VIEW APARTMENTS).

PARAMETERS	**Existing Model (Base-Case Model)**	**Model Alternatives**		**Recommended Model (Model 3)**	
		(Model 1)	**(Model 2)**		
Orientation	E-W Axis	E-W Axis	E-W Axis	E-W Axis	
Window to Wall Ratio	18.8% N - 21.8% , S - 29% , E - 9%,W-9%	18.8% N - 21.8%, S-29%, E-9%, W-9%	18.8% N -21.8%, S-29%, E-9%, W-9%	18.8% N- 21.8%, S-29%, E-9%, W-9%	
Glazing Type	Single Glass Clear #U.F=7.1,#SHGC=0.82, #VLT=.76	Double Ref-C-H Clr 6mm /6mm Air U.F= 2.89 ,SHGC=.266, VLT=.2	Double Ref-C-H Clr 6mm/6mm Air U.F= 2.89, SHGC= .266, VLT=.2	Double Ref-C-H Clr 6mm/6mm Air U.F= 2.89, SHGC = .266, VLT=.2	
Building Envelope					
Wall Materials (External)	Int. plaster+ Brickwork + Ext. Plaster U.F= 1.56 , #R.V = 0.64	Int. plaster + Brickwork + Insulation +Ext. Plaster U.F= .36 , R.V = 2.78	Int. plaster+ Brick work+ Ext.Plaster U.F= 1.5, R.V = 0.64	Int. Plaster+ Concrete Block+Air Gap+Concrete Block+Ext. Plaster U.V= .79 , R.V= 1.27	
Wall Materials (Semi-Exposed)	same as above	Internal plaster + Brickwork+ Air-gap (15mm) + Brickwork + External Plaster U.F= 1.49, R.V = 0.67	same as above	Internal plaster + Brickwork+ Airgap (15mm) + Brickwork + External Plaster U.F=1.49 , R.V = 0.67	
Lighting (W/m^2)	#LPD =10	LPD = 7.5	LPD = 7.5	LPD = 7.5	
Air Tightness	No	Yes	Yes	Yes	
Internal Partition	Int. plaster+ Brickwork + Ext. Plaster U.F = 2.28, R.V = 0.44	Int. plaster+ Brickwork + Ext. Plaster U.F= 2.28, R-Value = 0.44	Int. plaster+ Brick-work + Ext. Plaster U.F= 2.28, R.V = 0.44	Int. plaster+ Brickwork + Ext. Plaster U.F = 2.28 , R.V= 0.44	
Roof	Int. plaster+ RCC slab+ mudphuska + ceramic tiles U.F= 2.0, R.V = 0.499	Int. plaster +RCC slab +Felt Bitumen + XPS extruded polystyrene + ceramic U.F= .29 , R.V = 3.4	Int. plaster +RCC slab +Felt Bitumen + XPS extruded polystyrene + ceramic U.F = .29 ,R.V = 3.39	Int. plaster +RCC slab +Felt Bitumen + XPS extruded polystyrene + ceramic U.F = .29 , R.V = 3.39	
					Reduction achieved (%)
Annual Energy Consumption (MWh)	180.6	152.5	146.94	146.43	18.9%
Annual CO2 Production (kgx10^3)	123.71	104.86	100.65	100.3	18.9%
Annual Heat Gain / Loss (MWh)					
Ext. Windows	124.68	121.86	110.22	110.29	11.54%
Walls	34.1	58.64	49.2	48.5	-
Roof	16.5	10.02	9.2	9.2	44.24%
Glazing	-18.5	-8.3	-7.8	-7.9	57.3%
General Lighting	47.47	22.5	22.7	22.7	52.2%

 # U.F(U-factor)=Thermal conductance,[W/m^{2}C] ,R.V(R-value)=Thermal resistance [m^2.C/W], LPD=Lighting Power Density [W/m]^2 , SHGC=Solar Heat Gain Coefficient Through Glass, VLT= Visual Light Transmittance.

VI. CONCLUSION

Internal gains through lighting, solar heat gain through glazing and roof insulation are found to be the three main energy predictors for OE and RCC & masonry work as the major determiner of the EE. Significant reductions of 52.2%, 57.3% & 44.24% are observed in the internal heat gain through lighting, glazing & roof insulation respectively. The results revealed a considerable reduction in the annual energy consumption from 180.6MWh to 146.43 MWh, when ECBC guidelines are followed in the existing base-case model. Aerated concrete blocks and Fal-G blocks give the best options for wall infill, with the savings of 19.2% of EE.

Although, OE has accounted for the bulk of energy use (80%), but efficient use of low embodied materials has effectively reduced the total energy-use (OE & EE). It is, therefore, concluded that the best approach to make an energy efficient apartment is to design a building as a complete entity by making best choices for construction materials and installed equipment at the commencement stage of the project.Model 3 is recommended as a best alternative for the energy efficient apartment buildings in composite climatic region of India.

REFERENCES

[1] India Energy Portal (IEP). GOI. [Online]. Available: http://www.indiaenergyportal.org/overview_detail.php

[2] D. C. Srivastava, "high performance buildings, policies and programs in India," in *Proc. Buildings and Appliances Task Force*, Beijingin, China, March 30, 2007.

[3] IHS Global Insight. India Construction: Importance of Infrastructure Construction in India. 15th March 2009. [Online]. Available: http://www.ihsglobalinsight.com/gcpath/India_Construction1-7.pdf

[4] B. V. V. Reddy, "Sustainable Building Technologies," *Current Science -Special Section: Application of S&T to Rural Areas*, vol. 87, 2004.

[5] P. S. Chani, "Primary energy estimation for contemporary housing in Northern India," Ph.D. Dissertation, Dept. Architecture and Planning, University of Roorkee, India, August 2000.
[6] India: Sustainable Urban Development. GAIA: A Multi-Media Tool for Natural Resources Management and Environmental Education. [Online]. Available: http://www.ess.co.at/GAIA/CASES/IND/RKE/Roorkee.html#clim
[7] P. Rickwood, "Residential operational energy use," *Urban Policy and Research*, vol. 27, no. 2, pp. 137-155, 2009.
[8] A. Dimoudi and C. Tompa, "Energy and environmental indicators related to construction of office buildings," *Resources, Conservation and Recycling*, vol. 86, pp. 86-95, 2008.

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