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LIFE CYCLE ASSESSMENT: CSEB & KILN FIRED BRICKS

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Abstract: The building sector is a major consumer of both renewable and nonrenewable natural resources. It was unavoidable that it would become the focus of environmental worries. Throughout its service life cycle, the process and operation of building construction consumes a significant amount of materials. In the design and construction of green buildings, the selection and use of sustainable building materials is critical. The goal of this chapter was to provide an overview of sustainable construction materials and their environmental implications. It also goes through the limitations of life cycle assessment as a methodological concept and framework for analyzing sustainable building materials. Here we are going to discuss the sustainability of the material on the basis of embodied energy and GHG emissions on specific location from manufacturing of the material to bringing it on site and application of that material.

***Index Terms*– LCA (Life Cycle Assessment), GHG Emission (Green House Gas Emission), Embodied energy, sustainable.**

1. Introduction

1.1 Background

The building industry is one of the largest sectors of the world's economy, and one of the largest consumers of energy and raw materials/natural resources (Berger, 2009). The construction industry is made up of businesses ranging from large building manufacturers to small building contractors. The building industry is responsible for constructing buildings, roads, bridges, and other structures that are used for the purpose of housing, work, and leisure. The industry also includes transportation, communication, water, and waste management systems. (Berger, 2009)

1.2 Need And Significance

LCA is a methodology for assessing the environmental impact of products and services. It involves evaluating the amount of "upstream" inputs required to manufacture and deliver a product or service, such as the extraction of raw materials, and the "downstream" emissions and wastes generated when a product is used, such as the emissions generated by the delivery of a service such as a delivery truck. It is therefore a powerful tool for helping companies and organizations to reduce their environmental impact, and to demonstrate to their customers the environmental benefits of their products and services. LCA has been used extensively in the past to assess the environmental impacts of products such as building materials, cars, computers, and packaging materials.

1.3 Aim

Comparative analysis of CSE blocks and kiln fired bricks as a sustainable building material for composite climate in particular building on the basis of life cycle assessment.

1.4 Objectives

- To study about the properties of the sustainable building material.
- Applicability of the material.
- To study about the life cycle assessment of different building material.
- To study about the sustainability parameters of CSE blocks & kiln fired bricks.
- Analyzing both materials in respect with our site.

1.5 Scope & Limitations

- There are certain parameters of sustainability in life cycle assessment i.e.
  - -embodied energy
  - -carbon footprint (GHG emissions)
  - - Thermal properties
  - -structural properties
  - -recyclability
  - -environmental impact
  - -construction techniques

In this study we will only be talking about embodied energy, carbon footprint (GHG emissions), & thermal properties of the above materials.

$$EE_T = E_p + E_t + E_c$$

EEt= Total embodied energy
EEp= Energy consumption at production of building materials
EEt =Energy in transportation of building materials
EEc=Energy at construction stage of the building

Will be using this formula to calculate the total embodied energy and total GHG emissions from both the materials.

Scope of the study is limited to calculate cradle to site embodied energy and carbon footprint and thermal comfort of a particular building in composite climate using both the material.

1.6 Methodology

- literature review of life cycle assessment of different material
- Literature case study of Auroville earth institute for better understanding of the use of CSEB as eco- friendly building material.
- Quantitative Analysis: includes calculation of embodied energy and GHG emissions.
- Qualitative Analysis: includes the thermal performance using the materials.
- Software: Design builder

- Comparative analysis of both materials in respect to our site.

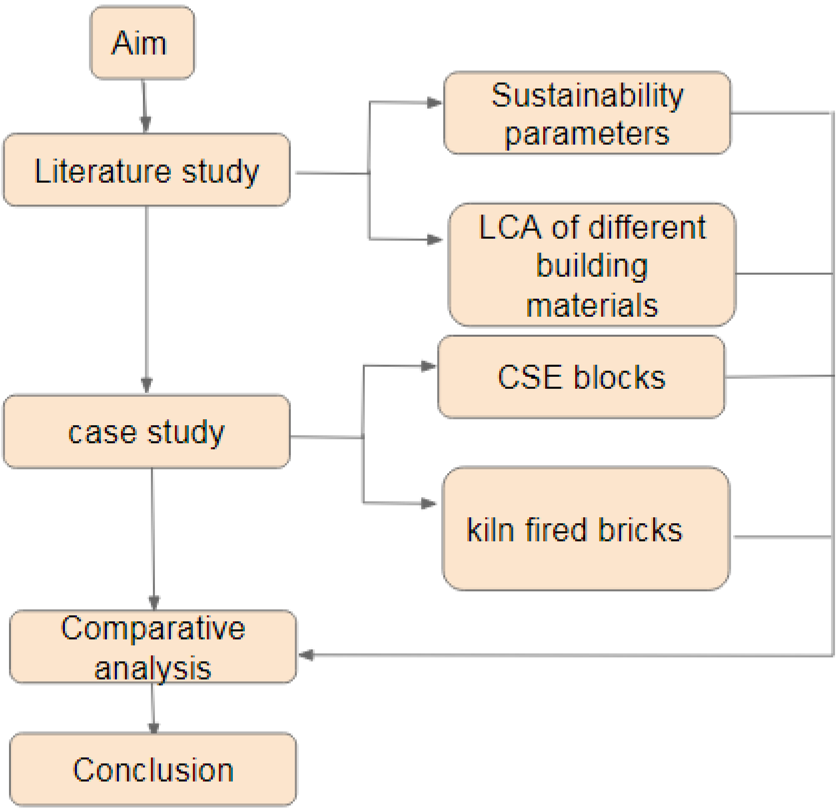


Figure 1 methodology

2. Literature Study

2.1 Introduction

LCA is a method of detailed examination of the life cycle of the product in response to create some environmental awareness on the part of the general public, industry and government. LCA (life cycle assessment) is a cradle to grave or cradle to cradle analysis, evaluating the environmental impacts of a product based on all-natural resource inputs and emissions from the entire supply chain. LCA (life cycle assessment) has a fixed standard frame work mentioned international standards (ISO) 14040. (V.MuralikrishnaValliManickam, 2017)

2.2 Stages of Lca (Life Cycle Assessment)

LCA study comprises of 4 stages:

Stage 1: The first stage of LCA consists of defining your purpose. This is accomplished by writing goal and scope aims.

Stage 2: In this step inventory analysis gives all the information about the energy consumed and GHG emissions in the initial stage i.e. from the extraction of raw material to the processing of the material.

Stage 3: Details from inventory analysis serve for impact assessment. It includes all the categories of the indicator result.

Stage 4: interpretation of LCA includes a critical review for the better understanding of the whole process. (V.MuralikrishnaValliManickam, 2017)

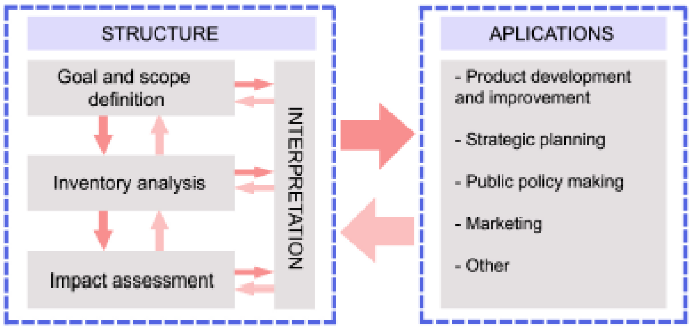


Figure 2 Life Cycle Analysis stages and its application. Compiled by author based on the ISO 14040:2006.

2.3 Sustainability and Sustainable Materials

Sustainability can be described as meeting the needs of the present without compromising the ability of future generation to meet their own needs (Oscar Ortiz, 2008). There are three pillars of sustainability needed to be balanced for the above statement to be true natural environment, social and economy and it can be maintained by balanced needs, common goods and equitable distribution.

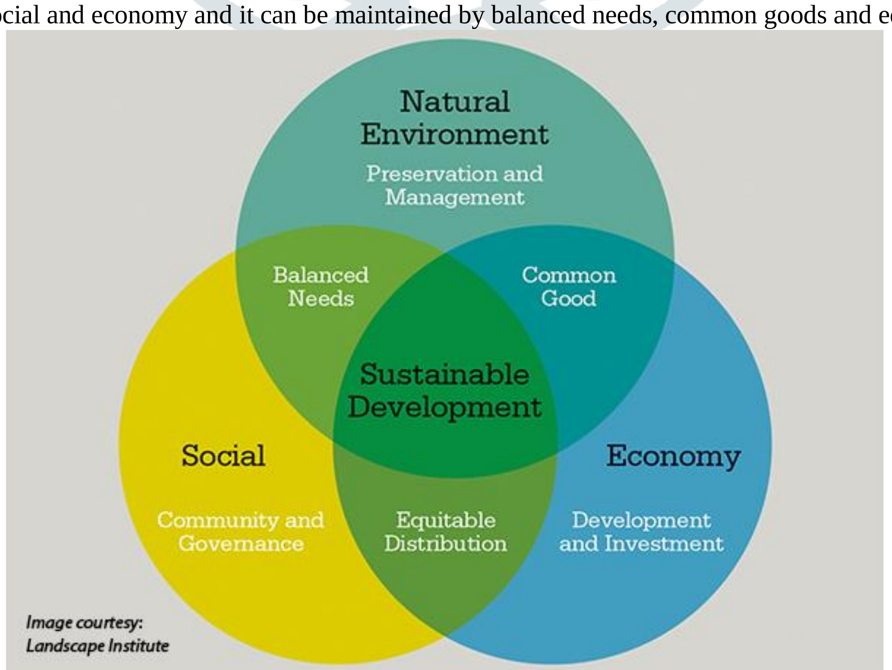


Figure 3 sustainability diagram

A sustainable material is a material that is suitable for use in the long-term causing minimum damage to the environment, animal welfare, or human health. It is often used to describe materials that can be used repeatedly without losing their effectiveness, or in a way that doesn't cause harm to the environment or human health. Examples of sustainable materials include recycled plastics, paper, and textiles such as wool and cotton. In some cases, a material can be made more sustainable by reducing the amount of material used in products, such as by using lighter packaging or designing products that last longer.

Sustainability of a material also depends upon the availability of raw material, energy consumed in the initial phase to application of the material. The amount of energy required to produce a material depends on a number of factors, such as the type of energy source used to produce the material, the percentage of the material that is used in the final product, and the complexity of the manufacturing process. It also depends on the energy efficiency of the product, which is determined by the amount of energy required to produce a unit of that product. For example, the energy required to produce a bottle of soda is significantly less than the energy required to produce a car.

Thus, LCA (Life Cycle analysis) helps us to evaluate the environmental impact (negative or positive) to determine the sustainability of the material.

2.4 Literature Case Study

Figure 4 Pathways World School, Aravali, Gurgaon (Composite)

2.4.1 Introduction

- The school is located just 25 kms away from Delhi International Airport but away from the pollution of the city, and has an ambience of hill resort.
- It is located away from the heavy traffic of the city thereby a pollution less and noise less environment for the growth of the child. The site is however not well connected to the rest of the city through public transport. The direction coordinates are 28°18'39.99"N & 77° 0'45.36"E.

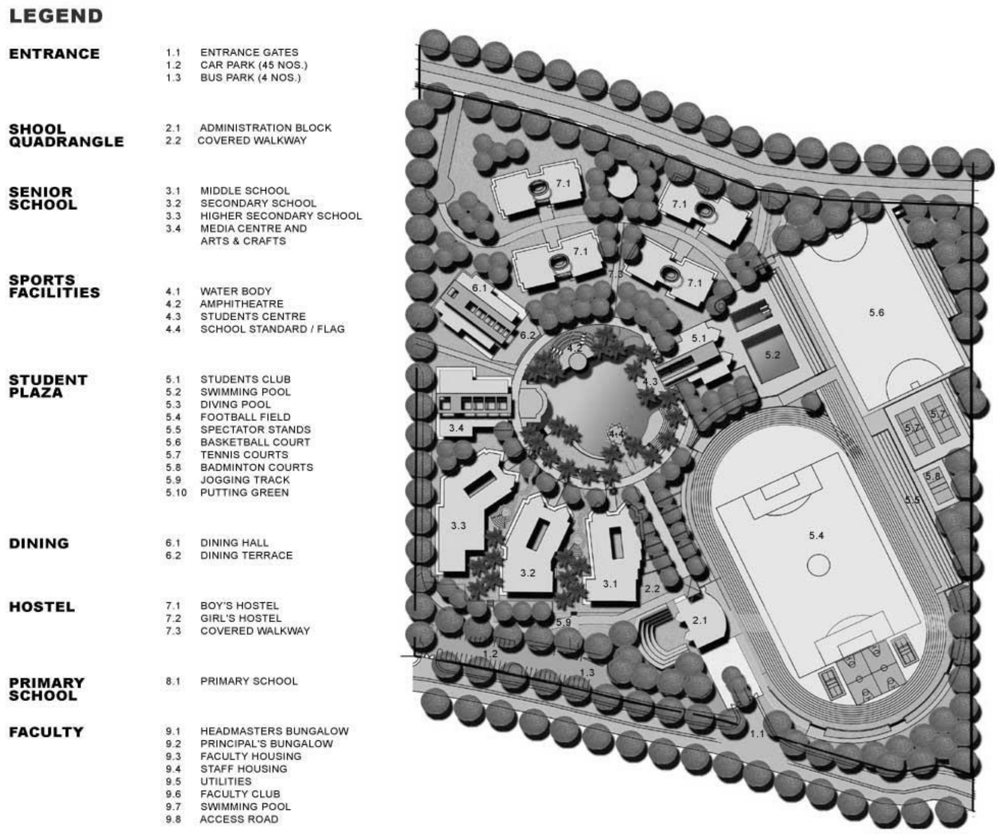


Figure 5 Legend

2.4.2 Relation between Built-Up and Open Space

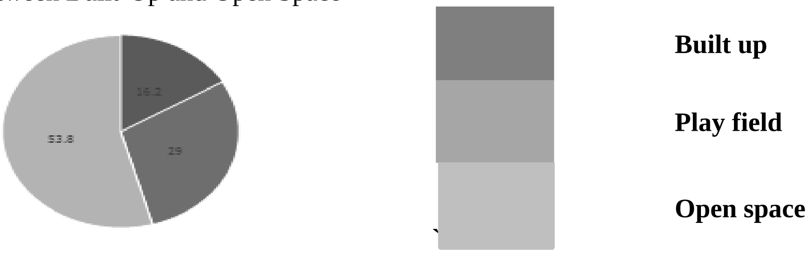


Figure 6 relations between built-up and open space

2.4.3 The Building Blocks

- ❑ Chanakya (Administrative Block)
- ❑ Panini (Primary school- daycare to class 5)
- ❑ Aryabhatta (Middle school- class 6 to class 8)
- ❑ Takshila (Senior school- class 8 to class 12)
- ❑ Nalanda (Media Centre & Library)
- ❑ Kasturi (Dining area, Laundry & Storage area)
- ❑ Anandani (Sports Centre)
- ❑ Residential Blocks.

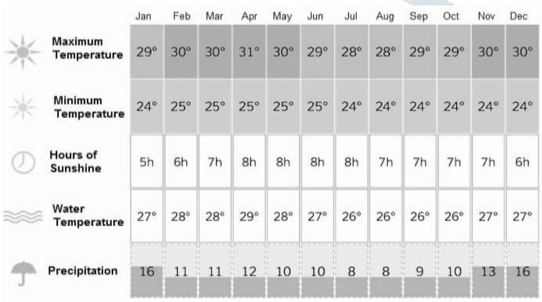
Figure 7 the building blocks

2.4.4 The Concept

The term pathways reinforces the idea that it is the path that one takes in life and the manner in which that path is covered and not the destination.

The school is planned with the understanding that learning does not begin nor end in the classroom. The entire site has been laid out as an eclectic mix of formal and informal areas to encourage different learning styles.

- ❑ Sustainable habitat.
- ❑ Securing the environment for the future.
- ❑ Introducing some old Indian architecture techniques that not only make the buildings environmental friendly but also holds the Indian culture.
- ❑ Cost effective.
- ❑ Circular planning.
- ❑ Green campus.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum Temperature	29°	30°	30°	31°	30°	29°	28°	28°	29°	29°	30°	30°
Minimum Temperature	24°	25°	25°	25°	25°	25°	24°	24°	24°	24°	24°	24°
Hours of Sunshine	5h	6h	7h	8h	8h	8h	8h	7h	7h	7h	7h	6h
Water Temperature	27°	28°	28°	29°	28°	27°	26°	26°	26°	26°	27°	27°
Precipitation	16	11	11	12	10	10	8	8	9	10	13	16

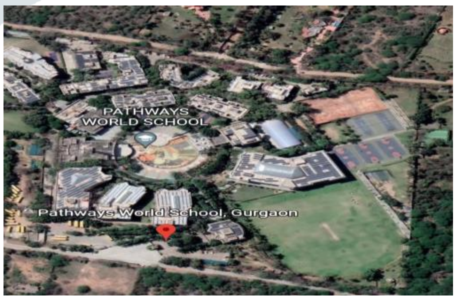


Figure 8 Climate Data *Figure 9 Locations*

2.4.5 Site Details

- Total plot area = 32 acres = 129499.4m
- Ground coverage = 26.95 acres = 109265.1 m2
- Permissible F.A.R. = 1:1.1
- Academic Block area = 984.6794 m2
- Residential Block area = 5801.888 m2
- Residential Block area = 5801.888 m2
- Area provided for parking = 9824.497 m2
- =2.4 acres (10% of plot area)
- Elevation from MSL- 320m
- Terrain type- Hill

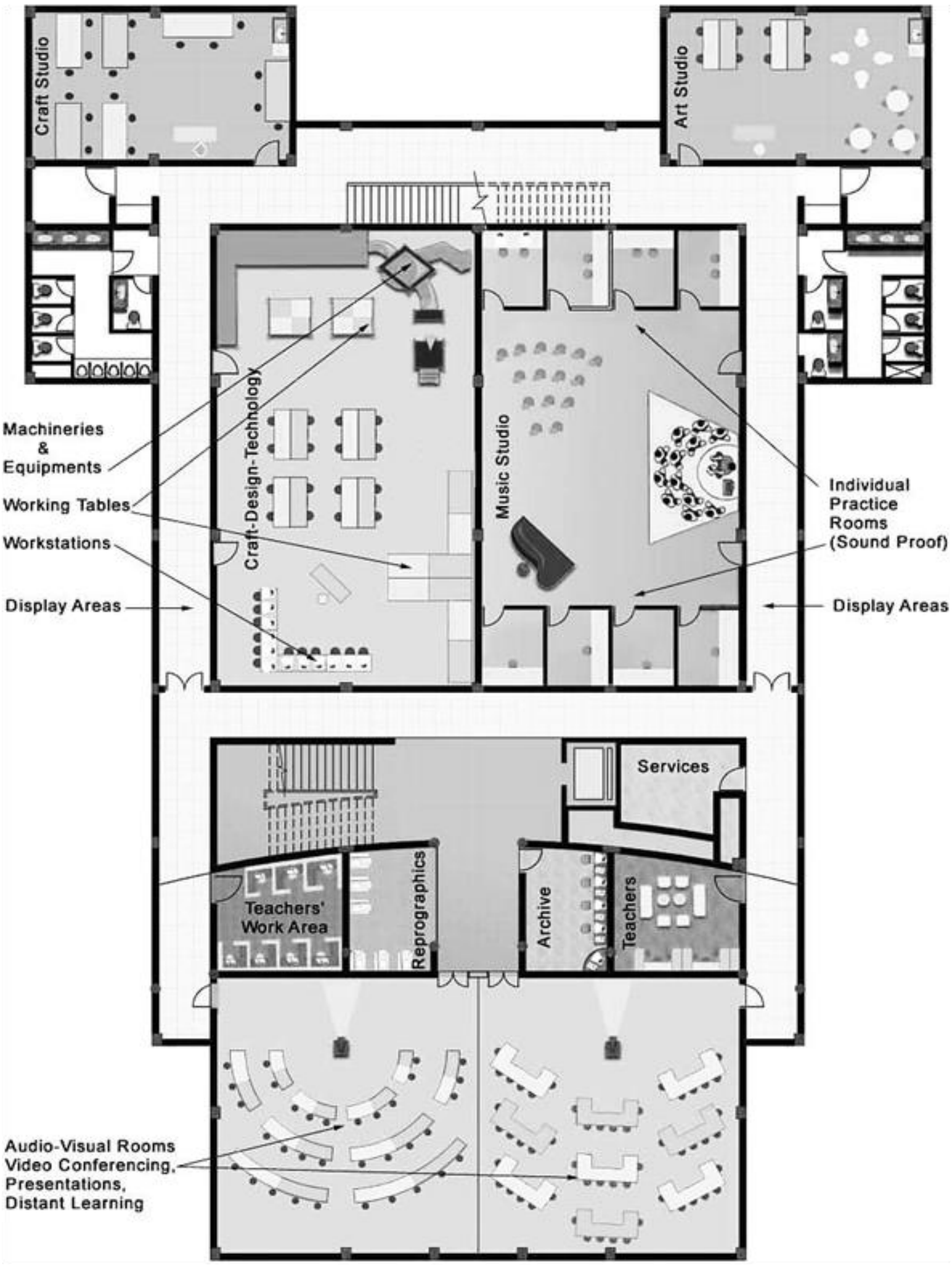


Figure 10 media center and arts and crafts

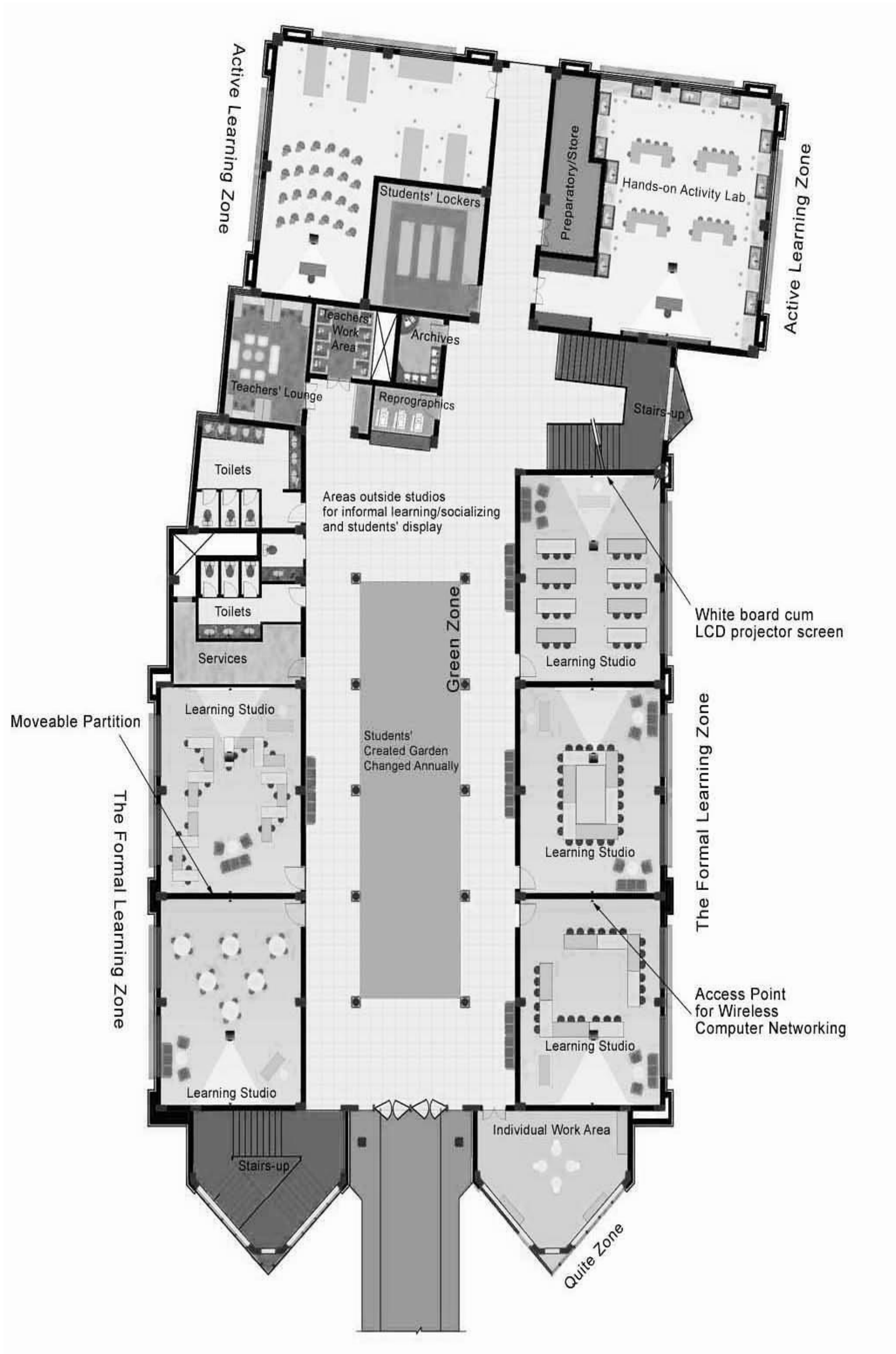


Figure 11 academic block

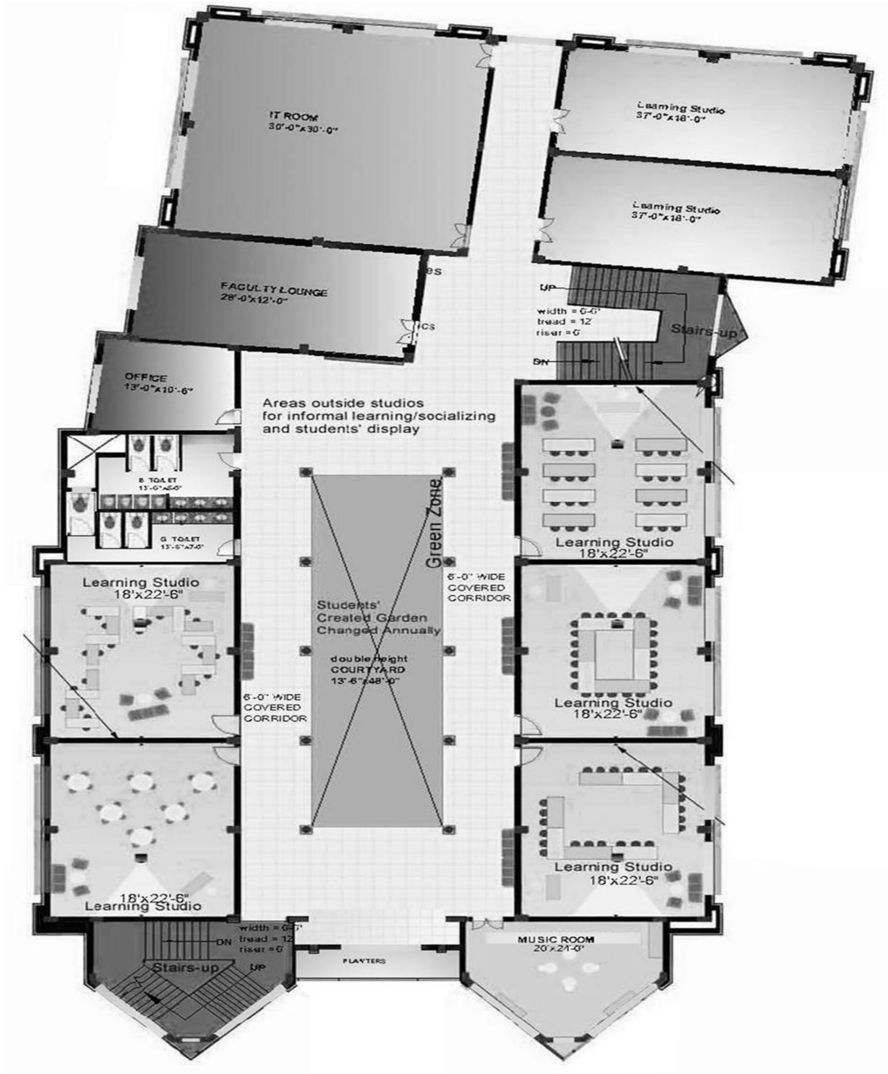


Figure 12 academic block

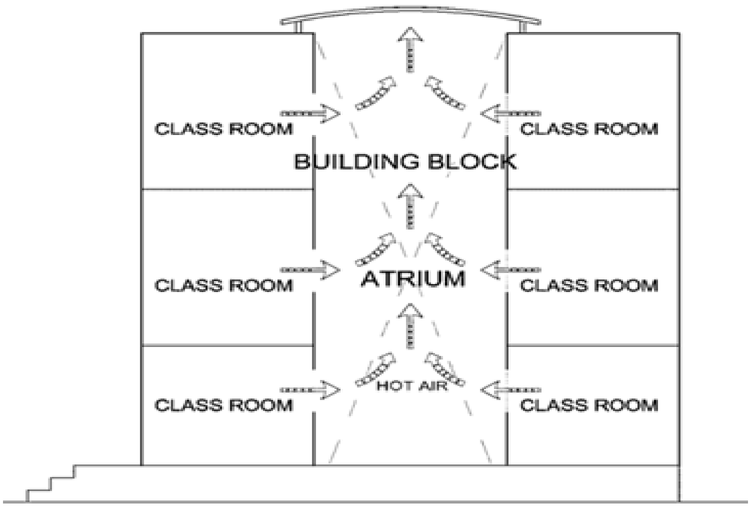


Figure 13 academic block

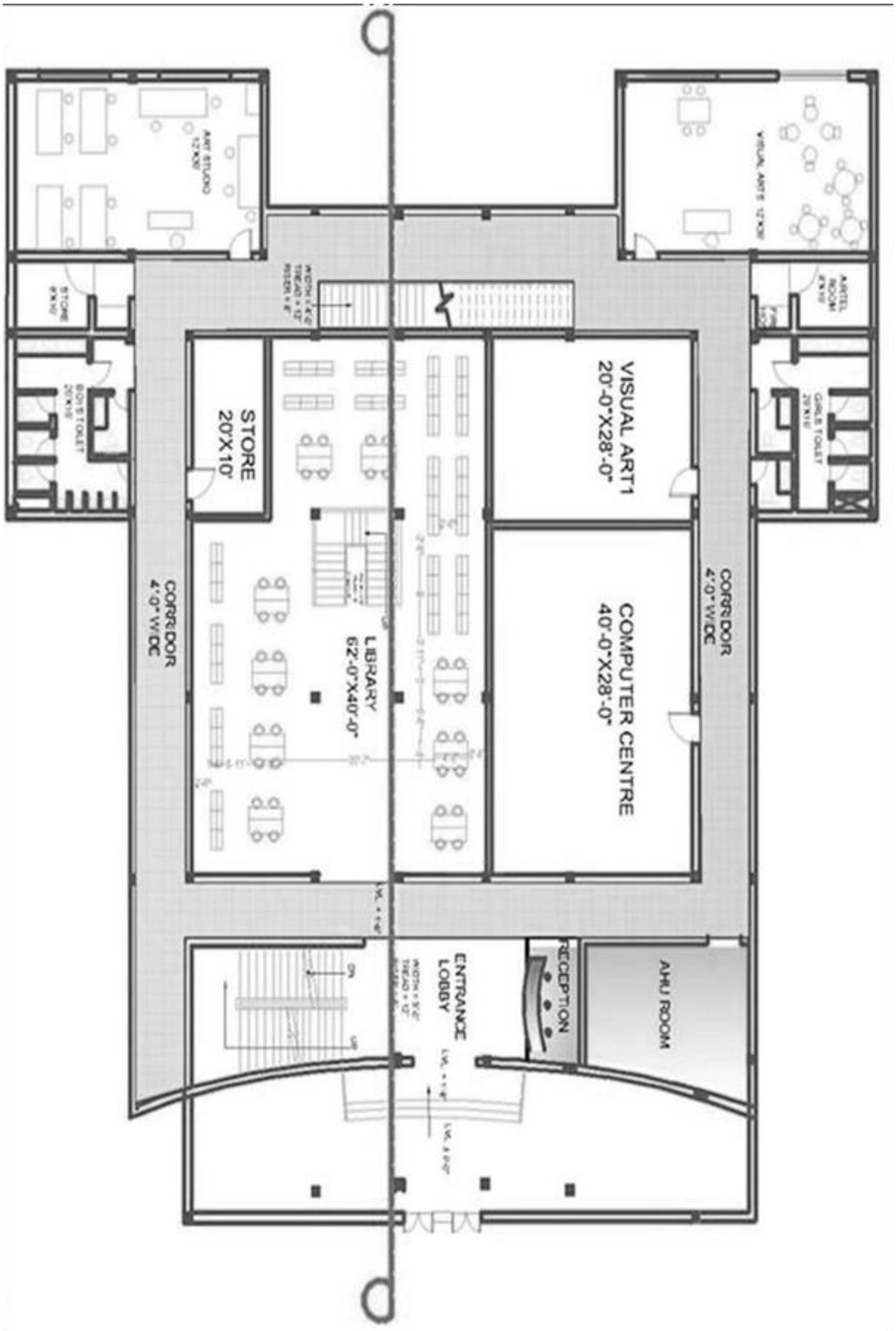
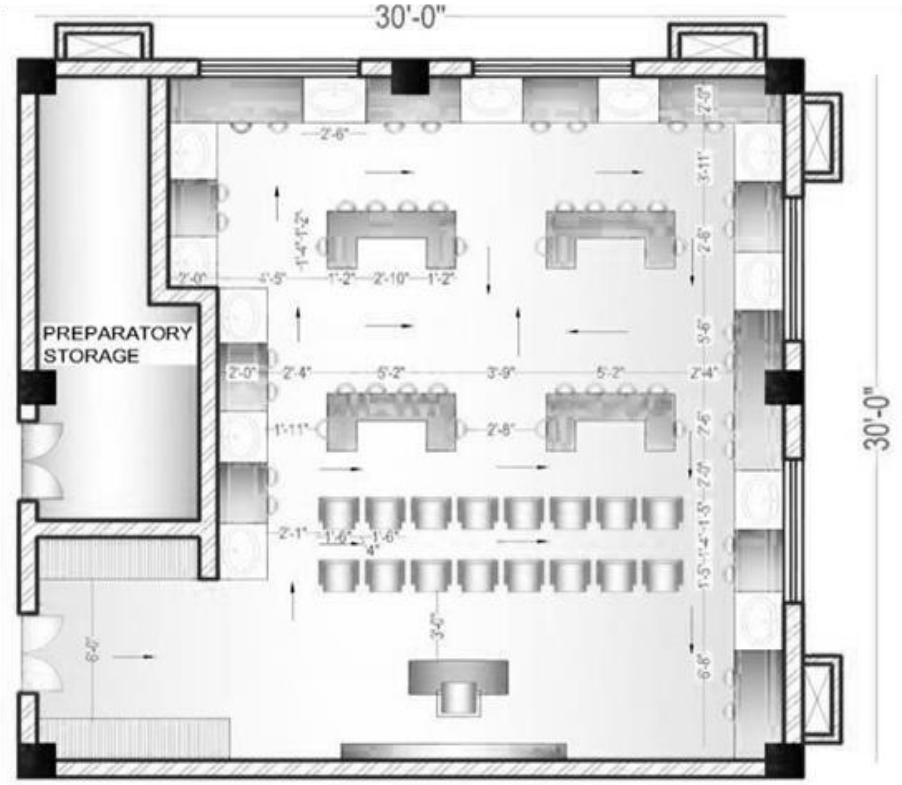
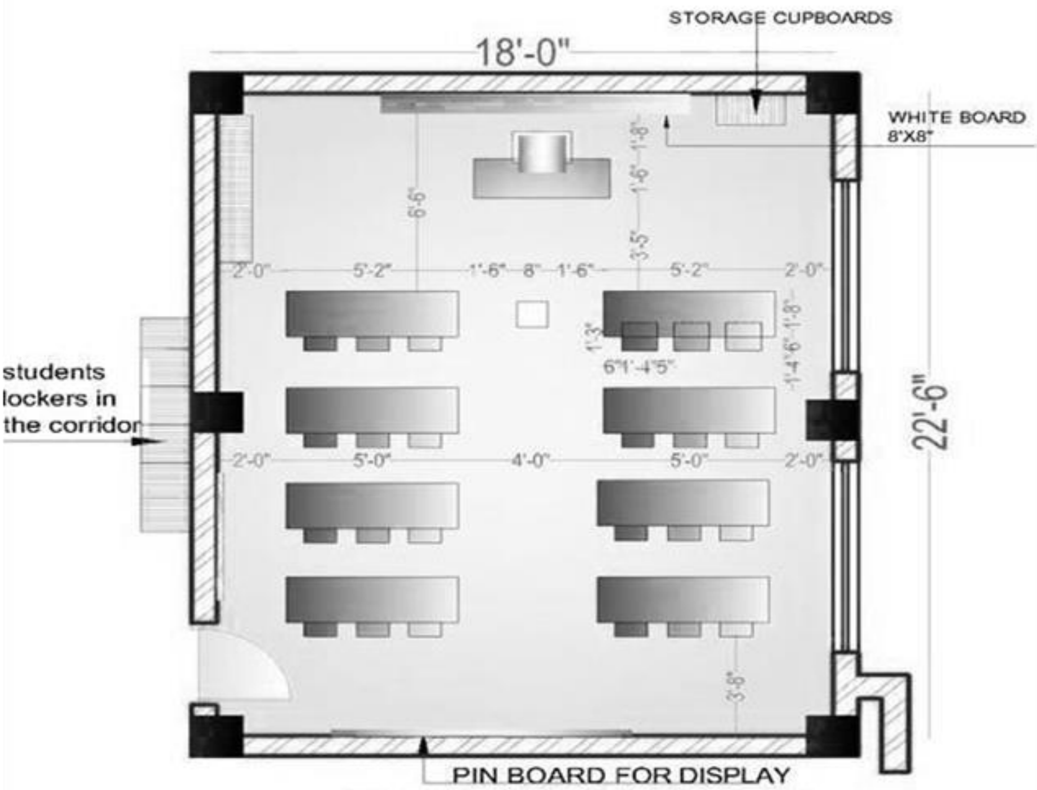


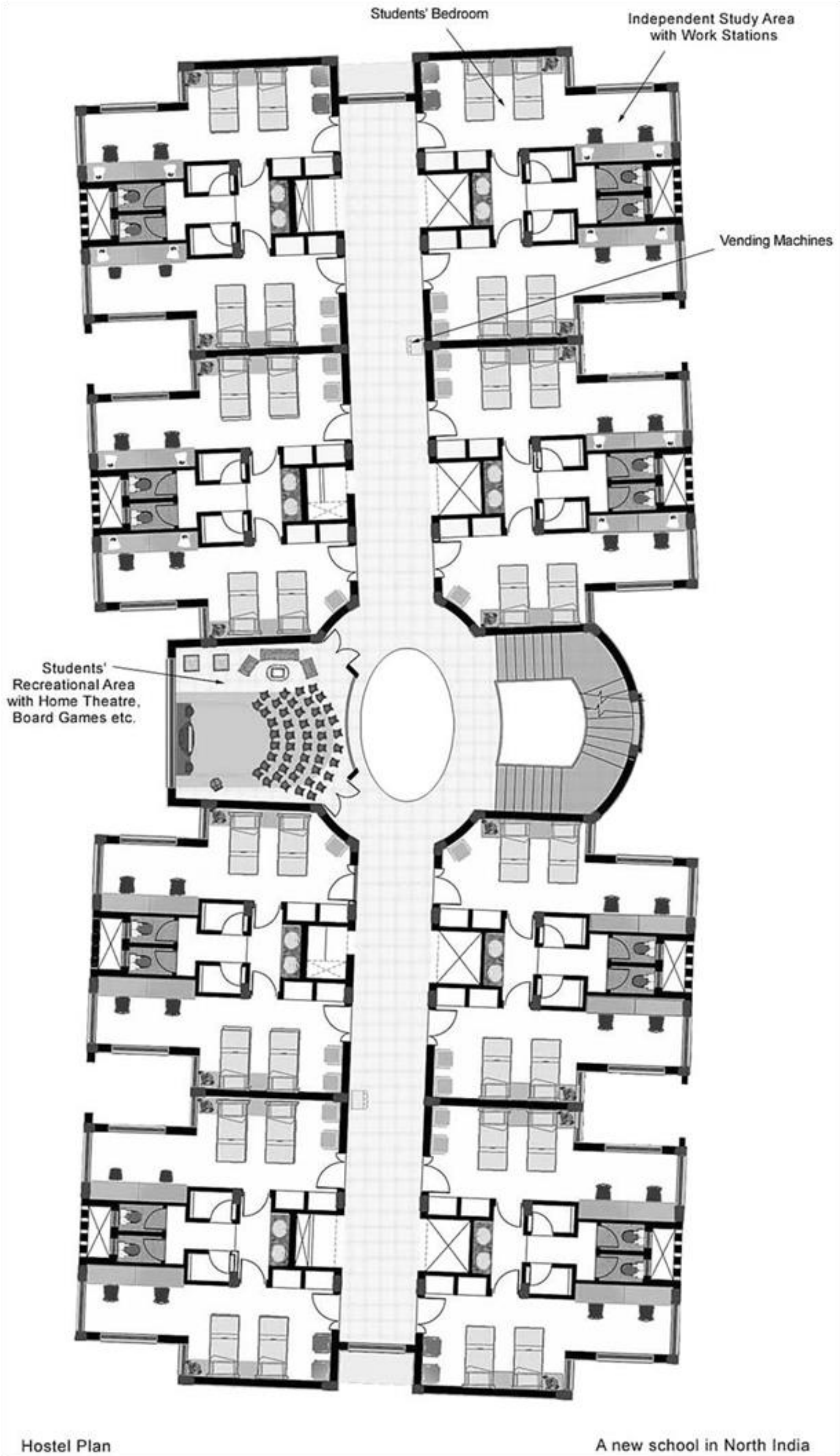
Figure 14 media center and arts and crafts



LAB = 30'-0"X30'-0"



PLAN = 18'-0" X22'-6"



2.4.6 Infrastructure

Ceiling Heights
Usually about 4.2m high thus allowing proper space for the air circulation & it further helps in keeping the structure cool.

Walls
- ❑ Use of cavity walls.
- ❑ A 9” thick brick wall on the outside, then an air gap ranging from 4” to 10” and then a 4.5” or 9” wall on the inside.
- ❑ The cavity wall does not let this heat enter inside the rooms.
- ❑ The energy required to condition the air in the rooms is greatly reduced.

Lights

- ❑ The CFLs and T5s are the most energy efficient. And the mirror optics further reduce the requirement of number of Luminaries.
- ❑ Building of large atriums in the buildings also allows good amount of diffused natural light in the buildings.

Roof

- ❑ The roofing is done in a traditional way.
- ❑ The Brick Bats over the RCC Roof for insulation. Then plastered and then on top, broken China Mosaic of white and light colors are laid.
- ❑ This china mosaic reflects the heat from the sun and being of light colors hence it does not absorb any heat either.

Rainwater Harvesting Unit

- ❑ storm water drain network is very well designed.
- ❑ This network guides the water again to the larger drains to go out of the campus.
- ❑ Rain water harvesting pits are built and are strategically located near to a Bore Well.

Windows

- ❑ Large windows are designed for sufficient lux levels
- ❑ inside the room.
- ❑ The cavity walls are designed of around a thickness of 18” to 20”. The windows are placed on the inner side of the cavity walls. This automatically gives a shade of 18” to 20” and thus the sun does not strike directly on the
- ❑ windows.
- ❑ The Window profile used is UPVC.
- ❑ Double Glazed glass unit having 6mm Reflective Glass on outside, 12 mm Gap filled with Argon Gas and 6 mm Clear Low ‘E’ Glass inside.

Sewage Treatment Plant

- ❑ The Sewage Treatment Plant is designed to use least of chemicals and power.
- ❑ Total power required to run a 150 KLD Plant is 7.5 KW thus saving huge power costs.
- ❑ All the wastewater is channelized to the installed in house Sewage Treatment Plant.
- ❑ The water is treated and filtered with appropriate chemical properties to be used for horticulture.
- ❑ Water is then supplied to carefully designed irrigation systems.

Green Spaces

- ❑ 75-77% of the areas are open spaces, playfields, plantations etc.
- ❑ Thousands of trees of varied species are planted on the open areas.
- ❑ There is a dense plantation along the boundary walls mainly of trees that grow good height and are dense. This acts both as a noise and a visual buffer for the institute.
- ❑ Regular watering of these trees creates evaporation which in turn creates a cooler atmosphere.

Solid Waste Management System

- ❑ There is an in house composter installed for better reduction of the waste produced by the buildings.
- ❑ There are compost pits in which natural manure is produced with the waste.
- ❑ This makes the buildings environmental friendly and also makes the institute LEED certified.

Electrical Supply Provisions

- ❑ 11KV transformer is installed in the campus for proper supply and distribution of electricity in the institute.
- ❑ A large DG set is also provided for a quick power backup system.

Achievements

- ❑ total energy requirements are 40% less than that of conventional buildings;
- ❑ total HVAC (Air Conditioning) requirements are 60% less than that of conventional buildings;
- ❑ And saved about 8-10% in our building costs too

2.5 Literature Case Study

Figure 15 Akal Academy, Baru Sahib.Himachal Pradesh (Cold and Cloudy)

2.5.1 Introduction

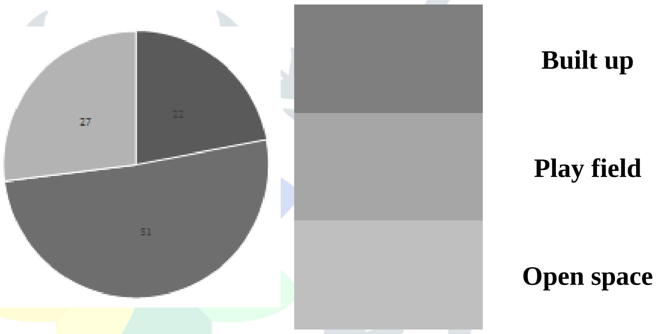
- The school is located in the peaceful and sylvan surroundings of Baru Sahib, away from the hustle and bustle of the urban environment. Efforts are being made to keep the academic activity away from other blocks. The site lies at the edge of a 30m wide road.
- The site is however not well connected to the rest of the city through public transport. The direction coordinates are 30.7537° N, 77.2965° E.

Figure 16

Figure 17

2.5.2 Site Details

- Total plot area = 8800m2
- Academic Block area = 3455 m2
- Residential Block area = 5801.888 m2
- Number of parking provided for parking = 25
- Elevation from MSL- 1900m
- Terrain type- Hill



2.5.3 THE CONCEPT

The entire school is planned in different levels in a U shape layout. The site has been laid out as mixture of formal and informal areas to encourage different learning styles.

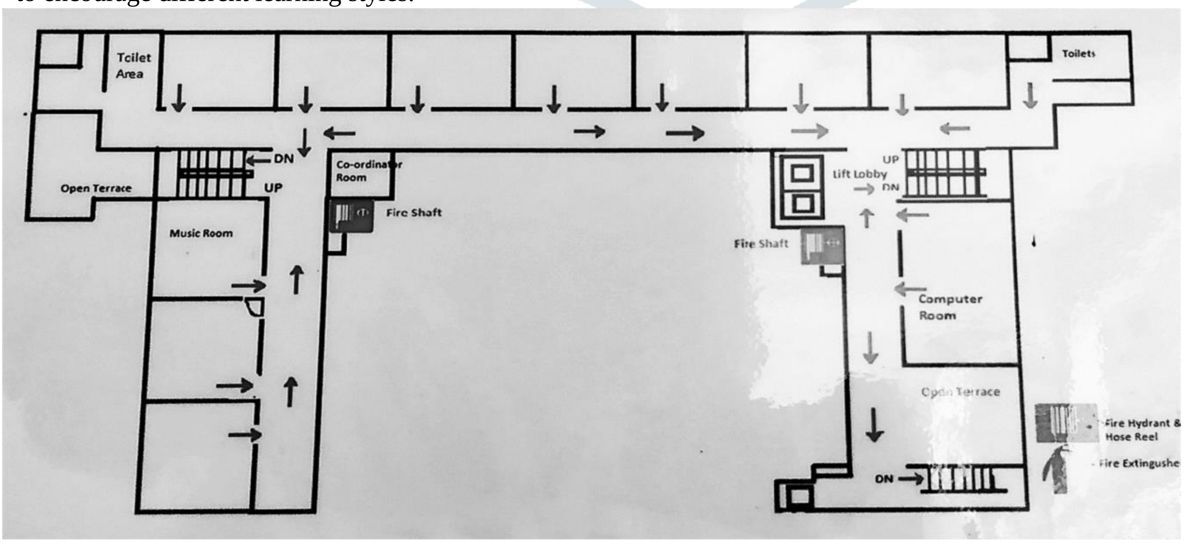


Figure 18

Figure 20

Figure 21

Figure 22

2.5.4 Infrastructure

Solid Waste Management System

- There is an in house composter installed for better reduction of the waste produced by the buildings.
- There are recyclers which turns the waste into many useful daily use products like paper, cloth etc.

Rainwater Harvesting Unit

- storm water drain network is very well designed.
- This network guides the water again to the larger drains to go out of the campus.

Sewage Treatment Plant

- Sewage treatment plants work round the clock to ensure that all effluents are treated and biodegradable.
- Around 5.5-6 lakh liter of waste water gets treated everyday.
- Minimizing waste and making it more environment- friendly. Adding to this all the sewage is collected & churned into useful products like handmade paper.

Green House

- Well maintained green houses are built for proper growth of plants and efficient use of trated water.

3. Case Study: Auroville Earth Institute Villupuram, Tamilnadu

Criterion for Selection: - I have selected this case study because it will help me understand the data in Indian context, and it has the data for comparison of embodied energy and carbon footprint of different building material which will further help me in data analysis.

Location: Villupuram, Tamilnadu, India
Architect: Ar. Roger Anger
Construction material: Compressed Stabilized Earth block (CSEB)
Climate: Tropical
Building typologies: Housing and community buildings and public building such as schools & workshops

3.1 Introduction

The use of raw earth for construction dates back thousands of years, but throughout the twentieth century, the majority of the knowledge of earth builders was lost, and earth construction was rendered obsolete. Thanks to the efforts of the Auroville Earth Institute, Auroville is currently rediscovering these traditional skills and proving that earth is a beautiful building material that can be used to produce modern, ethereal, and progressive architecture for the third millennium. (Unesco Chair for Earthen Architecture at the Auroville Earth Institute)

Since the beginning of Auroville in the 1970s, a number of experiments with earth construction have been conducted with varied degrees of success. The building of the Auroville Earth Institute in 1989, the Visitors' Center from 1989 to 1992, and the Vikas Community from 1992 to 1998 marked the beginning of a new era in Auroville's earthen construction. (UNESCO Chair for Earthen Architecture at the Auroville Earth Institute)

This 1200 m2 Visitors' Center received the "Hassan Fathy Award for Architecture for the Poor" in 1992. It was constructed using compressed stabilized earth bricks to demonstrate the technology's potential as a top-notch building material. The Vikas Community's third building is four stories and was a nominee for the "World Habitat Award 2000." Since then, the value of using earth as a building material has been acknowledged for its affordability, comfort, and quality, all of which support local and sustainable development. Today, Auroville is home to a wide variety of earthen projects, including offices, residences, schools, and apartments. (UNESCO Chair for Earthen Architecture at the Auroville Earth Institute) .

Figure 23 Visitors Centre

Figure 24 Vikas Community

Figure 25 Visitor Center

Source: - (auroville earth institute unesco chair earthen architecture)

Compressed stabilized earth blocks (CSEB), the culmination of more than 50 years of global research and development, are used to build the majority of the projects. Additionally, stabilized rammed earth is frequently utilized for walls and, to a lesser extent, foundations. CSEB has various advantages to local country fired in Auroville. In Auroville, CSEB is superior to regional country burnt bricks in a number of ways:

- CSEB and stabilized rammed earth walls are always less expensive than fired bricks;
- The initial embodied energy of CSEB produced on site with 5% cement is 4 times less than that of local country fired bricks
- In most cases, the strength of these blocks is greater than that of native country-fired bricks.

Auroville also employs three more earth-based approaches. Only about ten buildings have been constructed using these techniques:

- Adobe blocks (traditional sun-dried mud bricks)
- Raw rammed earth
- Wattle and daub, which is mud plastered on a split bamboo or Palmyra tree wattle.

3.1.1 A Good Earth to Build With

The red soil of Auroville is colored by iron oxides, which have extraordinary qualities and make remarkable building materials. Around 5% of the earth's weight in Auroville is stabilized using cement. Lime in the Auroville region is of insufficient quality to be used. Additionally, the majority of the soils in Auroville are silty sands, which are unsuitable for lime stabilization. Cement is therefore better suited for ground stabilization. (UNESCO Chair for Earthen Architecture at the Auroville Earth Institute)

3.1.2 Management of Resources

Resource management is extremely important when working with the planet. Remove the topsoil so that it can be used again for gardening or farming. Always think about the eventual purpose of the excavation. An effective use of the earth's resources can contribute to the creation of a new, harmonious balance between nature and structures, where each supports and completes the other. Quarries can be utilised for a variety of purposes, such as water harvesting ponds, waste water treatment ponds, pools, basement flooring, or shallow depressions for landscape design, work or play spaces, gardens, etc. Auroville serves as an example of how quarries can be used in this fashion. (Unesco Chair for Earthen Architecture at the Auroville Earth Institute)

Figure 26 Quarry used for a shallow Percolation pit

Figure 27 Quarry used for a biological wastewater treatment (lagooning)

Figure 28 Quarry used for a biological Wastewater treatment (baffle reactors)

Source: - (auroville earth institute unesco chair earthen architecture)

3.1.3 Compressed Stabilized Earth Blocks

CSEB is the most widely utilized earth technology today, both globally and in Auroville, because it represents a blend of traditional techniques and modern technology.

Figure 29 Aurum Press 3000 for producing about 75 different blocks

Figure 30 about 75 different blocks produced by the Aurum press 3000

Source: - (auroville earth institute unesco chair earthen architecture)

With a dry compressive crushing strength of 50 kg/cm2 (5 Mpa) and a wet compressive crushing strength of 25 kg/cm2, CSEB in Auroville are 5 percent cement stabilized. The rate of water absorption is about 10%. Country-burned bricks have a 12% water absorption rate and a dry compressive strength of about 35 kg/cm2. (Unesco Chair for Earthen Architecture at the Auroville Earth Institute) .

For the Auram, a steel company in Auroville called Aureka manufactures manual presses that were created by the Auroville Earth Institute. Today, compressed stabilized earth bricks are sold all over the world using the press 3000. Many machines have been marketed throughout Asia, South Asia, and Africa. Presses are now being exported in greater numbers to the United States, The Middle East, And Europe. (UNESCO Chair For Earthen Architecture At The Auroville Earth Institute)

3.2 Earth versus Other Building Materials

In Auroville, fired brick has traditionally been used for construction. The bricks are heated by the villagers themselves in ineffective rural kilns. They ultimately create low-quality building materials, a lot of pollution, and a lot of wood use: For every 250,000 burned bricks, the residents of Auroville burn about 100 tones of wood. There are also wire cut bricks, which are high-quality burned bricks that are manufactured. (UNESCO Chair for Earthen Architecture at the Auroville Earth Institute)

Table 1 types of bricks used in auroville (auroville earth institute unesco chair earthen architecture)

Sr.No.	Bricks	Specifications
1.		Half CSEB 240 (24 X 11.5 X 9 Cm)
2.		Wire cut fired brick (22 x 10.5 x 7.2 cm)
3.		Country fired brick (± 22 x 10.5 x 6.5 cm)

3.4 Energy Effectiveness

Costs are too frequently reduced to a monetary value. The environmental cost should also be taken into account, especially in light of the material's embodied energy. Materials derived from the earth require a lot less energy to produce. When compared to country-burned bricks, CSEB has roughly ten times the initial embodied energy. In actuality, the CSEB generates almost four times less carbon than bricks burned in a country fire.

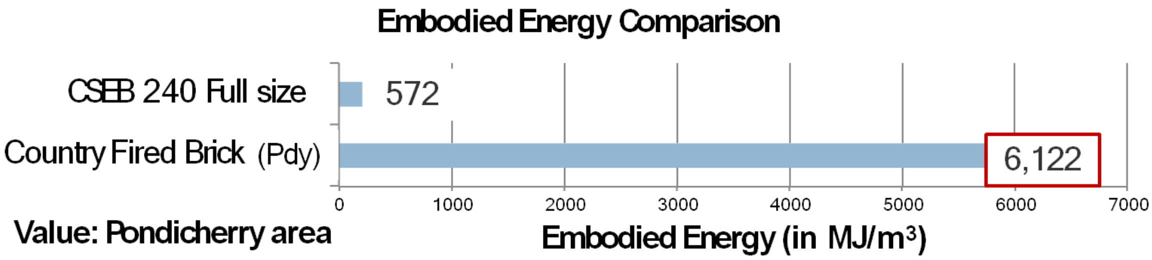


Figure 31 Embodied Energy Comparison (auroville earth institute unesco chair earthen architecture)

CSEB are environmentally friendly as:
- No firing is required, but only curing (4 weeks with cement stabilization)
- Less transportation is required and production is manual
-CSEB consume 10.7 times less energy than country fired bricks (Pondicherry)

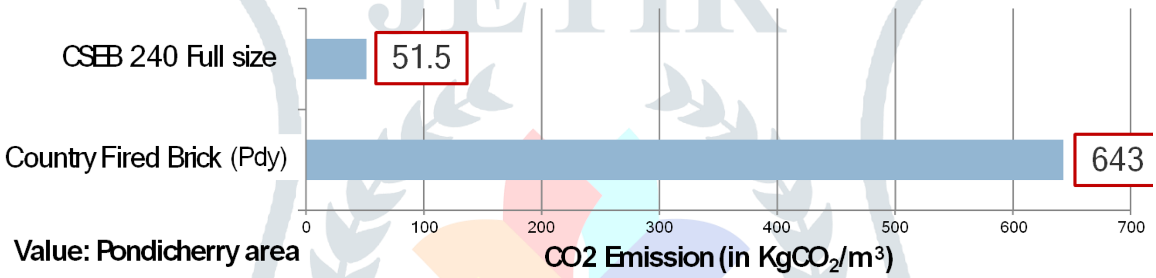


Figure 32 GHG Emission Comparison (auroville earth institute unesco chair earthen architecture)

— CSEB emit 12.5 times less carbon dioxide than fired country bricks (Pondy)!!!

— 50 tons of wood burnt for 100,000 country fired bricks in Pondicherry area!!!

3.5 Cost Effectiveness

Earthen structures have the advantage of being labor intensive and utilizing local resources. As a result, they are usually less expensive than traditional materials and processes. The design, kind of finishing, and project management will all influence the final cost of a structure. The technologies used in each situation are cost-effective. (auroville earth institute unesco chair earthen architecture)

Auroville always charges between 15% and 20% less per finished cubic meter of CSEB masonry than it does for burned bricks. Stabilized rammed earth walls are even more affordable than CSEB masonry, which is already less expensive than compressed stabilized earth block walls. The only difference between CSEB and stabilized rammed earth is that the blocks must cure on the ground before being lifted and put together by masons. Semi-skilled employees construct the stabilized rammed earth walls, which remain in place at night. (UNESCO Chair for Earthen Architecture at the Auroville Earth Institute)

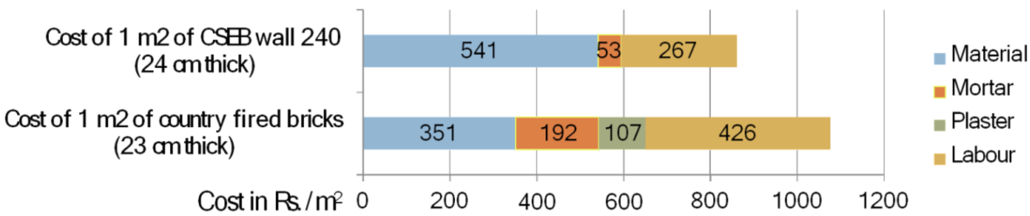


Figure 33 comparative analysis of cseb and country fired bricks

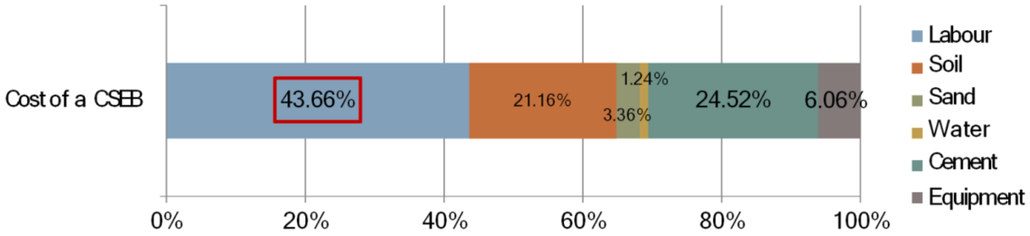


Figure 34 cost of CSEB

- CSEB are generally cheaper than fired bricks. Cost comparison per m2 of CSEB and fired brick wall (Auroville, July 2011)
- CSEB wall 24 cm thick = 861 Rs./m2
- Country fired brick wall 23 cm thick = 1076 Rs. /m2
- CSEB is a very labor intensive technology
- 13 people per press for manual pressing

- This gives job opportunities
- This gives livelihood to people
- This insures sustainability

3.6 Example of Embodied Energy Calculation Realization Apartments Built By Auroville Earth Institute.

Figure 35, Realization apartment (CSE)

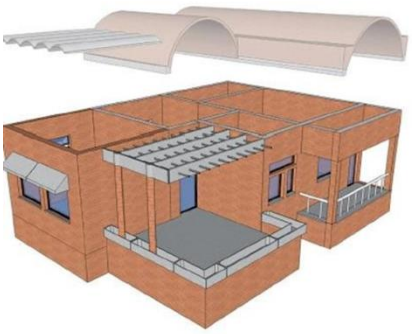
17 apartments built in 3 building blocks

- Initial embodied energy for realization is ~ 4 times less than a conventional building (RCC frame, RCC slab, infill with fired bricks). (2013)
- Low emission for construction and use (2013)

Special features of the building:-

- CSEB and stabilised earth from roof to foundation instead of conventional building material (RCC frame, RCC slab, infill with fired bricks).
- Rainwater harvesting.
- Wastewater biological system.
- Earth tunnel for natural ventilation.

3.6.1 Compression of Materials And Techniques



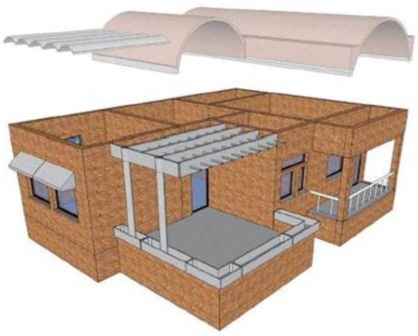
ENVIRONMENTAL IMPACT OF MATERIALS:

Material:	CO_2 Emission: ($kgCO_2/m^3$)	Embodied Energy: (mJ/m^3)
• Earth Block (5%)	51.531 *	572.58 *
• Earth Mortar 1:4:8 (7.5%)	61.813 *	686.81 *

CSEB MASONRY WALL (24cm):

• Cost/ m^2	1,666 Rs.
Material Cost (16 Rs./block)	25.7%
Labor Cost	74.3%
• Carbon Cost/ m^2	**13.630** $kgCO_2$ *
• Embodied Energy/ m^2	**151.44** mJ *

Figure 36 CSEB Masonry Walls (2013)



ENVIRONMENTAL IMPACT OF MATERIALS:

Material:	CO_2 Emission: ($kgCO_2/m^3$)	Embodied Energy: (mJ/m^3)
• Country Fired brick	642.866 *	6,122.54 *
• Cement mortar 1:4	178.525 *	1,983.61 *

COUNTRY FIRED BRICK WALL (23cm):

• Cost/ m^2	1,112 Rs.
Material Cost (4.25 Rs./brick)	80.8%
Labor Cost	19.2%
• Carbon Cost/ m^2	**120.807** $kgCO_2$ *
• Embodied Energy/ m^2	**1,342.3** mJ *

Carbon emissions: 8.8 times greater than CSEB blocks

Cost: 37 % less than CSEB blocks

Figure 37, Conventional Country Fired Bricks (2013)

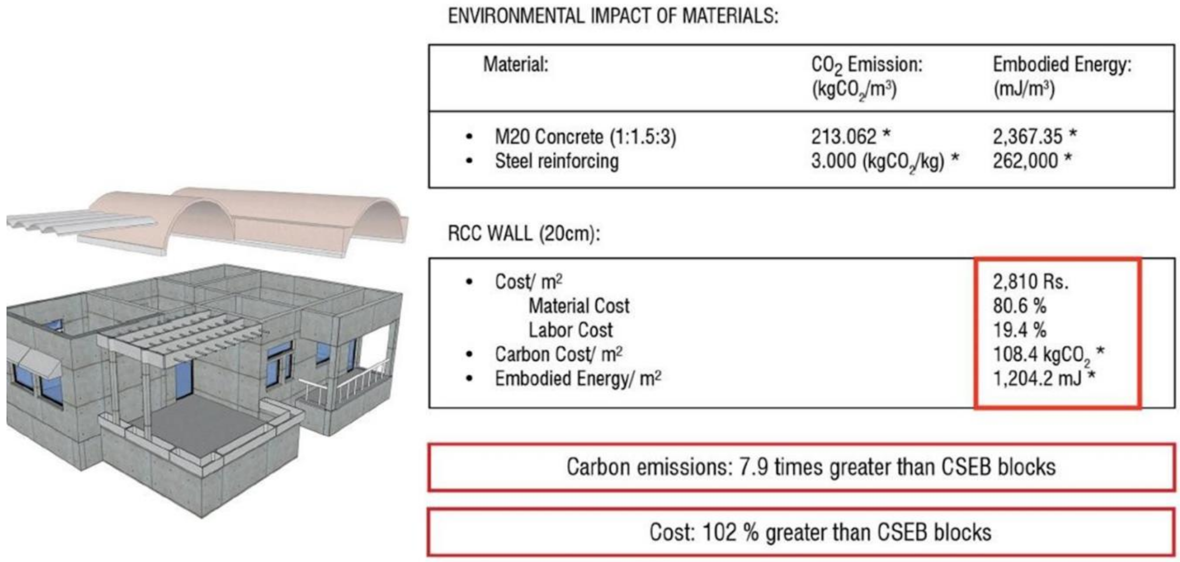


Figure 38 conventional reinforced concrete walls (2013)

Table 2 comparative chart of embodied energy and carbon footprint

material	Carbon emission /m²	Embodied energy /m²	cost/m²	Cost bifurcation	
				Material cost	Labor cost
CSEB Masonry	13.630 $kgco_2$	151.44mJ	1666 Rs. 16Rs./block	25.7%	74.3%
Country fired brick	120.807 $kgco_2$	1342.3mJ	1112 Rs. 4.25Rs./Brick	80.8%	19.2%
RCC wall	108.4 $kgco_2$	1204.2mJ	2810 Rs.	80.6%	19.4%

3.6.2 Inferences

- Carbon emission and embodied energy of country fired brick and RCC wall is 8.8 and 7.9 times greater than CSEB masonry respectively.
- Cost of country fired bricks is 37% less than that of CSEB, so CSEB are not cost effective as labor cost is greater of CSEB.
- Cost of RCC wall is the highest, 102% greater than that of CSEB.

4. DATA ANALYSIS

4.1 Introduction

The main aim of this chapter is to perform the Comparative analysis of CSE blocks and kiln fired bricks as a sustainable building material for composite climate in particular building on the basis of life cycle assessment (cradle to site) and thermal comfort analysis through design builder simulation and give recommendations on using it in the composite climate.

Firstly we are going to calculate the amount of embodied energy and GHG emission from the process of extraction of the material to bring it on site i.e. Cradle-Site LCA. It is done on the basis of energy released in initial stage i.e. manufacturing stage and transportation of material to site. Then we are going to analyze the thermal comfort from using both the material in the building through simulation in design builder.

Building Specifications

Location: Lucknow, India
Climate: Composite
Building typologies: Institute
Building Name: Academic Block, Faculty of Architecture and Planning, Lucknow.
Ground Coverage: 1418.76 SQ. M.
Number of Floors: G +3

4.2 Calculation of Embodied Energy and GHG Emission For The Present Case

Composition of CSE block

- Rammed earth
- Ordinary Portland cement (OPC)

$EE_T = EE_P + EE_t + EE_C$

EE_T = Total embodied energy
EE_P=Energy consumption at production of building material
EE_t = Energy in transportation of building material
EE_C = Energy at construction stage of building

Here we are only considering EE_P & EE_t for calculation embodied energy and global warming potential for cradle-gate LCA

Embodied energy for CSE block
EE_P =Rammed earth + POC
EE_P = 2.0 MJ/Kg (Indian data) + 0.91 MJ/Kg (Indian data)
EE_P =2.91 MJ/Kg……………………….. [1]
Diesel consumption for truck on road (8m3/12 Ton)
=11.93MJ/Km
CSE blocks are being transported from Mangalore to Lucknow i.e. 2179 Km
EE_t= 2179 KM X 11.93 MJ/Km/1000 Kg
= 25.99 MJ/Kg……………………… [2]
Total embodied energy
EE_T= [1] + [2]
EE_T=2.91MJ/Kg+ 25.99 MJ/Kg
EE_T=28.9 MJ/Kg
Global warming potential CSE block
EEP = Rammed earth + POC
EEP = -0.0084(Indian data) +0.91(Indian data)
EEP = 0.9184 KgCO2/Kg……………………….. [3]
Diesel consumption for truck on road (8m3/12 Ton)
=0.883 Kg CO2e / Km
CSE blocks are being transported from Mangalore to Lucknow i.e. 2179 Km
EEt= 2179 KM X 0.883 Kg CO2e/Km/1000 Kg
EEt= 1.92 Kg CO2e/Kg ….……………………… [4]
Total greenhouse gas emission
EET= [3]+[4]
EET=0.9184 Kg CO2e/Kg + 1.92 Kg CO2e/Kg
EET= 2.8384 Kg CO2e/Kg

Total embodied energy and greenhouse gas emission of CSE block from manufacturing plant to site (faculty of architecture A.K.T.U Lucknow.

Brick (zigzag Kiln)

$EE_T = EE_P + EE_t + EE_C$

EE_T = Total embodied energy
EE_P=Energy consumption at production of building material
EE_t = Energy in transportation of building material
EE_C = Energy at construction stage of building

Here we are only considering EE_P & EE_t for calculation embodied energy and global warming potential.

Embodied energy for brick
EE_P =Brick (zigzag Kiln)
EE_P = 6.5 MJ/Kg (Indian data)
EE_P = 6.5 MJ/Kg……………………….. [1]
Diesel consumption for truck on road (8m3/12 Ton)
=11.93MJ/Km
Assuming Brick are being transported from 30 KM of distance as it is locally available material here.
EE_t=30 KM X 11.93 MJ/Km/1000 Kg
= 0.05599 MJ/Kg……………………[2]
Total embodied energy
EE_T= [1]+[2]
EE_T=6.5MJ/Kg+ 0.05599 MJ/Kg
EE_T=6.55599 MJ/Kg

Global warming potential for brick
EE_P = Brick (zigzag Kiln)
EE_P =0.59(Indian data)
EE_P = 0.59 $KgCO_2$/Kg………………………..[3]
Diesel consumption for truck on road ($8m^3$/12 Ton)
=0.883 Kg CO_2e / Km
Assuming Brick are being transported from 30 KM of distance as it is locally available material here.
EE_t= 30 KM X 0.883 Kg CO_2e/Km/1000 Kg
EE_t= 0.02649 Kg CO_2e/Kg……………………[4]
Total greenhouse gas emission
EE_T= [3] + [4]
EE_T=0.59 Kg CO_2e/Kg + 0.02649 Kg CO_2e/Kg
EE_T= 0.61649 Kg CO_2e/Kg

Total embodied energy and greenhouse gas emission of Brick (zigzag Kiln) from manufacturing plant to site faculty of architecture A.K.T.U Lucknow

Table 3 comparative analysis of embodied energy and GHG emission

Material	Embodied energy	GHG Emission
CSE block	28.9 MJ/Kg	2.8384 Kg CO_2e/Kg
Brick	6.55599 MJ/Kg	0.61649 Kg CO_2e/Kg

According to the calculation brick (zigzag Kiln) is better to consider as construction material for our site. As embodied energy and GHG emission is less in brick because of less distance from manufacturing plant to site.

4.3 Simulation for Thermal Comfort Analysis

We are going to get three temperatures from design builder simulation air temperature, radiant temperature and operative temperature we are going to consider operative temperature for thermal comfort.

Table 4 Specification of Simulated Model

S.no.	Component	Specification
1	Structure	Load Bearing Structure with continuous spread stepped Footings.
2	Walls	230/200 mm thick burnt clay brick masonry in 1:6 (cement: Coarse sand) mortar. The masonry types are changed in the Study./ CSE block 150 mm thick.
3	Roof	Flat RCC roof (M25), 115 mm thick, TMT- Fe 500 D Steel Reinforcement (1%).
4	Flooring	40 mm thick plain cement concrete (1:2:4).
6	Plaster/Rendering	12/15mm thick 1:6 (cement: coarse sand) mortar.

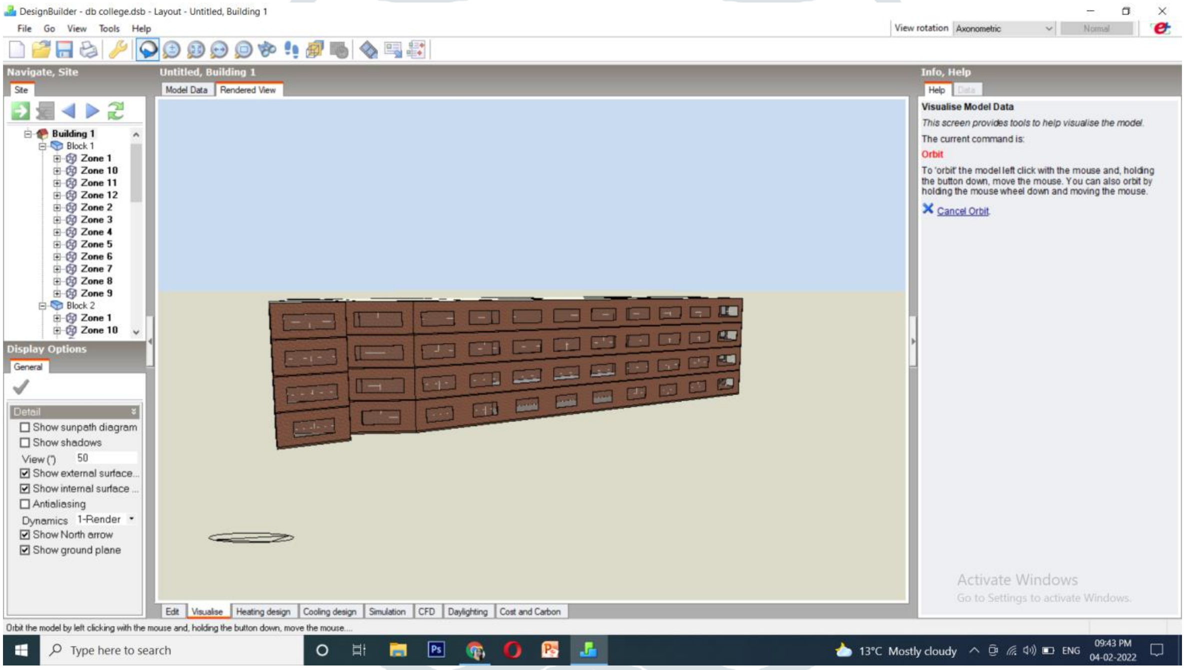


Figure 39 Simulation Model

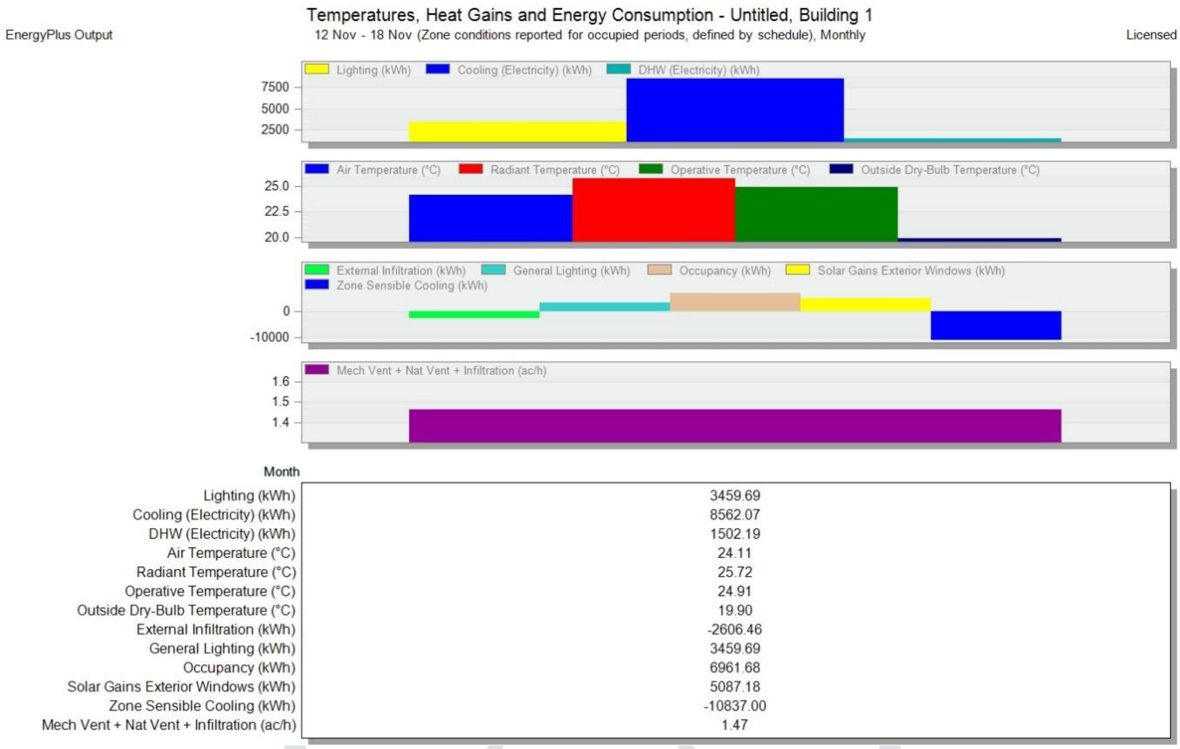


Figure 40 Winter Week (Brick)

Operative Temperature: 24.91 ^{O}C

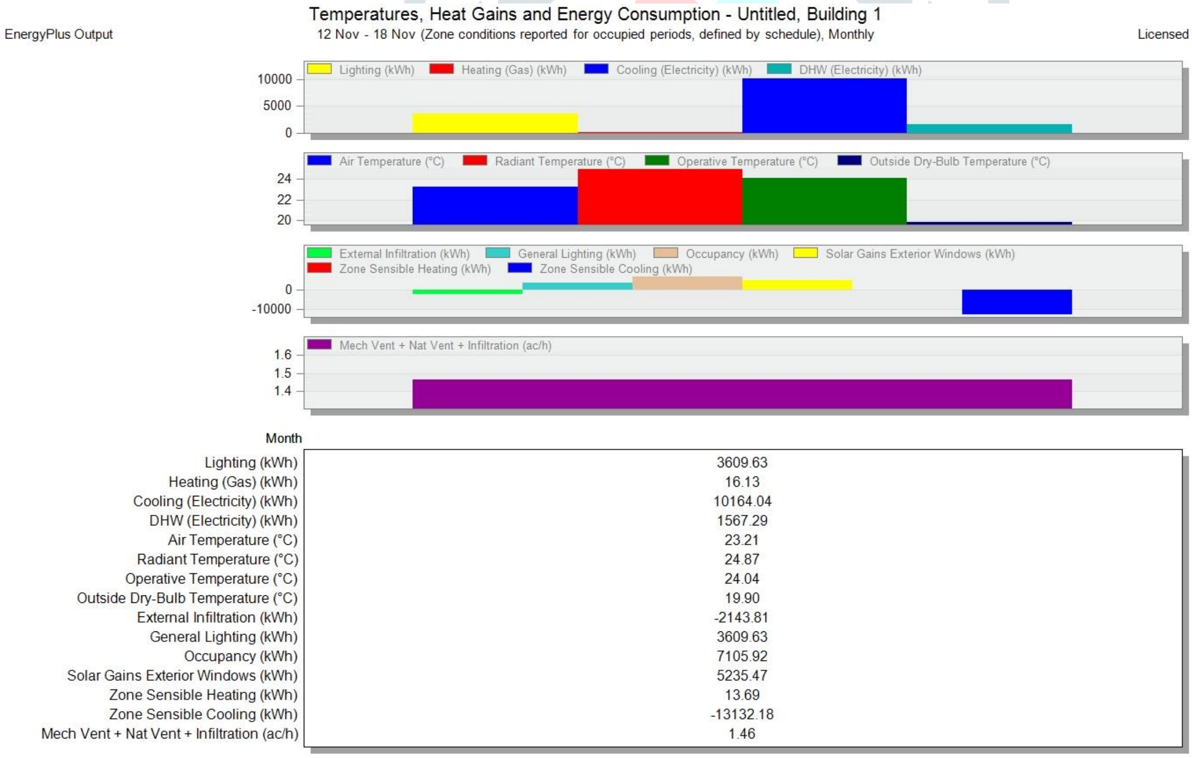
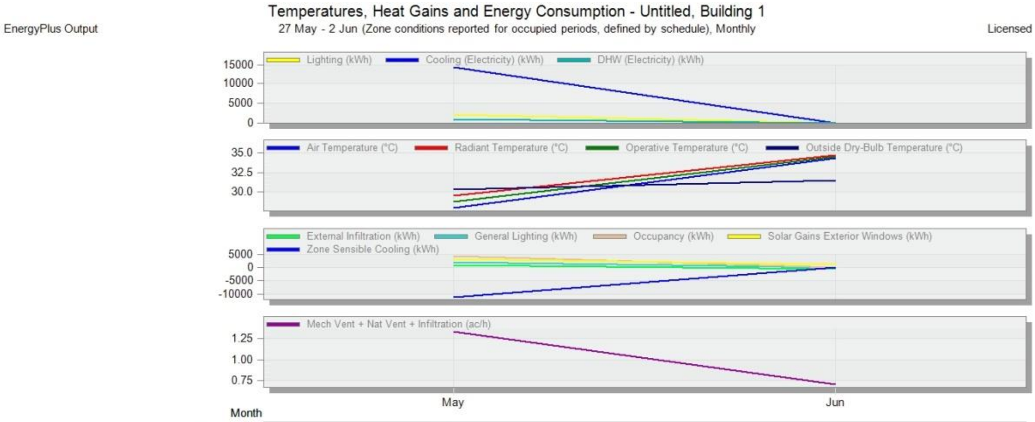


Figure 41 Winter Week (CSEB)

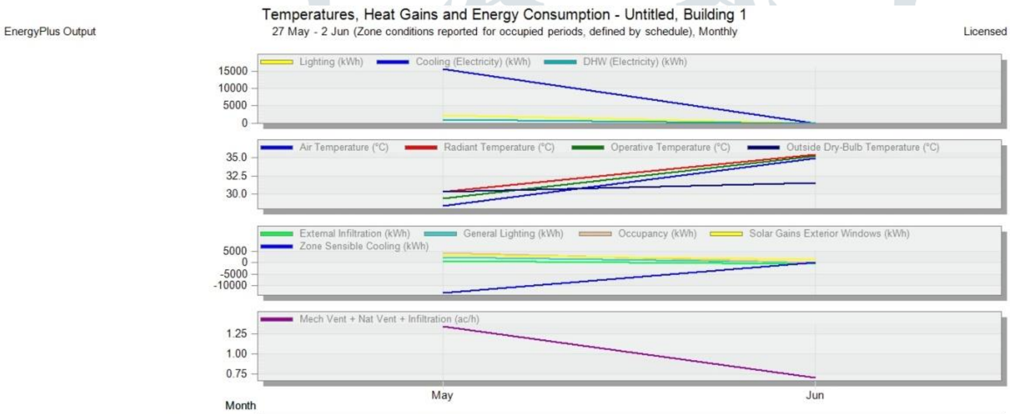
Operative Temperature: 24.04 ^{O}C



Month	May	Jun
Lighting (kWh)	2075.81	0.00
Cooling (Electricity) (kWh)	14185.46	0.00
DHW (Electricity) (kWh)	901.31	0.00
Air Temperature (°C)	27.94	34.35
Radiant Temperature (°C)	29.50	34.77
Operative Temperature (°C)	28.72	34.56
Outside Dry-Bulb Temperature (°C)	30.31	31.54
External Infiltration (kWh)	928.81	-473.13
General Lighting (kWh)	2075.81	0.00
Occupancy (kWh)	4338.75	106.79
Solar Gains Exterior Windows (kWh)	3107.03	1256.98
Zone Sensible Cooling (kWh)	-11229.65	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	1.34	0.71

Figure 42 Summer Week (Brick)

Operative Temperature: 28.72 ^{O}C -34.56 ^{O}C



Month	May	Jun
Lighting (kWh)	2165.78	0.00
Cooling (Electricity) (kWh)	15595.93	0.00
DHW (Electricity) (kWh)	940.37	0.00
Air Temperature (°C)	28.43	34.86
Radiant Temperature (°C)	30.36	35.38
Operative Temperature (°C)	29.40	35.12
Outside Dry-Bulb Temperature (°C)	30.31	31.54
External Infiltration (kWh)	763.57	-579.95
General Lighting (kWh)	2165.78	0.00
Occupancy (kWh)	4184.36	50.55
Solar Gains Exterior Windows (kWh)	3204.21	1295.77
Zone Sensible Cooling (kWh)	-12992.97	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	1.34	0.71

Figure 43 Summer Week (CSEB)

Operative Temperature: 29.40 ^{O}C -35.12 ^{O}C

5. Conclusion and Recommendations

5.1 Conclusion

Table 5 Comparative Analysis of Present Case at Lucknow

Material	Embodied energy	GHG Emission
CSE block	28.9 MJ/Kg	2.8384 Kg CO_2e/Kg
Brick	6.55599 MJ/Kg	0.61649 Kg CO_2e/Kg

- From calculating value of embodied energy and carbon footprint for 1 unit of the material for cradle to gate life cycle assessment tells us that for composite climate both values are very high in CSEB as compared to country fired bricks as 1 unit of CSEB of size 300x150x90 can weigh up to 16 kg and weight of 1 country fired brick of size 230X115X70 is only 3-4 kg.
- From a single unit of CSEB the amount of embodied energy is 462.4 MJ/Kg and GHG emission is 45.4144 Kg CO2e/Kg while from country fired brick is 26.22 MJ/Kg and 2.47 Kg CO2e/Kg respectively, both values are much higher in case of CSEB.
- According to the calculation country fired brick is better to consider as construction material for our site. As embodied energy and GHG emission is less in brick because of less distance from manufacturing plant to site.

Table 6 comparative analysis of operative temperature

Material	SUMMER WEEK (27 MAY-2 JUN)	WINTER WEEK (12 NOV- 18 NOV)
CSEB	29.40 ^{O}C -35.12 ^{O}C	24.04 ^{O}C
Country Fired Brick	28.72 ^{O}C -34.56 ^{O}C	24.91 ^{O}C

- Firstly whenever we are talking about the composite climate we design in this climate taking in mind the summer season because it serves for longer period of the year.
- The national building code of India specifies a narrow comfort temperature range between 21 °c and 28 °c for all types of buildings and for all seasons.
- If we see in the table there is no bigger difference in the temperature there is only difference of 1^{o}c in the summer week, but in case of country fired brick it is seen that the temperature is less than that in case of CSEB.

4.2 Recommendation

Based on the above analysis and conclusion, it is seen that CSE block does not fulfill the need of sustainable building material here in composite climate as here it is not a common practice and requires skilled worker, so eventually it has to be transported here from thousands of kilometers which will definitely increase embodied energy and GHG emissions. And it is not at all cost effective for composite region. There is no big difference in thermal comfort from both the material, a slight temperature difference shows that country fired brick are more compatible in composite climate.

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