EMBODIED ENERGY IN RESIDENTIAL COST EFFECTIVE UNITS (Single Storied) Up to 50 Sqm Plinth area

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Abstract:
It is believed that about 30 % of Energy is used in construction activities alone, and building construction constitutes a major part of all construction activities. Now the emphasis is towards construction of Green buildings with the objective of minimizing the uses of energy in building in terms of Embodied energy and maintenance/operational energy (Electrical, Water, Thermal, Sound, Sanitation, HVAC etc). In Green buildings all the emphasis is on the usage of Fly ash, Construction wastes, materials from the vicinity (To reduce Transportation energy) and materials with less EEV- Embodied Energy Value, besides effective utilization of water, rain water harvesting, Solar, wind , Landscaping and orientation of buildings to minimize the usages of energy in buildings.
There are many agencies like TERI-GRIHA, USGBC, LEEDS & BEE- Energy Conservation Building Conservation code, who are advocating the concept of Green Buildings very aggressively in India, by releasing guidelines on the planning and designing of buildings as well as they are doing certification of the green buildings, however they have not yet quantified the basic Minimum EEV of different types of buildings and their minimum maintenance/operational energy required on area or volume basis, so that, this can be quantified easily, by metering these parameters (Embodied and Operational Electrical Energy) rather than doing highly time/cost consuming model analyses on several complicated but not very conclusive hypothesis.

Keywords: *EEV- Embodied Energy Value, Cost effective houses, HUDCO- Housing and Urban Development Corporation Limited, IHSDP-Integrated Housing and Slum Development Programme, Housing Typology, Interlocking Blocks*

1. Introduction

An attempt has been made in this paper, to quantify the EEV of Single storied house up to 50 sqm of plinth area, as Hudco -Housing and Urban Development Corporation Limited has designed/constructed hundreds of this type of houses in the country. The Typology of the house taken in this paper are : Houses with Strip footing in brick masonry in cement mortar 1:6, DPC 40 mm Thick 1:2:4 PCC, Brick wall 230/115mm thick in cement mortar 1:6, 12mm/15mm cement plaster 1:6 , CC skirting/Dado 12 mm thick 300/1200 mm high, RCC M20 roof 115 mm thick, CC Gola, khurrah, Mud Fuska with Brick tiles, parapet in brick work 900mm high, CC Coping 40mm thick PCC, IPS- Indian Patent Stone flooring, minimum Joinery, etc.
This Exercise is based on the bill of quantities of the single storied tenement type of houses designed/constructed by HUDCO and is cost effective houses. If the Cluster approach is to be adopted, the quantities of Materials will vary.
The bill of quantities of the various types of houses proposed by HUDCO are quantified, analyzed and the basic building materials are calculated as cement, sand, aggregates, steel, bricks on per square meter of plinth area basis, which require the almost all the energy in Construction of the house. The components like plumbing, electrical, finishing items are not calculated as mostly these houses had the basic minimum of them.

2. Objectives and Methodology

The main objective is to study the embodied energy values of materials used for cost effective houses up to 50 sq.m. The most important criteria for judging the energy efficiency of this housing typology has to fixed- whether Embodied energy or Maintenance/ Operational Energy. The following methodology was used:

a) This Exercise is based on the bill of quantities of the single storied tenement type of houses designed/constructed by HUDCO and is cost effective houses.
b) If the Cluster approach is to be adopted, the quantities of Materials will vary.
c) The bill of quantities of the various types of houses proposed by HUDCO are quantified, analyzed and the basic building materials are calculated as cement, sand, aggregates, steel, bricks on per sqm of plinth area basis, which require the almost all the energy in Construction of the house.
d) The components like plumbing, electrical, finishing items are not calculated as mostly these houses had the basic minimum of them.
e) The energy used for running the energy efficient electrical fixtures in the house is evaluated.
f) The comparison in the Embodied energy and Maintenance/ Operational Energy is done over the life cycle of the house say 50 years.

3. Embodied Energy Values for Materials of Construction

Table 1: Basic EEV of Materials: (Reference: IE (I) Journal-AR-Page 47-50, vol 84, October-2003, Dr P S Chani, Dr Najamuddin, and Dr S K Kaushik):
EEV of Different basic construction Materials (1):

Items	EEV (MJ)	Units	Sizes in mm
Soil	0	0	0
Cement	6.70	MJ/Kg	0
Sand	0	0	0
Fly ash	0	0	0
Steel	32.00	MJ/Kg	0
Standard Burnt Bricks	4.50	MJ/Bricks	229*114*76
Clay Fly ash Bricks	2.32	MJ/Bricks	200*100*100
Sand Lime Bricks	2.79	MJ/Bricks	200*100*100
Hollow Cement Concrete Blocks	11.00	MJ/Blocks	400*200*200
Aerated Blocks	11.50	MJ/Blocks	400*200*200
Fal G Blocks	7.90	MJ/Blocks	300*200*150
Solid Concrete Blocks	10.40	MJ/Blocks	300*200*150

The EEV has been taken as the same, without adding for handling/transportation etc inputs.

Table 2: Calculation of EEV of Hydra form block :(Hydra form India (P) Ltd) (2).

Assumptions:

Block Dimension(mm)	**Length (+-)(mm)**	**Width (mm)**	**Height(mm)**
	230	220	115
Production Capacity (Model: M7S2E)	2800	Blocks per shift, 8 working hours	
Weight of Soil based block(kg)	11		
Weight of Fly ash based block (kg)	9.5		
Total weight of Soil based mix (kg)	30800		
Total weight of Fly ash base mix(kg)	26600		
Volume of each Block (in Cu.m)	0.006		
Total volume of blocks produced(Cu.m)	16		
Density of soil base block(per Cum)	1890		
Density of Fly ash base block(per Cum)	1633		

The calculations for the EEV for SEB Interlocking block using Hydra form Technology and Fly Ash interlocking block using Hydra form technology are given below in Table 3 and Table 4 respectively.

Table 3: EEV break up for SEB

Raw Material	**% age**	**Weight (kg)**	**EEV (MJ)**
Soil	62.00%	19096	0
C. Sand/ St. Dust	30.00%	9240	0
Cement	8.00%	2464	16509
Total	100.00%	30800	16509
Power : 18.5 kwh x 8 hr x 3.64 MJ			539
Total EEV per day production			17048
EEV per Hydra form Block (SEB) (size: 230 x 220 x 115)			**6.09**

Table 4: EEV break up for Fly Ash interlocking block using Hydraform technology

Raw Material	**% age**	**Weight (kg)**	**EEV (MJ)**
Fly Ash	65.00%	17290	0.00
C. Sand/ St. Dust	27.00%	7182	0.00
Cement	8.00%	2128	14258
Total	100.00%	26600	14258
Power : 18.5 kwh x 8 hr x 3.64 MJ			539
Total EEV per day production			14796
EEV per Hydra form Block (Fly Ash) (size: 230 x 220 x 115)			**5.28**

4. Model

Some 200 No of typical houses were studied for the purposes of understanding the house Materials economics and this gives the inputs for calculation of EEV. Shown below in plate 2, is the house design for the units proposed by HUDCO for the IHSDP schemes taken up in the city of Meerut, India. The broad specifications are mentioned in plate 1.

Plate 1: Specification for the housing Typology studied:

S.no.	SPECIFICATIONS	
1	Structure	Load Bearing Structure
2	Wall	230mm Thick Brick Masonry In 1:6 Cement : Coarse Sand, Mortar
3	Roof	Flat Rcc Roof (M20),115 Mm Thick With TMT Fe 500d Reinforcement
4	Flooring	40 Mm Thick Cement Concrete (1:2:4) Flooring
5	Skirting/Dado	12 Mm Thick 300/1200mm High, 1:6 Cement :Coarse Sand Mortar
6	Plaster	12/15mm 1:6 Cement : Coarse Sand
7	Mud Fuska	100 Mm Average With Brick Tiles
8	Parapet	900mm High In 115 Mm Thick Brick Masonry In 1:4 Cement Sand Mortar
9	Joinery	Ms Frames With Steel Grills And Glass Panels
10	Cc Gola/Khurrah/Coping	1:2:4 Pcc

Plate 2: TYPICAL LIG HOUSE drawings (3)

Comparison for Masonry used in Construction: The masonry can be chosen from one of the various choices available, the compressive strength and the comparative EEV (MJ/kg) as shown in Table 5.

Table 5: Comparative Chart for Embodied Energy Value (EEV) & Compressive Strength for Different Building Materials

Building Material	Size (cm)	Comp. Strength (kg/ sq.cm)	Weight (kg)	Density (kg/cu.m)	EEV(Block) MJ	EEV (MJ/kg)
Brick (conventional)	22.9x11.4x7.6	+- 75	2.75	1386	4.5	1.64
Hollow concrete block	40x20x20	+- 40	26.88	1680	11	0.41
AAC/CLC	40x20x20	+- 40	19.2	1200	11.5	0.60
Solid Concrete Block	30x20x15	+- 75	21.6	2400	10.4	0.48
HF (fly ash block)	23x22x11.5	+- 70	9.5	1633	5.3	0.56
HF (soil-cement block)	23x22x11.5	+- 50	11	1890	6.1	0.55
FalG Block	30*20*15	+- 75	18	2000	7.9	0.44

Basic Construction Materials per Sqm of Plinth area and the EEV of the units per sqm of plinth area are as follows in Table 6 – Table 13:

ENERGY (EEV) OF DIFFERENT BUILDING COMPONENTS (BRICK MASONRY)

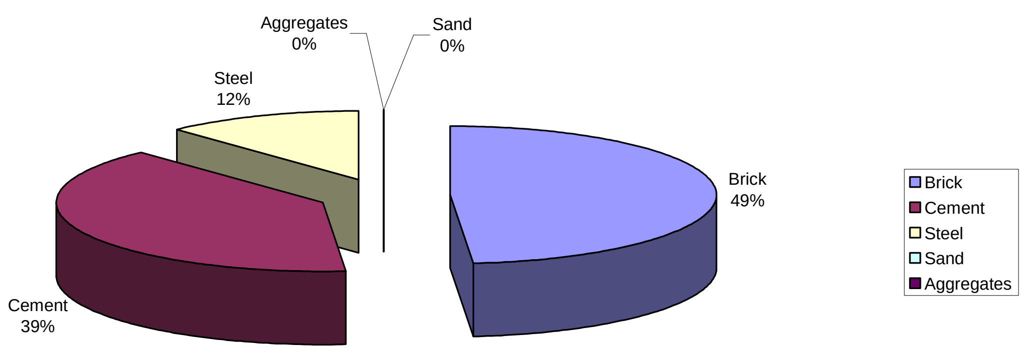


PLATE 2: TYPICAL LIG HOUSE

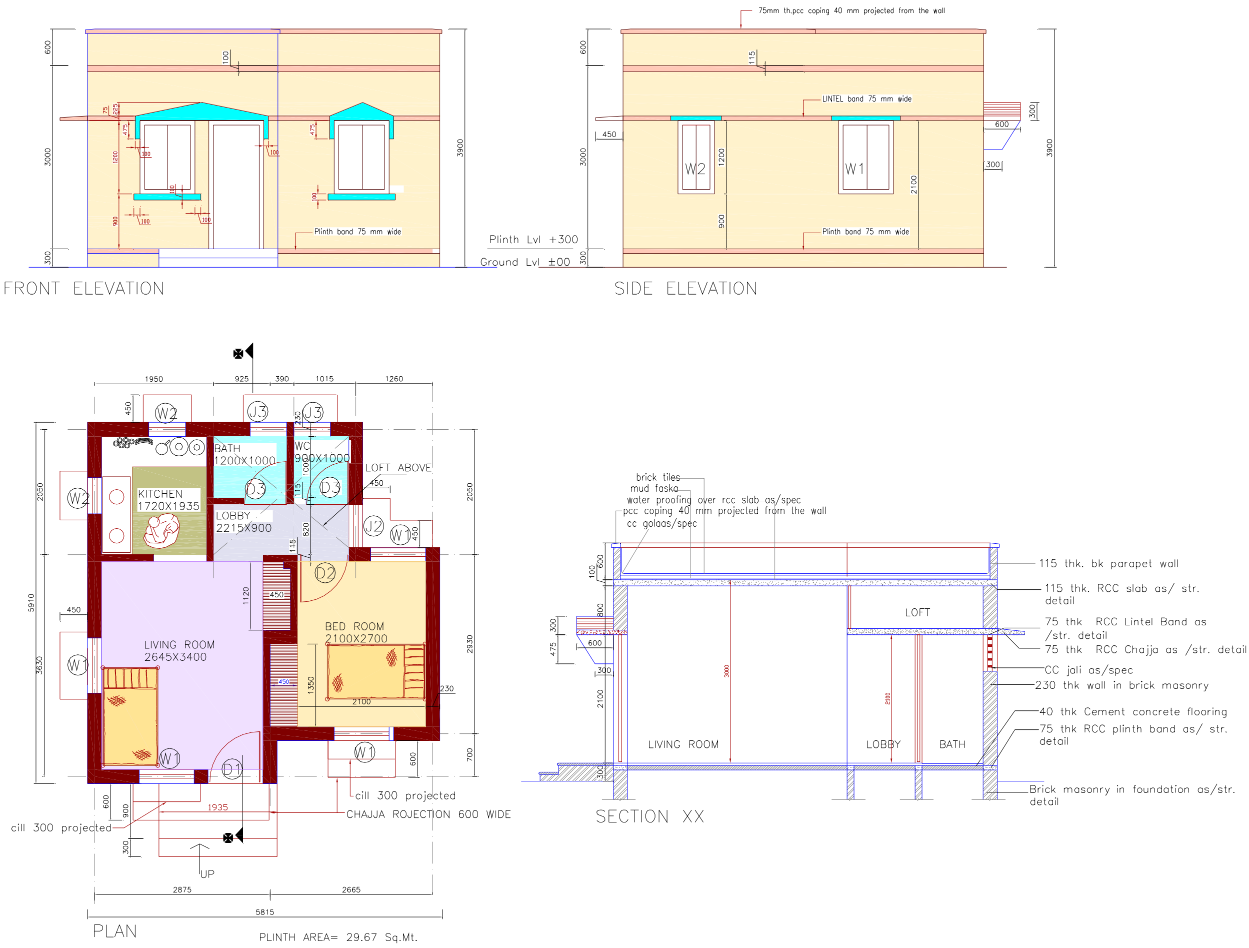


Table: 6 (4) **Computation of EEV in a Single Storied Cost effective house with following masonry option**
Bricks English Bond: EEV (MJ) of Building per Sq.m. of Plinth Area

Item	Material requirement per Sqm of Plinth Area	**EEV**	**EEV per Sq.m. of Plinth Area**
Brick	460 Nos	4.5 MJ/Brick	2070
Cement	5 Bag	6.7 MJ/Kg	1675
Steel	16 Kg	32 MJ/Kg	512
Sand	0.65 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**4257.0**

ENERGY (EEV) OF DIFFERENT BUILDING COMPONENTS HF SEB BLOCKS

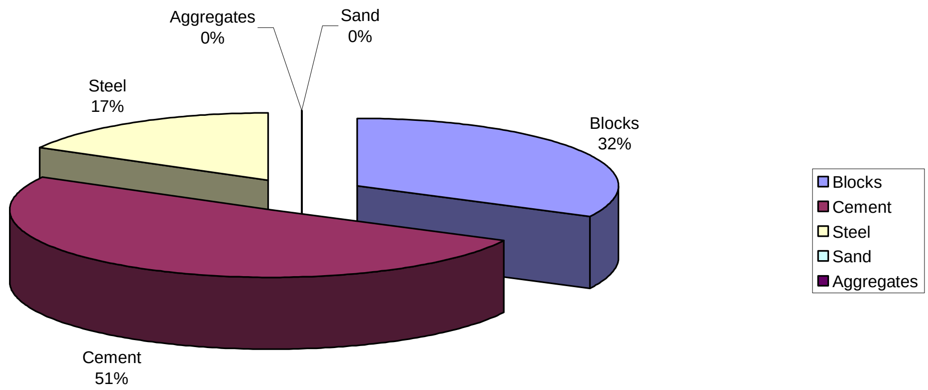


Table 7(4)

HF SEB BLOCKS EEV (MJ) of Building Per Sqm of Plinth Area

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	160 Nos	6.09 MJ/Brick	974.4
Cement	4.55 Bag	6.7 MJ/Kg	1524.25
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**3010.650**

EEV 29% Less than Brick House

ENERGY (EEV) VALUES FOR BUILDING COMPONENTS (FLY ASH BLOCKS)

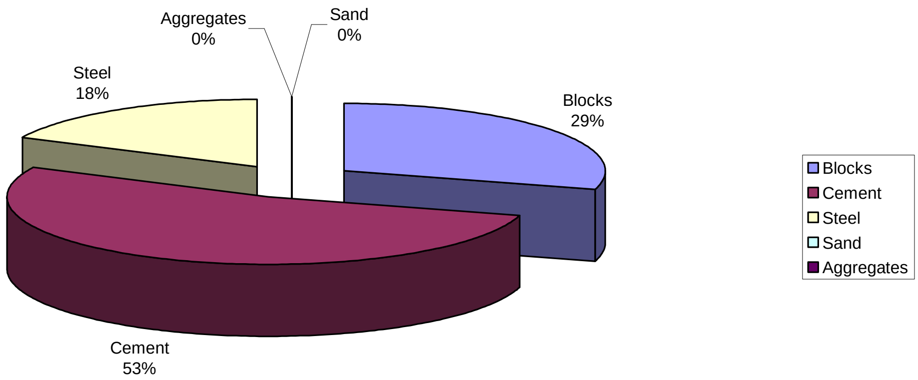


Table 8: (4)

HF Fly ash BLOCKS	EEV (MJ) of Building Per Sqm of Plinth Area		
Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	160 Nos	5.28 MJ/Brick	844.8
Cement	4.55 Bag	6.7 MJ/Kg	1524.25
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**2881.050**

32% Less Than Brick House

ENERGY (EEV) VARIOUS BUILDING COMPONANTS BRICK RAT TRAP BOND

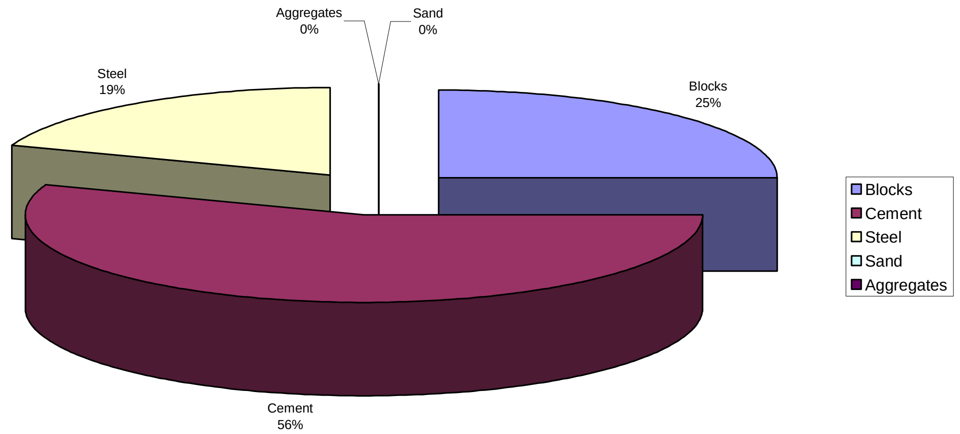


Table 9: (4)

Bricks EEV (MJ) of Building Per Sqm of Plinth Area

Rat-Trap Bond

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Brick	420 Nos	4.5 MJ/Brick	1890
Cement	5 Bag	6.7/MJ/Kg	1675
Steel	16 Kg	32 MJ/Kg	512
Sand	0.65 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**4077.000**

4% Less than Brick House

ENERGY (EEV) VARIOUS BUILDING COMPONENTS HOLLOW CONCRETE BLOCKS

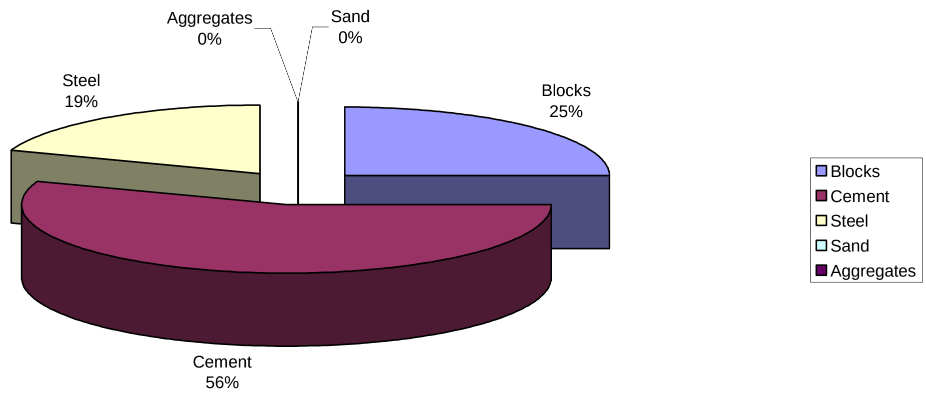


Table 10: (4)

Hollow Concrete Blocks EEV (MJ) of Building Per Sqm of Plinth Area

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	60 Nos	11 MJ/Brick	660
Cement	4.4 Bag	6.7/MJ/Kg	1474
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**2646.000**

38% Less than Brick House

ENERGY (EEV) VARIOUS BUILDING COMPONENTS FAL G BLOCKS

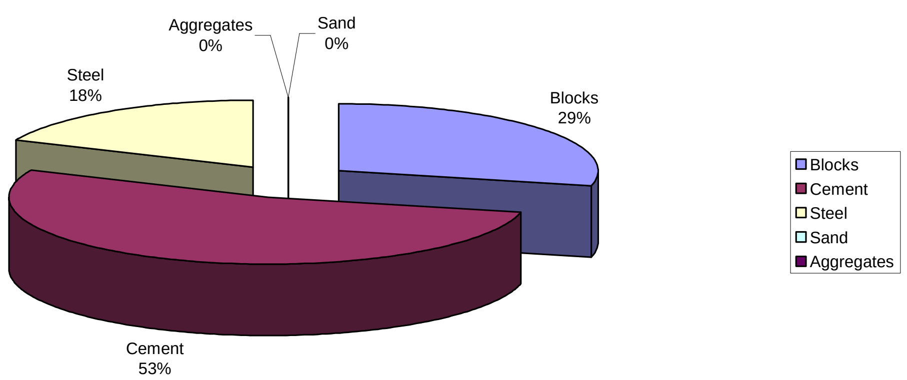


Table 11: (4)

FalG Blocks EEV (MJ) of Building Per Sqm of Plinth Area

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	102 Nos	7.9 MJ/Brick	805.8
Cement	4.45 Bag	6.7/MJ/Kg	1490.75
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**2808.550**

34% Less than Brick House

ENERGY (EEV) VARIOUS BUILDING MATERIALS SOLID CONCRETE BLOCKS

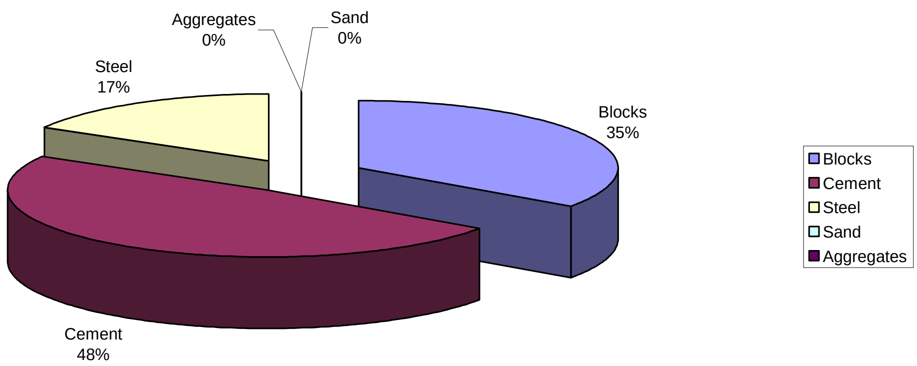


Table 12: (4)

Solid Concrete Blocks EEV (MJ) of Building Per Sqm of Plinth Area

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	102 Nos	10.4 MJ/Brick	1060.8
Cement	4.45 Bag	6.7/MJ/Kg	1490.75
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**3063.550**

28% Less than brick house

ENERGY (EEV) BUILDING MATERIALS AAC/ CLC BLOCKS

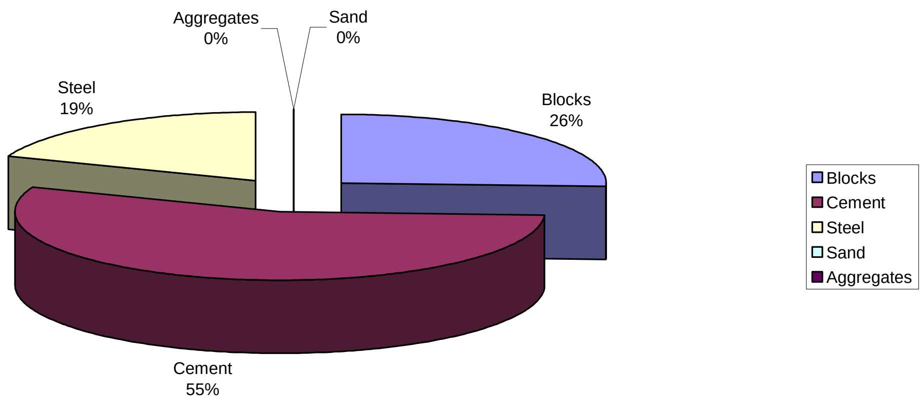


Table 13: (4)
AAC/CLC Blocks EEV (MJ) of Building Per Sqm of Plinth Area

Item	Material requirement per Sqm of Plinth Area	EEV	EEV per Sqm of Plinth area
Blocks	60 Nos	11.5 MJ/Brick	690
Cement	4.4 Bag	6.7/MJ/Kg	1474
Steel	16 Kg	32 MJ/Kg	512
Sand	0.55 Cum	0	0
Aggregates	0.45 cum	0	0
Total			**2676.000**

Table 14:

Comparative chart for EEV with Different Masonry Option for a Single Storied House Per Sqm of Plinth Area			
S No	**Masonry**	**EEV(MJ)/Sqm of Plinth Area**	**% Saving**
1	Brick	4257.000	0
2	Hollow	2646.000	38%
3	AAC/CLC	2676.000	37%
4	FalG	2808.550	34%
5	HF Flyash	2881.050	32%
6	HF SEB	3010.650	29%
7	Solid Concrete	3063.550	28%
8	Rat-Trap	4077.000	4%

It is seen that the masonry alone constitute about 50 % of EEV and if this can be replaced by LOW EMBODIED ENERGY materials, there will be tremendous saving in the EEV of the Houses.

Table 15 :(Year 2007 Prices in Indian Rupees)

Building Material	**Size (in cm)**	**Wall Thickness**	**No of units/sqm**	**Cost/Cu.m (Rs)**	**Cost/Sq.m (Rs)**
		(in cm)		**(Approx)**	**(Approx)**
AAC	40 x 20 x 20	20	13	3600	720
Brick	22.9 x 11.4 x 7.6	23	116	2400	552
Hollow Concrete Blocks	40 x 20 x 20	20	13	2700	540
HF (fly ash block)	23 x 22 x 11.5	23	40	2800	616
HF(soil-cement block)	23 x 22 x 11.5	23	40	2800	616

Table 16:
Materials input per sqm of walling with 1:6 Cement Sand mortar

Building Material	Wall Thickness	Units of Blocks Required	Cement (kg)	Sand (cum)	Plaster	EEV of Blocks	EEV of Cement
Brick	(9" thick wall)	116	14.5	0.06	Required	521.7	97.2
Hollow Concrete Block	(8" thick wall)	13	7.5	0.03	Required	137.5	50.3
AAC	(8" thick wall)	13	7.25	0.029	Required	143.8	48.6
HF (fly ash block)	(9" thick wall)	40	1	0.029	Optional	208.9	6.7
HF(soil-cement block)	(9" thick wall)	40	1	0.029	Optional	240.6	6.7

5. Maintenance/Operational energy:

In these residential units, only energy required are Electrical energy and cooking gas energy. The Electrical energy can be quantified as per electrical load sanctioned in these types of houses with most efficient electrical appliances used in the houses, like CFL 15 W for lights-7 nos, 2- 60 W fans, 1-Refrigrator 75 W, 1-TV, 1-Room cooler 100 W and power points.
Average running of the appliance per month is as per following table 17:
Total electrical consumption (units per hours) – (Source BSES Energy Bill -Delhi)
Total 3.30 Units per day or 99 Units per months in winters i.e. 356.40 MJ
Total 6.18 Units per day or 185.40 units per Month in Summers i.e. 667.44 MJ.

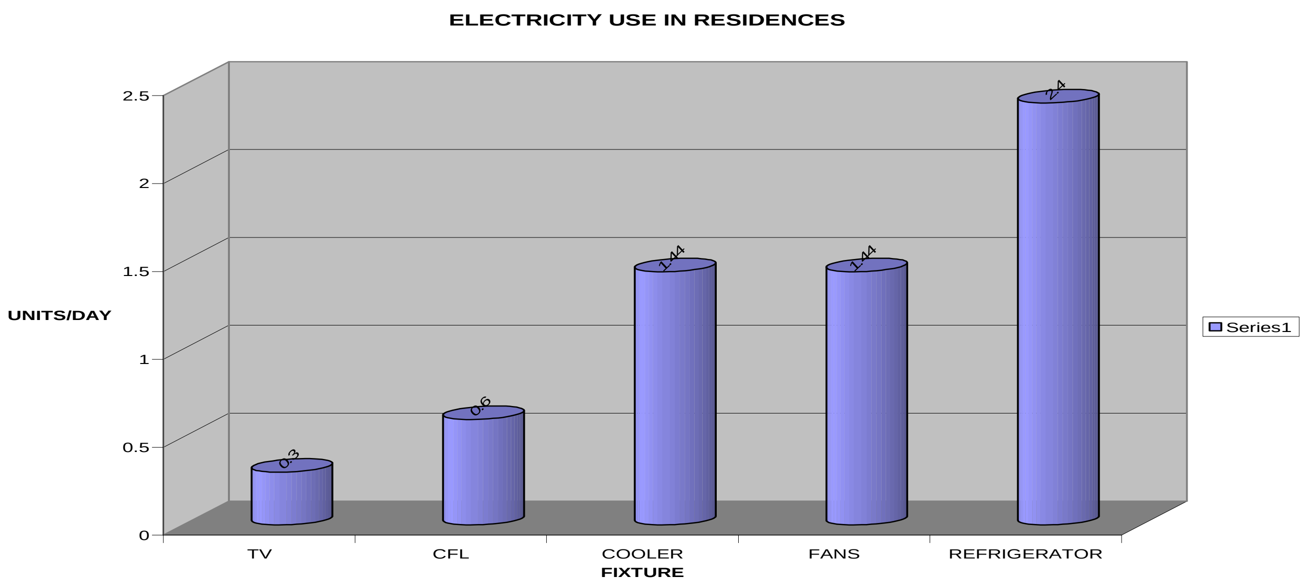
Table 17:

FIXTURE	WATTS	NUMBERS	UNITS/HOUR	DURATION/DAY (IN HOURS)	UNITS/ DAY
CFL	15	7	0.15	4	0.6
ROOM COOLER	100	1	0.12	12	1.44
FANS	60	2	0.12	12	1.44
REFRIGERATOR	75	1	0.1	24	2.4
POWER POINTS	100	2			
TV	40	1	.05	6	.30
TOTAL(SUMMER)					**6.18**
TOTAL(WINTER)					**3.3**

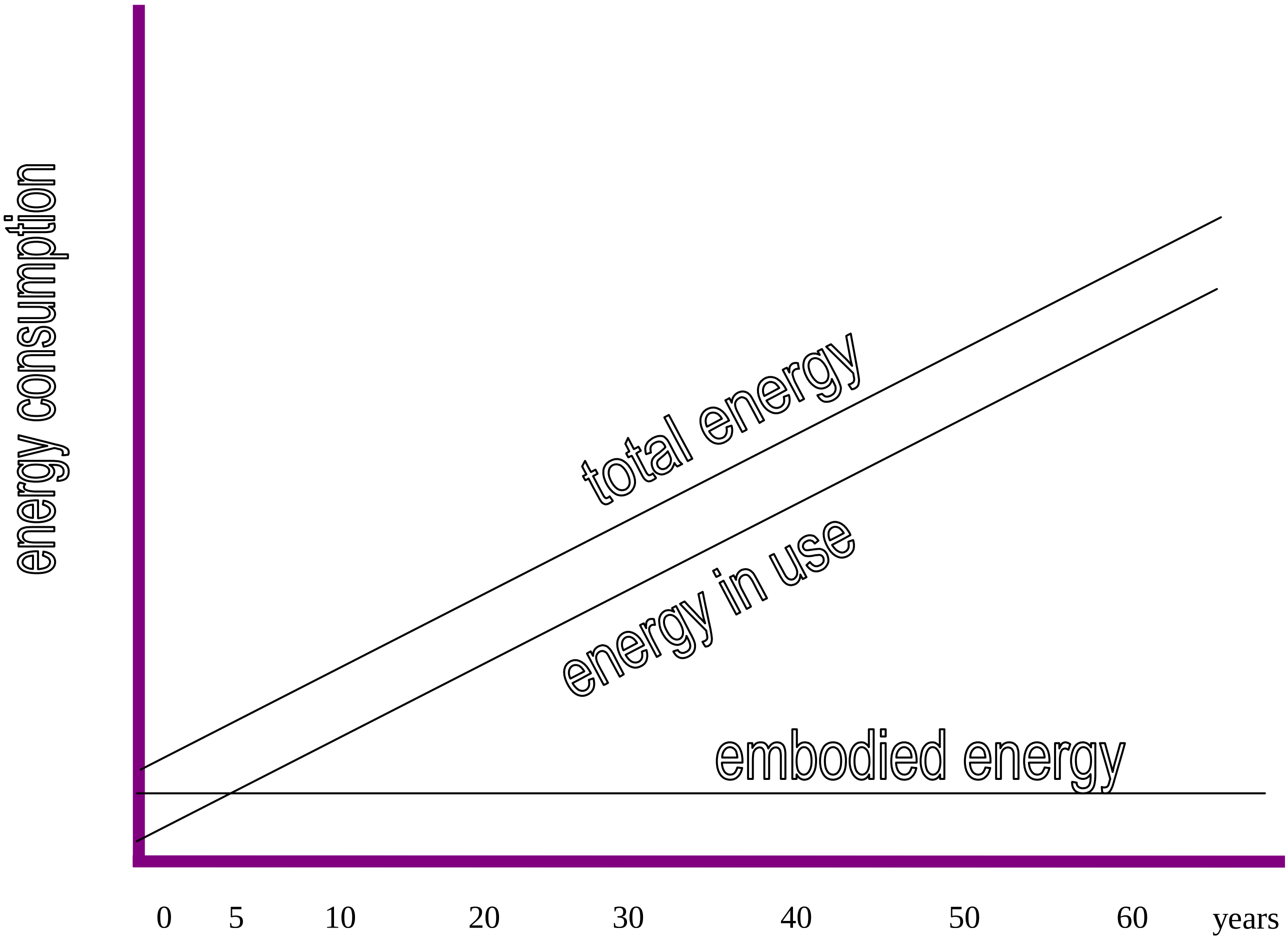
The Plinth Area of the Unit at Plate 2 is 29 sqm, EEV =29*4257MJ (Table 6) = 123.45 GJ

Maintenance/operational Energy per year= 99*3+185.4*9 (assuming 3 month winter & 9 month summer) = 1965.40 Units/Years or 7076.16 MJ/ year= 7.076 GJ/ year

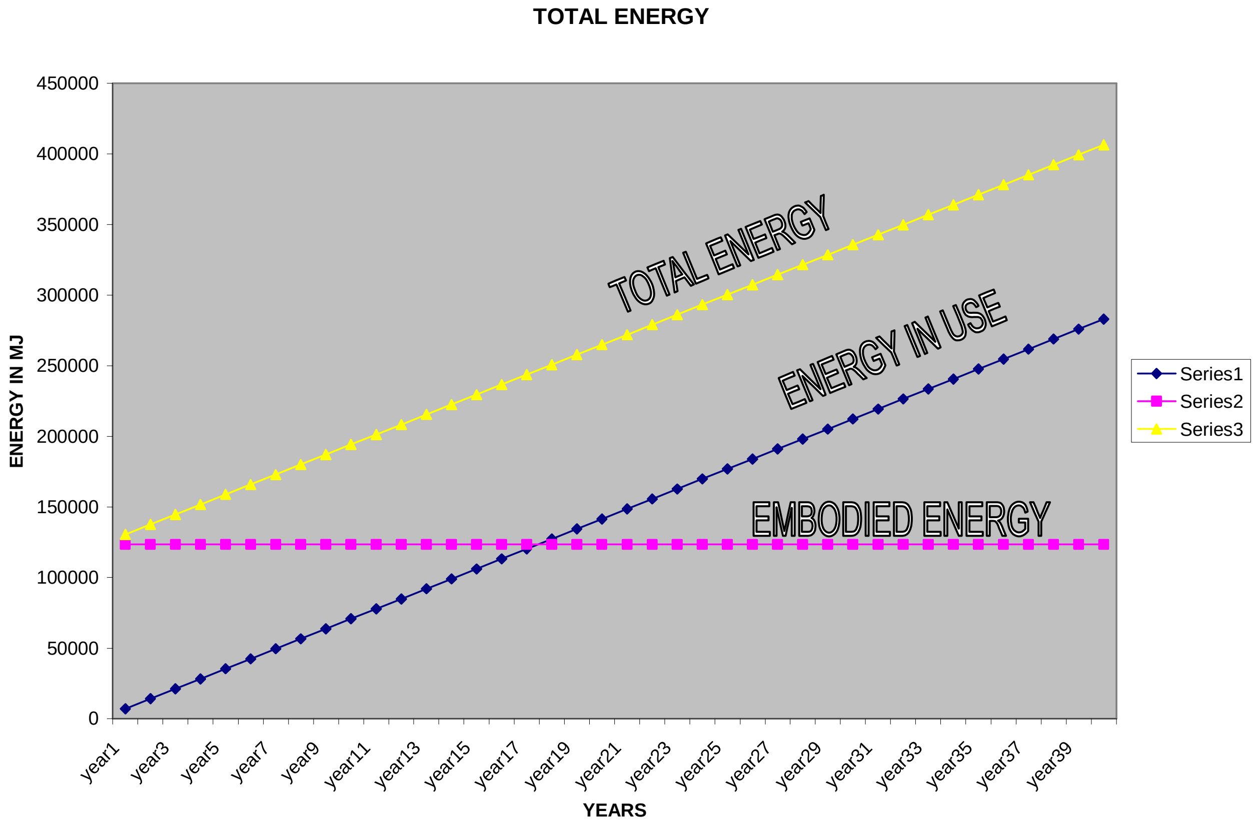
The Electrical energy in use overtakes the embodied energy of the unit after 17.4 years.



NORMAL HOUSE IN UK – GREEN HOMES (5)



COST EFFECTIVE HOUSE IN INDIA- ENERGY AUDIT



6. Conclusion:

In India Ratio of EEV to Maintenance Energy of the Residential units is much higher compared to UK houses and this should be main criteria for judging the Energy efficiency of the houses considering the fact that life of a house is about 50-60 years in India.
As a thumb rule the energy in use overtakes the embodied energy of the houses in five years of use of a residential building in UK and in India this takes about 20 Years. Hence, over the lifetime of a building it is definitely very useful to take steps to reduce the energy in use through active and passive solar/ climatic design measures, but it more important to use the building materials with low EEV and quantities of the materials must be minimized, especially masonry.
This is also clear that the masonry by burnt Bricks, takes very high amount of EEV, and the materials like Hollow Cement Concrete blocks, AAC/CLC etc requires much less EEV.
Hence Planning as well as Intervention by Cost effective building materials, can significantly bring down the EEV of the houses.

*** These are the views expressed by the researchers, based on their own study. Hudco may or may not have the same view on this finding.

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