A Study on Carbon Footprint and Water Footprint in Residential Building System

CP Ramesh, Babitha Rani H, Laishram Ashakumar Singh, Faisal Mehraj Wani, Basavaraj M

Abstract- **Energy and water are the basic resources that support economic as well as social development. Concerns are growing over the effects of rising carbon dioxide emissions from energy consumption and water shortage problems. Hence developments that can achieve "low carbon" and "water conservation" outcomes are becoming socially and politically desirable. Energy and water are closely related. Energy production and utilization processes require the use of water. Similarly, water acquisition, allocation, and utilization stages are accompanied by energy consumption. Benchmarking of energy and water footprint has been made for residential building in Bangalore city in climate zone of savanna climate with distinct wet and dry seasons. The electric and water bills of the building similar to the case studies has been collected for duration of 1 year for calculation of carbon footprint, water footprint of the building system. The different footprint diagram viz., carbon footprint, water footprint, embodied energy footprint and building footprint are presented. Embodied energy has been used for evaluation of carbon footprint. Embodied energy for the 2 building topologies chosen namely:- Case study 1, case study 2 are respectively.**

The carbon footprint for 2 buildings topologies chosen namely:-

Case study 1, case study 2 are respectively.

The water footprint for 2 buildings topologies chosen namely:-

Case study 1, case study 2 are respectively.

When it comes to the total amount of footprint, the 2BHK & 3B individual houses (kammanahalli houses) consumes maximum energy and consumes more water.

INTRODUCTION

Now a days Buildings are currently responsible for more than 40% of global energy and one third of global greenhouse gas emissions. Water consumption and pollution are mainly on some specific activities, such as irrigation, bathing, washing, cleaning, cooling and processing. The use of water resources has become spatially disconnected from the consumer. These reports explain about the embodied energy, water footprint and embodied carbon of the building over its lifecycle. This would include Extraction, manufacturing, transportation and placing. The operation and disposal of the building material are not included in embodied energy, which would consider in the life cycle approach. Operational energy consumption depends on the occupants.

Embodied Energy: Embodied energy is the energy consumed by all the processes which are associated with the manufacturing of materials and equipment, transport. The energy requirement to construct and maintain the place is called embodied energy for example, the energy required to make the brick, transport them to site, plaster, paint and re-plaster over the life of the wall. Best practice would also include energy calculation for demolition and recycling.

The concept of embodied energy originates from designing more sustainable building. embodied energy is a significant component of the lifecycle impact of building.

EMBODIED ENERGY- TERMS & DEFINITIONS

Initial Embodied energy- Energy required producing building. The non-renewable energy consumed in the acquisition of raw material, their processing, manufacturing, transportation to site, and construction. As a rule of thumb, embodied energy is a reasonable indicator of the overall environmental impact of building material, assemblies or systems. Recurring Embodied Energy – Maintenance Energy- Energy required refurbishing and maintaining the building over its effective life.

Figure 1.1- Embodied Energy Flowchart

Significance of Embodied Energy: The importance of energy conservation was on the operational energy of a building while embodied energy was assumed to be relatively in significant. Operational energy conservation may be accomplished with readily available energy efficient appliances, advanced insulating materials and the equipment of building performance optimization. For example an increase in the number of the star labeled home appliances can reduce operational energy gradually. Embodied energy, however, can only be reduced if low energy intensive materials products are the initial stages of building design. The calculations process is shown in figure 1.2

Figure 1.2 – Schematic Representation of Embodied Energy

Carbon Footprint Concept: It is defined as the total emissions caused by an individual, event, organization, and communities. Carbon footprint is the sum of all emission of CO_2 (carbon dioxide), which was produce during activity. A carbon footprint can be calculated for the time period of a year. The concept name of the carbon footprint originates from ecological footprint, discussion, which was developed by Rees and Wackernagel in the 1990s which estimates the number of "earths".

Water Footprint Concept: The water footprint is a measure of humanity's appropriation of fresh water in volumes of water consumed or polluted.

There are three component of water footprint: Green water – water store in the root zone of the soil and evaporated, or incorporated by plant. It is most applicable for agriculture, horticulture etc.

II. Blue water – water that has sources from ground or surface water resources.

III. Grey water – the amount of fresh water required to assimilate pollutant to meet specific water quality.

LIFE CYCLE ANALYSIS

It is a method of determining the real cost (or in this case, energy used) over the lifetime of a product, from cradle to grave. Life cycle analysis is particularly helpful for comparing a number of options that is, identifying the most effective option available. It is also useful for benchmarking products. In this manner, the relative cost, or efficiency of a product can be identified. In other words, it is a method of determining the real cost (in this case, energy used) over the lifetime of the products, from cradle to grave. Life cycle energy analysis is particularly helpful for comparing a number of options like, identifying the most effective option available. Life cycle analysis is an approach that accounts for all energy inputs to a building in its life cycle. The system boundaries of this analysis include the energy use during the following phases (figure 1.8): manufacture, use, and demolition

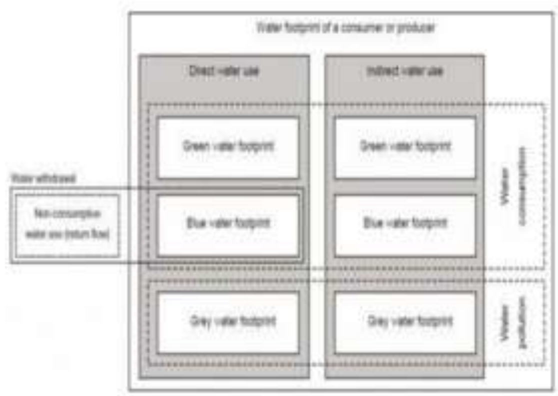


Figure 1.3 - components of a water footprint.

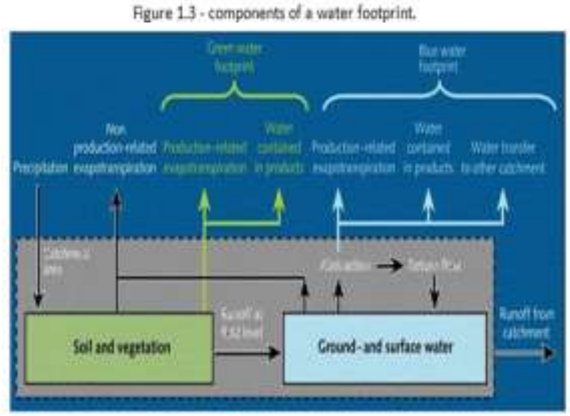


Figure 1.4 – The green and blue water footprint in relation to the water

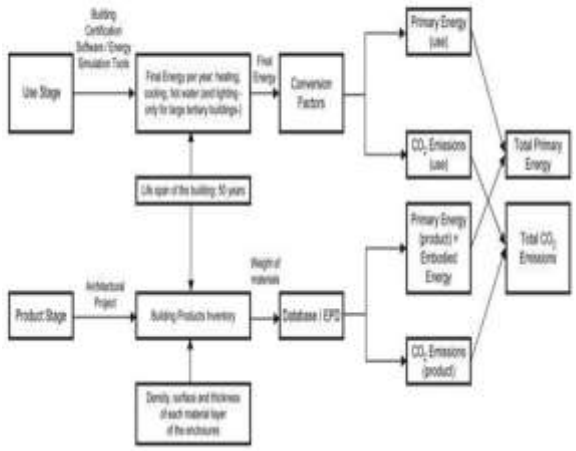


Figure 1.5- General structure of the LCA methodology

Scope and Objective: Scope of the analysis is limited to residential building, where in possible material, design, appliances and process alternates are used to compute the Energy footprint and Water footprint.

Methodology: This project study about the water and carbon emission and calculate their footprints. Four stages of carbon emission are calculated. Finally each water cubic meter of carbon emission for all stages are added together to get the accurate water footprint of the project. The energy use for the maintenance, repair, and renovation is will be appropriately considered. The total sum of embodied energy, operation energy and demolition energy will give the life cycle energy of the building.

LITERATURE SURVEY

Details of survey: "Calculating of carbon footprints for water diversion and desalination projects" a review paper by Jiahong Liu, Silan Chen, Hao Wang, Xiangdong chen, states the operation period reaches 30 years, the carbon footprint of China's south-to-north water diversion project will be about 0.179 kgCO2. The carbon footprints for UAE desalination plants were 2.999 kgCO2 for the multi-stage flash (MSF) method, 1.280 kg CO2 for the multiple effect distillation (MED) METHOD, AND 2.562 Kg CO2 for the reverse osmosis (RO) method. Overall, the results of this study demonstrate that the calculation of carbon footprints for water resource projects can be a valuable source of information for decision-making involving water utilization and conservation. "M.K.Dixit et al "(2012) depicts that "there is a potential to reduce the embodied energy of buildings by 30-44% through the use of alternative and local construction materials. The embodied energy of building is base upon both the quantity and the energy intensity of each material used. Variations and inconsistencies in the energy intensity of materials reported in literature can be attributed to several factors. These factors are: system boundaries, uncertainty in data collection, life cycle assessment methods used for embodied energy calculation, geographic location of the study area, fuel mix of energy produces, transportation, age of data sources, source of data, and completeness of data". "it is practically very difficult to calculate the embodied energy of these material, as there is a lot of variation in their production system and type of fuel used in making these building products in india". Author Richard Haynes explains in "Embodied Energy Calculations within Life Cycle Analysis of Residential Building 2010" that "as energy costs increase, controlling the cost of building will require reductions in energy demand". Also managing global greenhouse gas emissions from building construction is of key importance for minimizing climate change. The paper infers that there is a requirement to design a model to overcome the difficulty in calculating embodied energy, to estimates life cycle energy and CO2 emissions"ROUNAK j Goklaney (2011), discusses the relation between the green building's energy consumption and the associated cost resource. The result of his work illustrate that "Green building projects which operate on low energy forms have discounted payback and very good internal rate of return. The work highlights the long term value of green investments which will help convince companies, investors and consumers to invest into green buildings". It is also found that consideration of the local climatic condition along with the aesthetics at the design stage is important for the performance of energy efficient building.

Summary of literature: Based on the literature, it can be come to end that

- Brick, cement and steel are the major construction materials which are use for materials energy and water consumption.
- Uncertainties in data collection, system boundaries, life cycle methods of assessment etc. host of parameters makes the embodied energy calculation as a complex phenomenon.

Figure 3.1- Ground floor plan

Figure 3.2- First floor plan

CASE STUDY 2:Chikka Banaswadi, Bengaluru 13°0'25.6428"N 77°38'40.3548"E

In the present case study, a G+1 Building of 2BHK and 4BH (individual houses) is designed for a family of 7-8 members to meet all the needs of a middle class family. The house is a north-south building and facing north and has most of the windows and main door facing this direction. The entire windows are provided with lintel/projection of about 0.9m. This is a house designed for a site of 19.00m × 12.00m. The plan of this case study is shown in figure 2.3 and 2.4.

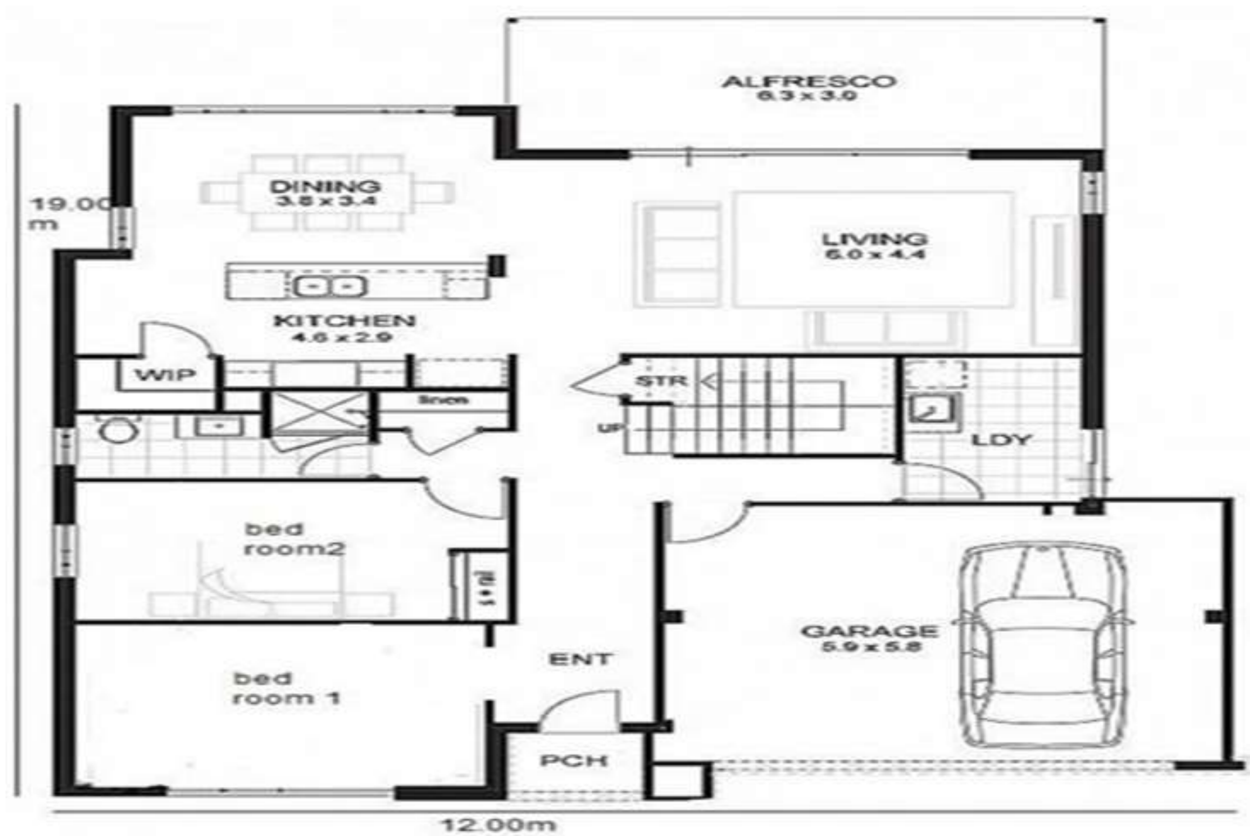


Figure3.3- Ground floor plan (individual house)

Table 3.1- Embodied energy and volume of components of building-Foundation and Basement

Particulars	In m3	QTY in kg	EE-MJ	EC-KgCO2e
Foundation and basement	15.36	36864.00	8422.20	758.32
Masonry basements	7.92	16610.89	4339.87	390.76
Plinth Ring Beams	1.62	3412.43	888.28	80.02
Damp proof courses(DPC)	1.09	2235.24	597.66	51.14
Earth filling	32.00	46720.00	0.00	0.00
Total	57.99	105842.56	14248.01	1282.88
Particular	In m3	QTY in kg	EE-MJ	EC-KgCO2e
Table 3.2- Embodied energy and volume of components of building-Superstructure				
Particular	In m3	QTY in kg	EE-MJ	EC-KgCO2e
CSEB Walls	43.37	63319.83	27366.47	2462.98
CSEB Ring beam	2.25	4725.00	1260.72	111.09
CSEB precast lintel& Beams	0.16	336.00	10234.56	50.40
RCC Springer Beams	0.05	105.00	201.6	21.00
Total	45.82	68485.83	39036.35	2645.46

Figure 3.4- First floor plan

Table 3.3 – Embodied energy and volume of components of building- Staircase

Particulars	In m3	QTU in kg	EE-MJ	EC-kgCO2e
Stair cases	1.38	2898.00	1304.10	8.40

Table 3.6 – Embodied energy and volume of components of building- Staircase

Particulars	In m3	Qty. in kg	EE-MJ	EC-kgCO2e
Stair cases	1.04	3245.00	1009.75	6.28

Table 3.4- Embodied energy and volume of components of building-Foundation and Basement

Particulars	In m3	QTY in kg	EE-MJ	EC-KgCO2e
Foundation and basement	10.36	36864.00	3608.6	385.09
Masonry basements	5.92	16610.89	2062.05	185.77
Plinth Ring Beams	1.62	3412.43	564.28	50.84
Damp proof courses (DPC)	1.78	2235.24	620.1	55.86
Earth filling	29.00	46720.00	0.00	0.00
Total	47.3	11448.09	6855.03	677.56

Table 3.5- Embodied energy and volume of components of building-Superstructure

Particular	In m3	QTY in kg	EE-MJ	EC-KgCO2e
CSEB Walls	22.52	63319.83	14210.12	1280.20
CSEB Ring beam	2.25	4725.00	1419.75	127.90
CSEB precast lintel & Beams	0.16	336.00	100.96	9.09
RCC Springer Beams	0.05	105.00	31.55	2.84
Total	24.98	18045.73	15762.38	1420.03

CONCLUSION

The analysis of Embodied Energy for a building is done during the planning stage, prior to the material selection process. As the planning and the materials selection process is carried out for each component of the building, the analysis of Embodied Energy is also carried out in a similar manner for the selection of the materials. The various building components are firstly categorized and then each component is listed out with the possible option of materials to be used for building. Hence, each component will have a good number of options of materials which can be used. Now for these materials Embodied Energy calculated and the best option is chosen for the work task, based on the building requirements. This shall lead to a healthy selection of material and will result in a sustainable future of these materials.

EMBODIED ENERGY, CARBON AND WATER FOOTPRINT DATA ANALYSIS

The preceding two chapters provided the complete details of the embodied energy and water footprint. In this chapter, discussions about the results are initiated. It is important to note that the computation were made on certain assumptions, crucial ones being that the buildings are acceptable as presented in the design. A general observation of the building typologies in a city like Bangalore reveals that the design presented are indeed accepted by a wide section of the population, however, when it comes to the choice of the materials and accessories, there is a wide range which is going to reflect on the total energy. This is discussed in the chapter extensively.

Data Collection: The water bills and electrical bills collected from many of the similar residential buildings is been photographed since the print on the bills is done by dot matrix printers and also the average value of the consumption is listed in table 3.1 and 3.2

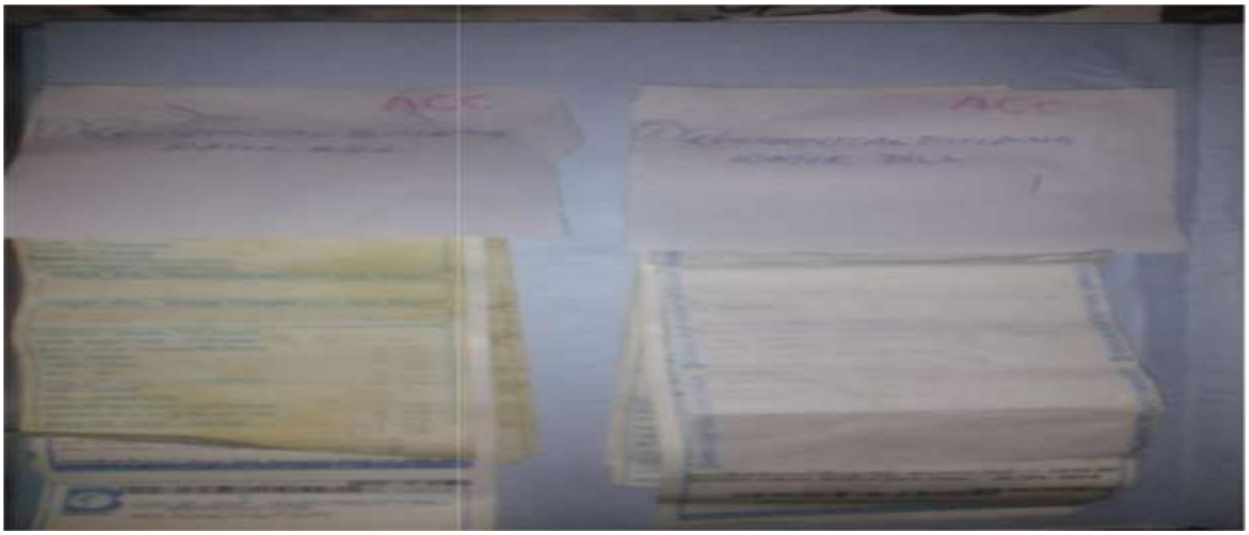
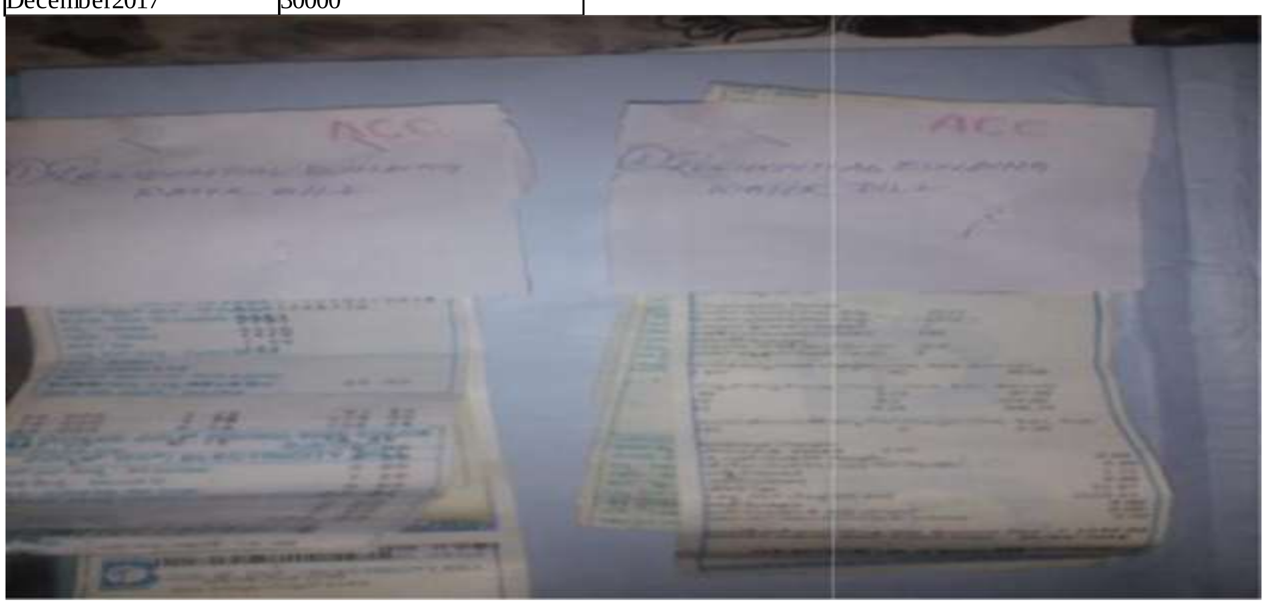


Figure 4.1- Electric and water bill of kammanahalli residential building case study 1

Month and year	Consumption in liters
June 2017	38000
July 2017	34000
August 2017	42000
September 2017	62000
October 2017	25000
November 2017	28000
December2017	30000
January 2018	34000
February 2018	58000
March 2018	62000
April 2018	55000
May 2018	48000

Table 4.1- Average water consumption collected from the bills for case study 1



Month and year	Consumption in liters
June 2017	25000
July 2017	33000
August 2017	9000
September 2017	18000
October 2017	25000
November2017	35000
December 2017	15000
January2018	17000
February2018	21000
March2018	32000
April2018	30000
May2018	25000

Table 4.2- Average water consumptions collected from bills for case study 2

From table 3.1 and 3.2, it can be seen that maximum water consumption is 62000 lt in month of October and April for case study 1 and for case study 2 November month use maximum water.

ANALYSES OF CASE STUDIES Case study 1

Table 4.3- Water Footprint, Embodied Energy and volume of Components of case study 1

Components	Volume (m3)	Embodied Energy(MJ)	Embodied carbon EC-kgCO2e	Embodied Water coefficient(kl/unit)
Foundation and Basement	57.99	14248.01	1282.88	219.515
Superstructure	45.82	39036.35	2645.46	371.632
Staircase and Railings	1.38	1304.1	8.40	11.193
Total	105.19	54588.46	3936.74	602.34

Total Embodied Energy = 54588.46 MJ, Total Built-up Area =138.77 m2,

total Energy footprint= 393.37MJ/m2

Total 602.34 Kl/unit of water is consumed for the construction respective bill has been attached.

Table 4.4- Water Footprint, Embodied Energy and volume of Components of case study

components	Volume(m3)	Embodied Energy(MJ)	Embodied Carbon (kgCO2e)	Embodied water coefficient(kl/unit)
Foundation and Basement	47.30	6855.03	677.56	155.66
Superstructure	24.98	15762.38	1420.03	259.57
Staircase and Railings	1.04	1009.75	6.28	10.60
Total	73.32	23627.16	2103.87	425.83

Total Embodied Energy = 23627.16 MJ, Total built up area = 228.00 m2

Total Energy footprint =103.63 MJ/m2

Total of 425.83 kl/unit of water are consumed for the construction respective bill has been attached in the above figure.

CONCLUSION

Energy footprint for 2 building: Case study 1 is 393.37MJ/m2, Case study 2 is 103.63 MJ/m2

Carbon footprint for 2 buildings: Case study 1 is 3936.74 kgCO2e,Case study 2 is 2103.87 kgCO2e

Water footprint for 2 buildings: Case study 1 is 602.34 kl/unit, Case study 2 is 425.83 kl/unit

When it comes to the total amount of footprint per tenement, the 5 BHK (kammanahalli house) consumes maximum energy and consume more water.

DISCUSSION AND CONCLUSION

The report is based on materials and construction techniques as practiced in Indian. Water is consumption by some activities, I.e. irrigation, bathing, washing, cleaning, cooling, and other activities. There has been little attention paid to the fact that in the end total water consumption and pollution relate to what and how much community consumes and to the structure of the global economy that supplies the various consumer goods and services.

Discussion: For transportation of building material in urban center area in India it cover a distance of 100km. 5-10% of diesel energy consumed for transportation of material. The energy footprints in terms of embodied energy are more in case study 1 where material utilized in the construction is more. The embodied energy directly proportional to the carbon footprint of the materials used. The water utilized during the constructions will be high when the water is been transported and further more if it has to be pumped. Used of energy efficient alternative building technologies can result to considerable reduction in the embodied energy of the building.

DETAILS	CASE STUDY 1	CASE STUDY 2
ENERGY FOOTPRINT MJ/m2	393.37	103.63
CARBON FOOTPRINTS KgCO2e	3936.74	2103.87
WATER FOOTPRINTS kl/unit	602.34	425.83

Table 5.1: Tabulation of final results

CONCLUSION

The result presented will assist in selecting an energy efficient building material leading to considerable reduction in embodied energy and water consumption of the building as a whole.

Choice of Materials: Choice of material is very important decision that has to be made by the engineer and the stake holder or owners of the building. This brings out the aesthetics of the building and every aspect of the building is solely dependent on the choice of material. In the current trend cost is a major factor for choice of material followed by appearance, in other way it can be seen that cost and embodied energy are directly proportional i.e. higher the embodied energy higher is the cost and vice versa is also true. Similarly lower the embodied energy higher will be the sustainability of the materials intern lower will be the cost.

Choice of Alternatives: There are always alternatives to the materials used in a building. Currently the choice of materials and appliances is driven by cost. But in terms of energy saving a few key point are discussed here; use of locally available material for the masonry work such as laterite block, stabilized mud block, marbles, and granite can be used. Polishing and high finished materials increases the total energy drastically such as polished granite, etc. minimizing the total material consumption is the major key for reducing the energy of a building, for example, plastering, wall cladding with polished granite etc. In case of operational energy, there are appliances in the market which do save energy compared to the conventional appliances.

Used water sense-certified fixtures and fixture fittings where available, By Provide rain water harvesting system to catch at least 25% of run-off volumes of water from roof and non- roof areas. By Providing water meters for the following, as applicable:(minimum three water meters). Potable water consumption at individual dwelling unit level. Catch rain water reuse, Hot water used through solar systems, at building level, Treated waste water consumption, Air-conditioning cooling tower make-up, Any other major source of water consumption such as, swimming pools, water fountain, common car wash facilities, etc.

REFRENCES

[1] Arjen Y. Hoekstra Ashok K. Chapagain, Maite M. Aldaya and Mesfin M. Mekonnen " The Water Footprint Assessment Manual" Setting the global standard,2011 EarthsCan Publishing for a sustainable future London, Washington,DC

[2] B.V.Venkatarama Reddy, K.S. Jagadish(2001) " Embodied energy of common and alternative building materials and technologies", (Elsevier) Department of civil engineering, Indian institute of science, Bangaluru 560012, India.

[3] Jaihong Liu,Silan Chen, Hao Wang,Xiangdong Chen, " Calculation of carbon footprint for water diversion and desalination projects" The 7th International conference on Applied Energy-ICAE2015

[4] Richard Haynes 2010 (Rivised 2013) Embodied Energy Calculations within Life Cycle Analysis of Residential buildings.

[5] T.Wiedmann, J. Minx, A definition of "Carbon Footprint"(EB/OL), http.//www.novapublishers.com/catalog/product_info.php?products_id=5999'2008-07-11/2012-12-18.

[6] A.Dimoudia, C.Tompab, Energy and environment indicators related to construction of building, department of environment Engineering,Democritus University of Thrace,Vass.Sofias 12,67100 Xanthi,2014 Greece b Hellenic open University,MSc "Environmental design of cities and building",patra,Greece

[7] Indian Green Building council-Green Homes Rating systems 2015 version 2.0

[8] Indian green building council, September 2015 (Edited with addendum 4.0)- Abridged Reference Guide, LEED 2011 for india.

[9] Virtual water 2015 available from http://en.wikipedia.org/wiki/virtual_water

[10] Suh S.Are services better for climate change? (j). Environmental science and technology,2006:40 (21):6555-6560