NET-ZERO URBAN HOUSING: A PROTOTYPE FOR SUSTAINABLE LOW-INCOME COMMUNITIES.

A DISSERTATION

Submitted in Fulfilment
of the Requirement for the degree of

MASTER OF ARCHITECTURE

by

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BBD UNIVERSITY

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June, 2025

CERTIFICATE

Certified that **AR. ROMIL SINGH**

(1220109002) has carried out the research work presented in this thesis entitled **“Net-Zero Urban Housing: A Prototype for Sustainable Low-Income Communities.**
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BUILDING” A CASE OF A OFFICE BUILDING for the award of **Master of Architecture** from BABU BANARASI DAS University, Lucknow under our supervision. The thesis embodies results of original work, and studies are carried out by the student himself/herself (print only that is applicable) and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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ABSTRACT

The purpose of this study is to evaluate various parameters taken to make an energy efficient office building. This analysis explores the energy consumption of an energy efficient building. For this reason an energy-efficient building has been chosen as the case model. The selected energy-efficient building is located in Gurgaon with a composite atmosphere. The analysis examines the steps taken to make every energy efficient building. The case building was analyzed by comparing different active and passive strategies of an already existing Net Zero Energy office building with better energy performance in composite climate. After analyzing various parameters, the amount of energy consumed by different means was evaluated and the parameters were selected which holds the large share of the total energy consumption of the office building. Building simulation on the existing building case model, based on the parameter, is performed to understand the strategies that should be used in enhancingthe case building's energy efficiency and reducing total energy consumption. Moreover, the data were analyzed and recommendations were made to improve the energy performance and the current building's overall EPI.

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CONTENT

OBJECTIVES

To study the energy consumption patterns and housing needs of low-income communities Understand current lifestyle, energy usage, and affordability constraints. To explore cost-efficient materials and construction techniques suitable for net-zero housing Evaluate low-carbon, locally available, and recyclable materials. To incorporate passive and active design strategies for achieving net-zero energy goals Use solar orientation, ventilation, insulation, and renewable technologies.To assess the socio-economic and environmental benefits of net-zero housing Analyze impact on health, utility costs, energy independence, and quality of life. To propose a scalable architectural prototype suitable for implementation in different low-income urban and peri-urban contexts Ensure adaptability, replicability, and community integration. To perform a cost-benefit analysis of the proposed housing model compared to conventional low-income housing Assess payback period, initial investment, and long-term savings. To develop a strategy for community engagement and participation in the design and implementation process Encourage user involvement in planning, construction, and maintenance

Concept of net zero energy buildings (NZEB)

A R T I C L E I N F O

Keywords:

Net zero energy buildings
Energy

Environment Climatic condition NZEB target

A B S T R A C T -

Buildings are a major primary energy consumer in the world energy sector, with a value of about 40% of total energy consumption. The absence of traditional sources of energy currently promotes the development of Net Zero Energy Buildings (NZEBs). The general definition of net zero energy construction is very critical to grasp. The aim of the paper is to overview the literature on the existing NZEB to make them self-sustaining and net zero in order to improve energy efficiency of the buildings. If enough renewable energy could be used, NZEB could potentially be achievable with power production. Furthermore, different building-service systems utilizing renewable energy sources have been extensively investigated for possible uses in NZEB. The paper gives the detail of its climatic condition in various part of the world along with their consequences and its impacts. The NZEB concept will significantly define the demand and supply strategies for renewable energies and conversion accounting to achieve a NZEB target along with its renewable energy evaluation. Buildings account for a large proportion of the world's total energy and carbon emissions, and play an important role in formulating strategies for sustainable growth. To this end, smart systems implement applications with numerous and interdisciplinary features. Here, the paper gives a detailed literature review on NZEB.

1. Introduction

The term net zero refers to the balance between the amount of pro- duced greenhouse gas and the amount removed from the atmosphere. The term Net Zero Energy Building (NZEB) are characterized as zero net energy consumption buildings i.e. the total sum of energy used annually by the buildings is approximately equal to the total sum of the renewable energy produced on site. Recently, the idea of NZEBs, has changed from the study to practice. There are only a limited number of highly pro- ductive builders at present. The construction of NZEBs is becoming more and more feasible owing to advancements in building technology, renewable energy systems and academic research.

It is hard to locate a building that can be considered the first NZEB. One of the explanations may be that NZEBs might not be a new idea for a building, but just a modern term for houses. However few publications appeared in the late 70s and early 80s, in which phrases 'A zero energy home or an autonomous energy house' or an "energy-independent house" has been used. This was the moment when the oil crisis had its consequences, the problem of fossil fuel sources and energy usage has begun to be discussed.

Between 2014 and 2035, the global market for goods and services related to NZEB construction and renovation is expected to rise at a compound annual growth rate of 44.5%, surpassing $1.4 trillion last year. This is how the concept of NZEB is getting popular. Caulfield (2017) discussed about the exponential popularity growth of the NZEB for next two decades. The given Figure (1) shows the popularity and growth of NZEB revenue by products and services for next two decades. Iqbal (2004) defined NZEB as the term used for the building that incorporates available renewable energy technologies commercially with energy efficiency construction methods where no fossil fuels are consumed. Kilkis (2007) defined NZEB as a building, which has a total annual amount of zero energy transfer through the building during all electric and other transfers that occur during a particular time span. Laustsen (2008) gave the general definition for ZEB: zero-energy buildings do not use fossil fuels and rely entirely on solar and other renewable energy sources to meet their energy needs. Noguchi et al. (2008) defined NZEB as the house that consume as much as energy it produces over a certain period of time.

Similarly, Berardi (2018) discussed their methodologies for design and evaluation of ZEB and NZEB. Their work was based on a literature review guidelines of the national action plans. While a broad global

NZEB
ZEB
nZEB
PV
WWR
nZEH
BPS
IOT
PCM
PV/T
DOD
EMP

Net Zero Energy Building
Zero Energy Building

Nearly Zero Energy
Building Photo
Voltaic

Window-to-Wall
Ratio Near Zero
Energy House

Building Efficiency
Simulation Internet of
Things

Phase Change
Material Photo
Voltaic/Thermal

NZERTF Net Zero Energy Residential
Test Facility
ARRA
LC-ZEB
ASD

American Recovery and
Reinvestment Act Low Cost Zero
Energy Building Acceptable Site
Construction

EE
C
RE
S

Energy Management &
Conservation Renewable
Energy Sources

EPBD Energy Performance of Building
Directive HVAC Heating, Ventilation and
Air-Conditioning MENA Middle East and
North Africa Regions DOE
Department of Energy

LCC Life Cycle Cost

CDD Cooling Degree Days

HER
S
FC
M

DS
M

Home Energy rating
system Fuzzy
Cognitive Maps ZESH
Zero Energy Solar
Homes Demand Side
Management

HOMER Hybrid Optimization of Multiple Energy
Resources EHI Energy Harvester Interface

overview of the concepts of ZEB and NZEB is targeted and addressed topics such as the methodologies of energy balance, the limits of NZEB and NZEB type and energy. In the literature various NZEBs have been identified and evaluated over the decades, However the NZEBs was either defined differently or without an exact description in almost every article has been used. Quite frequently, the forms in which the zero energy target has been reached that affected the meaning of NZEBs.

The lack of common understanding of NZEBs became noticeable, as this concept of construction is thought to be an efficient ways to reduce the use of electricity and greenhouse gas emissions from the building energy sector. The

analysis has shown that NZEBs are a complicated term that has been defined with the broad variety of words and terms.

1.1. *Aim and methodology*

The aim of the paper is to investigate the literature on the existing NZEB to make them self-sustaining and net zero in order to improve energy efficiency of the buildings. Because of the goal of reducing the use of non-renewable energy sources, the paper works on three key

objectives with theoretical approaches which are listed below:

- Supply of energy from different sources of renewable energy.
- Increase the energy efficiency of building.
- Reduce dependency on fossil fuels.

In general terms, two design strategies are involved in NZEBs: reducing the need for energy in buildings by implementing EEMs (en- ergy-efficient measures) and incorporating RETs (renewable energy (RE) and other technologies) to meet energy demands.

The initial stage is to gather research papers, abstracts, and unpub- lished material from Google Scholar, Elsevier, Science-Direct, IEEE, Springer, Taylor Francis, Wiley, Inderscience, and Emerald, among other sources. As part of state-of-the-art analysis, following a thorough examination of the concepts and iterative study process, this paper came up with some relevant keywords. Keywords like “net zero energy building,” “energy analysis of NZEB,” “energy integration to NZEB,” and “performance of NZEB under various climatic conditions” were

used to find relevant documents in the database. A total of 2982 results were found during the search. There were 1563 academic journals, 165 conference materials, 296 magazines, 647 trade publications, and 59 books produced between 2002 and 2022. A second stage was developed to discover the most important material from widely circulated articles. The number of materials chosen had been reduced to 219 at the end of the second iteration phase. Only peer-reviewed publications and research papers were taken into consideration. Unpublished thesis and abstracts were not considered. Only 170 of the 219 items were deemed relevant. The year of publishing was used to minimize the number. Because they had the most up-to-date information, the most current papers were chosen for the investigation. We looked at publications over

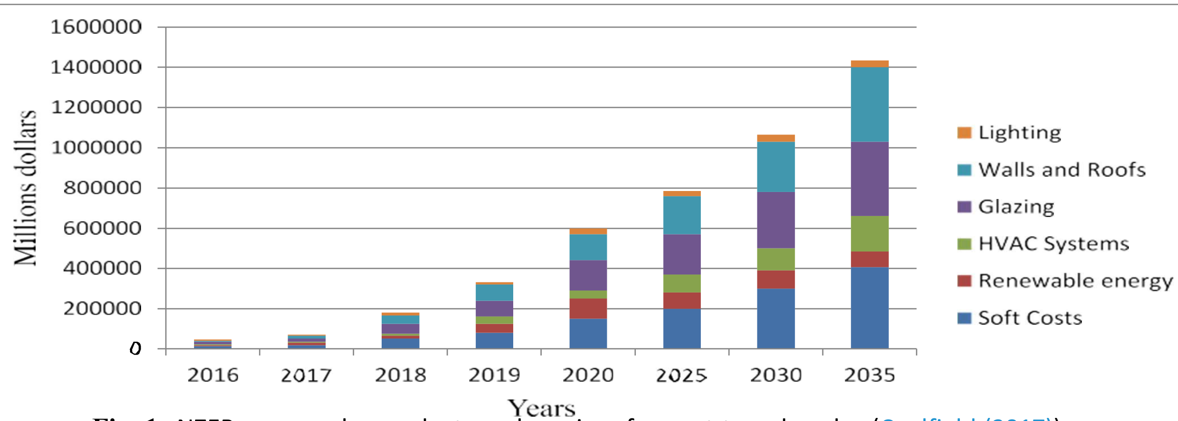

Fig. 1. NZEB revenue by products and services for next two decades (Caulfield (2017)).

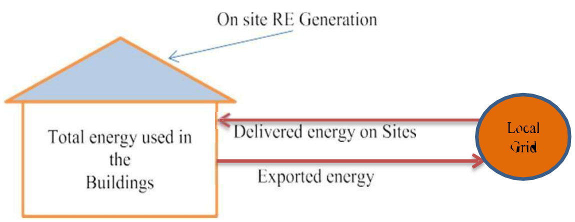

Fig. 2. NZEB's idea

the previous 20 years, but we concentrated mostly on relevant papers published in the recent 10 years, with the last five years receiving the greatest attention.

1.2Definition of NZEBs

For zero energy solar homes, Charron (2008) also offers a definition: "Homes using solar thermal and solar PV technologies to generate as much energy as their annual load are referred to as net-Zero Energy Solar Homes (ZESH)." As per ASHRAE (Kilkis, 2007): "ZEB is a building, uses no more energy than is provided by the building on-site renewable energy sources on annual basis". Although studies describe ZEB projects in which biomass, wind energy are seen as potential RESs, these sources of renewable energy are not as common as solar energy.

Before creating a NZEB specification, the following are the most important issues to consider: (1) the balance metric, (2) the balancing time, (3) the type of energy usage used in the balance, (4) the type of energy balance, (5) the agreed renewable energy supply options, and (6) the link to the energy infrastructure and (7) the requirements for the energy efficiency and the indoor climate.

The literature on zero energy is becoming popular with the NZEBs definition. Most of the papers focus on the demonstration of various zero energy buildings; however there are a range of documents which have been substantially recorded. It helped to explore the interpretation and definition of the NZEBs idea. The general ideas for NZEB is shown in Figure (2); the total energy requirement of the building can be met through the on-site energy generated by the renewable energy sources and if that is not sufficient then the energy from the local electrical grid can be utilized. Whenever the energy generation by the onsite renewable energy sources are more than the requirement of the building, then the excess amount of energy can be fed to the local grid.

Torcellini et al. (2006) furnished the zero energy building design and indicated that the four well-documented concepts were explored: net zero energy locations, net zero energy source energy, net zero energy cost, and net zero emissions. Noguchi et al. (2008) work was aimed at bringing together the public and private sectors to develop homes that combine resources and energy-saving systems to reduce their environ- mental effects. In order to minimize the negative effect on the climate, the Eco Terra housing prototype described.

As part of the Energy Efficiency in Building Project, Brahme, et al. (2009)Brahme et al. (2009) discussed the modelling of single-family residence as a case-in point to demonstrate the most common strate- gies considered during NZEB design process, the ease of using various instruments to model these strategies, and issues of quality control of input/output. Hernandez and Kenny (2010) explained fields such as renewable energy evaluation and the idea of 'net energy' as used in ecological economics, which takes into account the energy used during the manufacturing phase of a commodity, is commonly applicable. In order to describe a life cycle zero energy construction, it provided a model and specification of a simplified approach to account for embodied energy along with usage of energy in action and reclaims the original principle of 'net energy.' The LC-ZEB (Low Cost Zero Energy Building) is defined as a structure whose primary energy consumption in service is equal to or less than the energy produced by renewable energy systems plus the energy embedded in materials and systems over the building's lifetime.

The study of Marszal et al. (2011) focused on the different ap- proaches to potential methodologies for Zero Energy Building (ZEB) calculation. The paper addressed a coherent ZEB definition and a rigorous methodology to measure electricity. Zhivov et al. (2010) had shown the optimization process of net zero energy and its illustration for a cluster of buildings in Fort Bliss. The optimized cluster would reduce the amount of renewable energy needed to make the building cluster net zero. Kaneda et al. (2010) discussed about the use of plug in loads as building are being more energy efficient along with the reduction in the energy consumption. Novotny (2011) discussed the connection between water conservation, reclamation; reuse and energy use to the objective of achieving a net zero carbon footprint in sustainable cities in the future. Nielsen, et al. (2011) calculated the size of NZEBs to be con- structed inside DH areas and studied how the heat mismatch of NZEBs have an effect on various forms of danish DH systems. Voss et al. (2010) studied about the zero-energy home and focused on the context and different effects affecting the energy balance method.

Hamdy et al. (2012) tested the performance of the optimization al- gorithms to find the cost optimal solutions for nearly zero energy buildings, which has high energy performance whereas Kneifel (2012) aimed to construct a full simulation of building energy that replicate the design of the NZERTF (Net Zero Energy Residential Test Facility) to estimate its energy efficiency, both in aggregate terms and at the level of individual occupants and equipment.

Marique et al. (2013) investigated "Definition of Zero Energy Neighborhood". Authors proposed a method of calculation considering three key topics: the consumption of energy in buildings, the effect of the place on energy consumption for everyday mobility and the use of en- ergy in buildings from renewable energy sources. Sharma (2013) reviewed the developments on zero energy building envelope with respective to the benefit in the building designers and constructors. The paper discussed the state of the art on different components of the construction envelope such as materials for insulation, potential insu- lation, materials, walls, roofs, doors and windows glazing off the energy efficiency possibilities. Integration of photovoltaic with the house en- velope for on-site power was also addressed.

Attia et al. (2013) investigated the use of output modelling tech- niques for construction. Attia et al. (2013b) investigated the use of simulation results of construction as a means of NZEBs' design decisions. For Solar Deng et al., 2012, Kazanci et al. (2013) addressed the heating, cooling and ventilation concerns of the house. Various innovative ap- proaches were examined, namely the use of soil, photovoltaic/thermal panels (PV/T panels) and phase change material (PCM). The U.S. Army enacted a policy in January 2014 directing all facilities to introduce net-zero energy policies by reducing energy consumption and rising renewable energy output. Gibson (2014) compared and ended with persistence and successful anchoring of change in the culture of the Army toward net zero energy strategies. Perlova et al. (2014) discussed the reduction in CO_2 emission due to transition towards low energy consumption buildings construction. Saberbari and Saboori (2014) simulated a grid-connected NZEB in order to obtain the optimized configuration of the construction in terms of availability and expenses of system.

Zhivov et al. (2010) demonstrated the Energy Master Planning (EMP) concept and automated Net Zero Planner (NZP) tool. Jadhav (2015) integrated energy-efficient technology into the design, devel- opment and operation of both new and existing buildings by reducing its environmental impact.

Kotireddy et al. (2015) carried out optimization results of different net zero energy building plans, with different net zero energy designs under uncertainties related to potential energy demand and onsite en- ergy balance. Banerjee (2015) discussed the idea of zero energy con- struction for the low-energy building designs. Hu (2016) had practiced net zero energy building art. The paper explained the significance of promoting net-positive institution building and addressed the differences between net-zero and net-positive buildings, buildings that produce more energy than they consume and their similarities. International Journal of Scientific Research in Science, Engineering and technology. (n.d.).concentrated on India's net zero energy building campaign. As per their study the main objective of green construction is to allow effective use of resources and reduce the negative effects on the environment.

Vora et al. (2017) focused on the construction sectors that can play a crucial part in dominant energy use. To mitigate the environmental impression by buildings, NZEBs and solar buildings are emerging as a promising explanation. He proposed buildings that minimize energy consumption and optimally use solar energy both passively and actively. Study by Rezaei and Kamelnia (2017) showed that there are five general techniques for achieving zero energy construction. Through case study, they tried to discover zero energy building design solutions. As per the study six active cases were chosen and their design solutions were grouped into five categories, including the following: conservation of electricity; passive solar solutions; active solar solutions; efficient energy systems; and other renewables. Their findings indicated that 'passive solar solutions' are more evolved and provide flexible solutions. As NZEB should have balance between energy produces and consumed in a building and usage of renewable energy, which is shown in Figure (3). AbuGrain and Alibaba (2017) looked at how an existing multi-story building in the Mediterranean could be made more

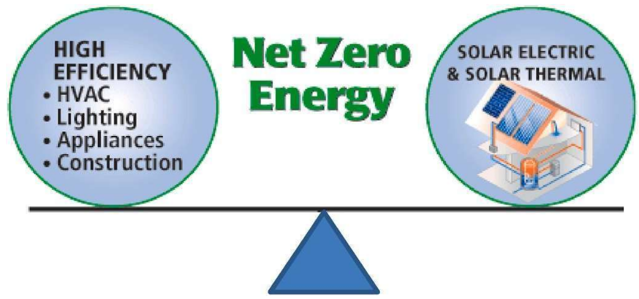

Fig. 3. Balance in Energy produced and energy consumed.

energy efficient. In Denmark, most buildings are connected to electricity grids and about half are to district heating (DH) Systems. Connecting buildings to larger networks of energy allows them to send or receive energy from these systems. NZEB typically have very low energy costs. . Khan et al. (2017) aimed to build a sports gymnasium with almost zero electricity in Cal- olziocorte building, Italy. In the first instance, the base case was con- structed with conventional buildings materials and the overall demand for energy is estimated. Greco et al. (2017) described the economic variables that can improve investment in cantered with public and local authorities, private businesses, energy-neutral refurbishments, Institutes and end-users of science. Energy efficiency research has recently been proposed to minimize buildings' energy use by planning the energy consumption structural parameters.

Adoption and implementation of NZEBs on a wide scale will poten- tially greatly contribute to the greening of the construction industry. However, is still in the early stages. Jain et al. (2017) tried to determine the governance background for the introduction and adoption of NZEBs by niche development. Harkouss (2018) outlined the methodology of cost-effectiveness ability to maximize net-zero energy building design and were evaluated by an energy simulation and optimization program coupled with a ranking decision-making technique. Singh (2018) emphasized the function and significance of the building envelope and related construction facilities in achieving the NZEB goal and addressed the different phenomena and certain materials used in the building envelope.

Gupta et al. (2019) assessed the new buildings and included an over view of an existing building to make it a perfect NZEB. Al- Yoklic et al. (2010) conducted a survey on more than 60 residential buildings in

Al-Amarah region, Iraq to investigate the existence of the most common building materials used in building envelopes. For each combination of elements, the findings were tabulated and compared. The results showed that the best alternative for exterior windows is reflective glass. Alsilani (2018) research studied three main objectives:

(1) To analyse the efficiency of house energy
(2) To evaluate the effect on energy consumption of the actions of the occupants
(3) To evaluate the energy performance of indirect evaporative cooling system use compared to conventional cooling systems.

Whereas Galleghar (2019) showed one way of home energy perfor- mance measurement, that is through a Home Energy rating system (HERS) rating. Alhalabi (2020) focused on the redesigning of the buildings with the means of the converting them into zero buildings through active and passive measures. Bordbari et al. (2019) proposed a multi-objective probabilistic prognosis method of optimization on the basis of statistical techniques, i.e. the method of the empirical rule and two-point method of calculation for the study of energy efficiency in buildings. Gallardo and Berardi (2019) assessed the energy and thermal efficiency of a radiant cooling panel system with integration of phase change materials (PCMs) for use in retrofit projects for construction. Cucuzzella and Goubran (2019) examined infrastructure projects that present a deliberate merging through sustainable design between urban change, community growth, culture and technology. Piderit et al. (2019) identified a structure for the new norm to reach NZEB and this study recognized the need for advanced public policies to achieve the imple- mentation of buildings with an energy neutral concept to provide a standard structure for the NZEB.

Fabrizi (2020) found out two key terms: optimization and holistic plan to describe the ZEBs. Vidal et al. (2020) discussed the possible causes and health-related effects of excess heat in NZEB housing in the Northern Climate. Khakia et al. (2020) aimed to evaluate the energy efficiency of two-story residential buildings located mountainous village and to determine the influence of many parameters, namely construc- tion orientation, window-to-wall ratio (WWR), type of glazing, devices for shading, and insulation, depending on the energy quality.

The power in future buildings is created in the construction itself from harvested RES. In this sort of Buildings; the NZEB, known as the building's annual net energy is zero, meaning the building generates precise energy or even more energy as it absorbs during a year. Assembling the Net-Zero Energy Building's Energy System calls for significant fundamental investment and rigorous analysis, arrangement of atmospheric weather conditions and forecasting.

2. Performance analysis

This paper also presents the performance analysis of NZEB. Mertz et al. (2007) defined the method of conducting and comparing lifecycle costs for normal, CO_2-neutral and net zero energy buildings and iden- tified the lowest-cost energy net-zero house, the lowest-priced CO_2-n- eutral house, and the whole house at the least-cost. Wittkopf et al., 735. (2008) introduced the concept of Integrated

Photovoltaic Construction at the first zero-energy building in Singapore. The work presented introduced the design of the BIPV growth, requirements for final de- signs, and tender evaluations. Noguchi et al. (2008) put public and private sectors working together to build homes that incorporate wealth and resources energy saving systems with a view to reduce their pro- duction effect on the climate.

Brahme et al. (2009) described the single-family residence modelling to demonstrate the most common strategies considered during the design process of NZEB. Sartori et al. (2010) provided a harmonized structure for defining characteristics of Net ZEBs by evaluating the pa- rameters and selecting the relevant options thorough elaboration of sound Net ZEB concepts. Omar et al. (2010) used the results of the study

to define and fix the issue within the review of building design. The objective was to shift the building of the faculty from an energy user to an energy producer in order to achieve NZEB for education. Musall et al. (2010) summarized the status of two phases of research within the context of IEA Task 40/Annex 52 towards solar buildings with net zero capacity'. Lund et al. (2011) used an overall approach to the energy system to examine the mismatch dilemma of net zero energy and zero emission buildings and the results suggest that such compensation fac- tors are slightly below one for photovoltaic (PV) buildings and a little above one for wind turbine buildings. Whereas Kolokotsa (2011) did analysis of the technical advances in each of the critical ingredients that can enable the potential integration of effective NZEB, i.e. precise simulation models, sensors and actuators, and control of the construc- tion. Khandelwal et al. (2011) explored the ability to minimize a central air-conditioned building's annual energy consumption by advanced evaporative cooling systems. Hemsath et al. (2011) described the first phase of a residential study program to reduce the effect of new devel- opment on the atmosphere by using a zero net energy test house as a basis through research and education. Salom et al. (2011) presented Load Matching and Grid Interaction (LMGI) indicators and that can be used to calculate the versatility of the architecture of a building to adapt to variable generation conditions, loads and grid conditions

and Voss et al. (2011) reported on the background and the various effects affecting the energy balance approach.

Musall (2012) talked about the building-integrated co-generation and concluded that it is suitable especially for (future) biomass systems. Scognamiglio, et al. (2012) envisioned potential formal outcomes, pos- sibilities and problems for the usage of PV in ZEBs and new study problems for potential architectural partnerships between PV and ZEBs. Todorovic (2012) reviewed the critical position of Building Performance Simulation (BPS)-dynamic analysis of the inextricable link between building energy demand for HVAC and other building technical systems to achieve zero energy status for sustainable energy supply and renew- able energy sources (RES) availability. Gardzelewski et al. (2012) focused on residential design and construction in which solar design and construction was used. Strategies for Passive house are used to achieve Net-Zero use-Energy focus on illustrating optimal architectural and mechanical system design strategies for the construction of three places along the Rocky Mountain Front Range.

Deng et al. (2012) introduced a case study for a NZEB in Shanghai where energy-efficient passive architecture, solar collector system, Heating, Ventilation and Air-Conditioning (HVAC) system, indoor ter- minal units and the building's renewable energy power system was in- tegrated briefly, particularly the concept of the energy system. Aelenei and Gonçalves (2013) unveiled a sustainable system for the exchange of insights into the NZEB approach used in an office building and had

shown that the combination of traditional and creative energy efficiency interventions with

renewable systems is capable of achieving zero-energy performance without considerable effort. Bourrelle et al.

account two key points: (1) the effect of the urban type on energy needs and the renewable energy development on site and (2) the impact of the position on energy use in transport. BAU University architecture build- ing was selected as a case study to test the energy efficiency in compa- rable buildings in comparison with methods for zero energy architecture. Evola and Margani (2014) proposed a versatile techno- logical solution to improve the energy efficiency of Italian residential real estate built between 1950 and 1990, i.e. before strict energy con- sumption reduction regulations were implemented. Stefanovi´c et al. (2014) dealt with NZEB type defined for its cost.

DeKay (2014) used the concept of a Bundle-Up! Game to build climate design learning strategies and their complicated approaches whereas Ubinasa et al. (2014) overviewed the passive strategies used in Net plus Energy Houses and reflected the effects of passive design stra- tegies on comfort and convenience of houses. Kanters, et al. (2014) investigated the consequences of major design decisions on the renew- able energy efficiency of solar buildings with net zero energy. Mellawi, et al. (2015) presented net zero energy single family two-storey housing prototype, which is assessed using energy efficiency modelling tools to determine the environmental impacts during the early design phase to help develop a design that is capable of meeting our climate-related economic, environmental and social challenges.

Alajmi et al. (2016) showed the possibility of transforming a public building from an inefficient consumer of energy into NZEB and was

(2013) proposed a new NZEB energy balance strategy that takes into account the actual sum of energy needed by NZEBs and emphasized the increase in demand for grid electricity, as well as the importance of ensuring that no net non-renewable energy is needed for a house. Kur- nitski (2013) made several calls to adopt lower performing for heating and cooling energy needs. Kneifel (2014) compared the NZERTF's life-cycle cost performance design to a comparable building design consistent with the Maryland code using the outcomes of Energy Plus (E+) energy simulations for the entire house, electricity rate for local utilities Schedules, and a report from the contractor estimating the relevant construction costs.

Dama et al. (2014) proposed a case study of Milan, where the result indicated that natural night ventilation and ventilation optimized solar control with daylight integration might have a big effect on reducing

cooling, lighting and lots of systems without raising demand for heating. Marique et al. (2013) explored the possibility of applying the idea of 'zero-energy construction' to the neighborhood scale by taking into

accomplished by cost - effective energy efficiency initiatives (EEMs) and solar energy systems integration. Wongwuttanasatian et al. (2015) demonstrated the NZEB concept in Thailand as a self-energy provider and was updated in part to minimize its energy consumption by using a number of energy-efficient technologies. Whereas Vergini and Groum- pos (2015) defined a new approach to NZEB modelling by Fuzzy Cognitive Maps (FCM). The European Economic Community (EEC) is a pioneer in setting goals for all EU member states to install Net-Zero Energy Buildings (NZEB), with the first relevant date set for 2020. Attia (2015) defined the performance target for Nearly Zero Energy Buildings (nZEB) in EU members. Energy performance target specified in building codes for non-residential buildings of some EU member countries are shown in Table 1:

Table 1

Performance Target for nZEB in some EU members (Attia (2015); D'Agostino et al. (2017); Hamburg et al. (2020)).

Country	Non Residential Buildings N (kWh/m²/Year)		
	New	Existing	
Sweden	30–105	ND	Depend on type of building and Climate
Spain	45–60	120	Proposed indicators defines the net PE use and maximum total PE use Romania Depend on type of building and climate Depend on climate
France	50–102 70–110	120–140 ND	
Denmark	25	25	Include: Heating, Cooling, DHW and Lighting
Bulgaria	30–50	40–60	–
Austria	170	220	
Cyprus	125	125	
Hungary	60–115	ND	Depend on type of building
Latvia	95	95	
Malta	60	ND	
Netherlands	0	ND	
Poland	45–70–190	ND	Depend on type of building
Slovenia	70	100	
Slovakia	60–96 (offices) 34 (schools)	ND	Depend on type of building

Irulegi et al. (2017) suggested some important measures in the ret- rofitting process of the building envelope including upgradation of HVAC, Electrical Lighting, and renewable energy. Their analysis showed the proposed retrofitting strategies reduces the energy consumption as indicated in Table (2).

Table 2

Retrofit strategies with energy reduction.

Retrofit Strategies of Design	Reduction in Energy (in %)
1.Upgrading HVAC	23
2.Electrical Lighting	5
3.Renewable Energy	44

Latief et al. (2016) identified the NZEB architecture variables that fit the state of the tropical climate, where design variable analysis are orientation of structure, and passive design. Greco et al. (2016) identi- fied the factors affecting zero energy viability renovation of existing commercial buildings. The majority of building consumption is con- nected to the use of active systems to preserve the comfort of the interior of NZEB.

Harkouss et al. (2016) adopted the thermal comfort criterion as main optimization constraint and showed that the exclusion of cost parame- ters can lead to unfeasible solutions. D'Agostino et al. (2016) presented an evaluation of the present situation with respect to NZEB imple- mentation in the Member States in Europe whereas Chandanachulaka and Khan-ngern (2016) introduced the zero energy design for con- sumption for a small device on a stand-alone photovoltaic (PV) system dwelling house. Ferrari and Beccali (2017) evaluated the energy retrofit of a building representative in public tertiary stock, in order to boost energy efficiency towards the requirements of almost NZEB. The results showed that by implementing market-available and well-proven retrofit technical solutions, it is possible to reduce primary energy demand and related emissions by up to 40% from current values.

An analysis was carried out on photovoltaic solar systems to deter- mine the best system configuration from a financial and environmental perspective.

The review on performance analysis is tabulated below in Table (3): Attia (2018) proposed a book that focused on lessons learned from the design, planning, operation and integration of the most important subjects of the NZEB, such as multidisciplinarity, carbon footprint, comfort requirements, technology, climate sensitivity, quality of con- struction, and evidence-based design. Abdullah, et a. (2017) proposed an integration of photovoltaic as sensitive shading devices for an energy efficient office building. Gardea et al. (2014) overviewed the NZEBs undertaken with a passive design approach. Attia et al. (2017) offered suggestions for how to transform the gaps found into future growth opportunities of High-performance climate sensitive houses. Vora et al. (2017) analysed on the detection of factors affecting the construction of net zero energy buildings (NZEB) in the Indian sector industry. Irulegi et al. (2017) proposed a framework for analysing student comfort in real-world situations to identify and test strategies for achieving NZEB in university buildings and discussed the critical issue of addressing with energy and comfort in a specific building.

Karlessi et al. (2017) illustrated the concepts of the integrated design process and tied smart construction technology to the process. In order
to accelerate the three key aspects of smart buildings' interdisciplinary nature, it introduced phase towards the design and implementation of zero energy:

1. Smart buildings' design phase concepts and its integration
2. Smart buildings with smart technologies

Table 3

Performance analysis with representative references.

Representative references	*Research work/Investigation*
Shuai Deng et al. (2012)	Integration of energy system
Dama et al. (2014)	Versatile technological solution to improve the energy efficiency
Evola and Margani (2014)	Big effect on reducing cooling due to ventilation.
Vergini and Groumpos (2015)	NZEB modelling by FCM
Harkouss et al. (2016)	Thermal comfort criterion as main optimization constraint
Ferrari and Beccali (2017)	Energy retrofit evaluation of a building
Attia (2018)	Comfort requirements, technology, climate sensitivity, quality of construction, and evidence- based design
Ballarini et al (2019)	For the thermal and visual performance assessments, dynamic simulation was used to calculate energy and comfort using Energy Plus and DIVA, respectively. According to the findings, energy retrofit operations on the building exterior would result in considerable improvements in thermal performance, both in terms of energy savings (37% of yearly primary energy for heating) and thermal comfort.
Carpino et al (2020)	They looked at six months of monitoring data from a Danish nZEB. The impact of three different occupancy profiles on final energy use is investigated using a simulation model: the 'Compliance profile,' which is based on regulations, the 'Standard profile,' which is based on average data from surveys, and the 'Actual profile,' which is based on measured data from the actual building case. The three distinct occupancy profiles, as well as the results obtained by employing the three occupancy models in performance prediction, show significant disparities.
Marszal et al. (2010)	Energy measurement methodologies
Magrini et al. (2020)	A case study (single-family residential nZEB) is shown to demonstrate how careful and integrated design of the building exterior and systems not only allows for nearly entire renewable energy coverage, but also generates an energy surplus that can be shared with metropolitan grids.
Moran et al. (2020)	This research evaluates the best retrofit packages for gas-heated semi-detached and end-terraced houses in Ireland in terms of building material thermal efficiency and energy demand.

3. NZEB and its integration in smart grids

Rey-Hernández et al. (2020)

Oh et al. (2017) carried out state- of-the-art analysis of the recent

Bienvenido-Huertas et al. (2021)

The performance of a hybrid ventilation system called LUCIA, which combines Earth-to-Air Heat eXchangers (EAHX), free cooling, and evaporative cooling Air Handling Unit Heat eXchanger (AHU- HX), all controlled by a Building Management System (BMS) in a net Zero Energy Building (nZEB), is examined in this research paper. LUCIA nZEB, located in Valladolid,

research on nZEB implementation strategies as a consequence, it is possible to classify previous studies relating to NZEB into two groups based on two perspectives: i) passive strategies; (ii) active strategies. Review of these studies had shown that the use of passive building strategies is efficient in terms of energy savings, but not adequate in terms of the implementation of NZEB. The active strategies focusing on

Spain, is the world's first safe- building against Covid-19, approved by the international organisation WOSHIE.

The findings looked at heating and cooling needs, cluster analyses, and population effect, indicating that improving thermal attributes might provide buildings with higher energy performance for a larger number of people.

the RE and its back-up system. Skye and Wu (2018) compared the en- ergy efficiency and initial costs of PV and HVAC installations for resi- dential NZEB in various climate zones. Latief et al. (2019) used experiments and a case study to verify the design variables for an ideal Near Zero Energy House (nZEH) design, including building orientation, PV panels, fenestration, and passive design. Ramos et al. (2019) studied the combination of traditional recovery methods and the cooling ca- pacity of the building's thermal mass for night ventilation and quanti- fied using CFD simulations. Marszal et al. (2010) presented a summary of the energy measurement methodologies of NZEBs suggested by or- ganizations representing eight separate countries: Germany, Austria, Canada, Denmark, Italy, Norway, the USA and Switzerland. A few studies had been conducted prior to this date on the thermal satisfaction of NZEB; one of the aims of the study was to draw a distinction between

the thermal parameters for the thermal comfort assessment of a net-zero energy building occupant.

3. Various energy integration

Quite apart from the Net Zero Energy Building concept or metric, the minimization of energy use for efficient design should be a fundamental design requirement and the highest priority of NZEB. Energy efficiency is typically the most cost-effective approach with the highest return on investment and, prior to developing renewable energy strategies, opti- mizing efficiency opportunities would reduce the cost of needed renewable energy projects.

The independence of fossil fuels, and thus renewable energy sources usage, is the key principle of zero energy construction. It is possible to understand the renewable energy technologies: solar thermal, solar PV, biomass energy generation, and wind turbine. The meanings of NZEB in the prevalent literature do not concentrate on one specific renewable technology.Whereas the block diagram for integration of renewable energy sources with power converter for power supply to load is shown in Figure (4). Unidirectional and bidirectional power converter are used for supplying the power from renewable energy to loads. The current work will be carried out by studying the energy demand of buildings and how a building can become self-supporting and zero-neutral through RES. For ZEB with a standby generator, two renewable energy sources, comprising a photovoltaic system and a wind turbine, are considered.

The penetration of renewable energy into existing power systems involves extensive study, planning and development. Given the recent growing public attention on climate change issues, the share of renew- able energy resources in the generation of electricity is increasing day by day. The increased share of renewables would provide us with future- proof, robust, sustainable and climate-friendly energy systems. Caralis and Zervos (2007) analysed the combined use of the wind and pump storage to exploit the wind potential as renewable energy sources. Elkinton et al. (2009) explored the feasibility of the development of renewable energy housing to achieve zero net energy consumption by using PV and wind power systems and determine how the PV and wind power system designs and economics differ with various climates. And the respective four types of NZEB with renewable energy sources are shown in Figure (5). PV is very suitable for producing energy in a ZEB scenario,' on site' and of site'; this extends from the architectural scale to a broader scale, including the area close to the house or to the building. Yoklic et al. (2010) demonstrated how sustainable forest biomass re- sources, solar energy, rainwater harvested and logs of small diameters can be integrated into a system that provides most or all of the energy and water needs of a typical residential and effectively interpret the results and communicate the sustainable potential to the public and had shown that the integration of renewable energy building systems and rainwater harvesting systems can achieve annual net-zero energy re- quirements for electricity, including air conditioning.

The emphasis of NZEB is on the annual energy balance, significant differences in the amount of grid interaction necessary to achieve the
objective. Voss et al. (2010) reported on the study of buildings con- cerning the load matching and grid interaction. An experiment was carried out to test photovoltaic systems (solar electric systems) for a single device. Cole and Deyoung (2012) talked about the PV system. On the basis of the facility's to determine the optimal electrical demand, a

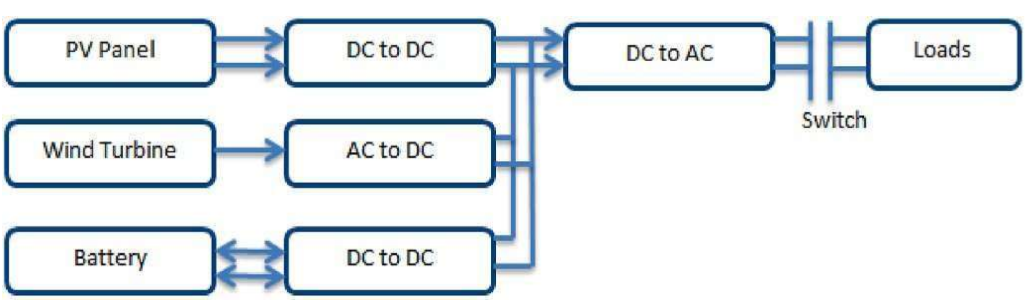

Fig. 4. Block diagram for integration of renewable sources for power supply to loads.

PV device and associated hardware were characterized device, and knew the potential consequences of its implementation. Pless and Tor- cellini (2010) gave the NZEB RE Supply Option Hierarchy which is shown in table (4):

Gallo et al. (2015) implemented the global energy balances for grid- connected buildings to measure the potential for self-consumption usage. For each event, therefore a global electrical balance was carried out between demands and the output of the PV array. Aelenei and Gonçalves (2013) had shown the wise combination of standard and innovative energy performance measures with renewable systems is capable of achieving zero energy performance without considerable effort. The Biomass offered de-centralized power generation potential coupled with opportunity of realizing organic fertilizer.

Musall et al. (2010) had shown that for NZEB, no further steps are required in order to achieve high fractions renewable electricity gen- eration. For Primary Energy only, Balances dependent on asymmetric weighting factors is required for a full renewable coverage of the energy demand. Diab et al. (2015) addressed economic and environmental is- sues by maximizing the fraction of renewable energy and minimization of emissions of greenhouse gases (GHG).

Omar (2016) aimed at reducing greenhouse gas emissions to zero and all greenhouse gas emitting activities must be avoided by using renewable energy. Depending on the place and surrounding environ- mental circumstances. Habash et al. (2014) examined the position of the role of the technologies and strategies above and addressed the problems facing. Whereas Feng et al. (2016) used three scenarios to analyse the contribution of solar PV and compare the generation of electricity in buildings with the demand for prototype building energy under the reference scenario. Contribution and comparison of solar PV to demand for prototype building is shown in Table (5).

Babu and Vyjayanthi (2017) created the NZEB prototype with incorporation of renewable energy applications. The real-time NZEB prototype is generated with reasonable assumptions for achieving home automation with Internet of Things (IoT) using wireless sensors. Latief et al. (2017) found the benchmarks that can be applied with respect to its possible obstacles while applying technology that energy generated by NZEB can also be exported to the central grid. Pen˜aloza (2017) studies enhanced understanding the implications of increasing bio based material use in climate change mitigation, as well as a building life cycle perspective.

Kaewunruen et al. (2018) research showed that three wind turbines with 7.2 m diameter will receive 23-year payback periods in order to install solar PV. The increased land demand for wind turbine of 7.2 m diameter is another inference to be drawn from the NZEB solution developed in this paper. Cui et al. (2019) had shown the indoor space arrangement of passive solar buildings which had got the crucial impact on the air temperature and it has been proved by investigation.

Elavarasan, et al. (2021) introduced the idea of Demand Side Man- agement (DSM). The Hybrid Optimization of Multiple Energy Resources (HOMER) simulation software was used to conduct optimization anal- ysis for a different type of combination that involves grid PV, grid PV- Diesel and grid PV-Hydrogen fuel to develop and approach for cost optimization. RameshJoseph and Narayanan (2018) suggested a suit-
able design for the Energy Harvester Interface (EHI) for the integration of PV and battery energy storage with the ability to work bidirectionally. Mahdavi Adeli, et al. (2020) showed that solar energy alone is not capable of providing the energy demand of buildings to achieve net-zero energy buildings so, other forms of energy should also be used. In addition, maximum thermal comfort was found to be reached in mild seasons.

In the NZEB environment, the incorporation of RES in addition to battery energy storage is an unavoidable necessity. In order to enforce the principle of the NZEB, it is anticipated that the buildings' current energy demand will be met by the contribution of RES to the net zero energy balance. To accomplish this, the EHI module cluster integrated to maintain a balance between supply and load demand, based on the

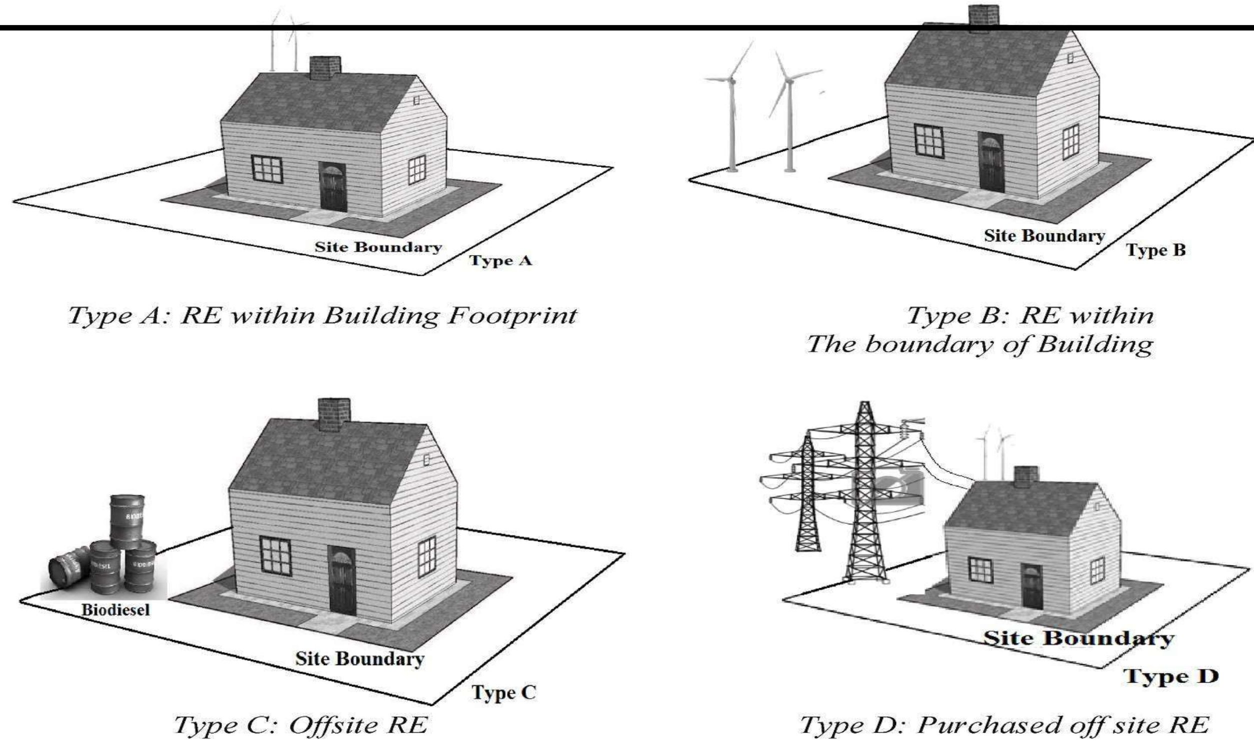

Fig. 5. Four types of NZEB (Salam (2021)).

Table 4

R E supply option Hierarchy.

Option No.	Approach	application
0	Mitigate the use of electricity in sites by use of energy efficient equipment and on demand site through green building technology.	Day lighting; passive solar heating; air-conditioning equipment, insulation high-efficiency heating natural ventilation; ground-source heat pumps; evaporative cooling
1	Use of RES that are accessible on the building foot print that are linked to the site's electricity or hot/cold water distribution system.	PV, wind and solar hot water located in the building
2	Use of RES that are accessible on the building site that are linked to the site's electricity or hot/cold water distribution system.	Located on parking lots or neighbouring open space, but not physically placed on the structure, PV, solar hot water, low-impact hydro, and wind
3	Use of RES available at the building site to generate electricity on building site and connected to its electricity or hot/chilled water distribution system.	Biomass, wood pellets, ethanol, or biodiesel that may be imported from off-site sources or collected from waste streams from on-site activities and utilized to create energy and heat on-site.
4	Purchase newly added off-site renewable energy sources that have been approved by Green-E (2009) or other comparable REC schemes. To preserve NZEB accreditation, continue to acquire generation from this new resource.	Wind, PV, emissions credits, or other "green" purchase alternatives offered by utilities. All purchases made off-site must be validated as newly added RE. A building might potentially work with its energy

hierarchical working of RES, the storage of battery power and the dis- tribution grid. An EHI is an important part of achieving the definition of the NZEB.

4. Concept and design of net zero energy buildings in various

supplier to construct specialised wind turbines or PV panels in an off-site location with strong solar or wind resources. In this case, the building might own the gear and collect power credits.

The hardware would be

maintained by the electricity company or a contractor.

climatic conditions

Global warming and climate change have become an increasing concern in recent decades.

With the main energy users being residential and industrial build- ings, sources have been exhausted at a much faster rate in recent de- cades. Medi (2008) showed climate change issue and the growing energy resource shortage results in NZEB.

Carrilho da Graca et al. (2012) investigated the viability of NZEB solar systems for a traditional single family residence in the mild Eu- ropean Southern Climate Region. Garde et al. (2012) discuss the inte- grated building design method where the most creative tactic was the re- introduction of the basic passive principles of tropical vernacular architecture:cross-natural ventilation and cross-natural ventilation effective solar protection. Similarly, Causone, et al. (2014) discussed about the idea of net zero building in the meditterean climate. Opti- mized design process through extensive simulations of energy, resulting in optimal energy balance and favourable conditions of thermal comfort throughout the year. At the 25th International Symposium on Intelligent Manufacturing and Automation (DAAAM) 2014, Perlova et al. (2014) included the idea of net zero energy construction where reduction of carbon dioxide emissions into the atmosphere was introduced for betterment of global climate. As 30–40% of all the primary energy used worldwide is estimated to be used in buildings. This high use of energy can affect the environment directly or indirectly. It also causes changes in the atmosphere, degrades the ecosystem and enhances air quality. The zero energy building utilizes renewable energy sources to fulfil the building's energy requirements. Alrashed and Asif (2015) examined the uncertainty about their adaptability in local climate, focusing primarily on four climatic variables associated with the application of NZEB, including air temperature, wind speed, relative humidity and global

Table 5

Contribution and comparison of solar PV to demand for prototype building.

Measures in Energy Efficiency	Solar PV Installation	Solar PV Efficiency	Impact Building Stocks in analysis
The study area spans over 100 km^2 encompassing 33,000 residential units in the city of Al- Khobar in Saudi Arabia. Villas and apartment buildings respectively offer 21% and 28% of their rooftops for PV application (Dehwah and Asif (2019))	Rooftop installation	15. 2%	When solar PV is used to cover 25% of a building's roof, it may offset 19% of the power demand while also reducing cooling load by 2% owing to the shading effect of the panels.
Authors discussed Building- integrated photovoltaics (BIPV) how grid- connected BIPV helped to reduce the load needs of a major commercial building in a hot area in Brazil (Braun and Rüther (2010))	considered building- integrated and building- applied photovoltaics (BIPV and BAPV)	Not	Simulation of the yearly solar generation profile of an on-site generator using real solar radiation data and simultaneous building power needs for the year 2007 revealed that the 1 MWp BIPV system could account for roughly 30% of the overall building's energy usage.
The potential of building- integrated and building- applied photovoltaics (BIPV and BAPV) generators on existing single- family detached residential structures in Florianopolis, Brazil (latitude 27◦S, solar irradiation 1550 kn/m2/ year) to supply each home and a part of the local utility feeder's energy consumption was quantified by the authors (Santos and Rüther (2012))		Thin-film amorphous silicon (6%) and classic crystalline silicon solar PV (14%)	They studied and compared the yearly output performance of thin-film amorphous silicon and classic crystalline silicon solar PV technologies, and offered solar PV kits for installation on all 496 roof tops in the mixed residential–commercial region. The suggested PV kits can readily fit on the roofs of ordinary single- family detached homes, with 87% of these generators producing at least 95% of the maximum theoretical generation output of an appropriately oriented and tilted PV system.

Modest adoption of efficiency steps which are compatible with autonomous reform	Not considered	Not considered	All Building Stocks
Aggressive adoption of all efficiency measures	Rooftop installation	Fixed efficiency: 15%	Buildings with fewer than 6 stories have the potential to achieve net zero
Aggressive adoption of all efficiency measures (discussed above)	Rooftop east and south west	efficiency 15% efficiency	Buildings with fewer than 10 stories have the potential to achieve net zero

solar radiation. For the four climate conditions, a sensitivity study for the studied locations was conducted.

Buonomano et al. (2015) discussed about the energy design and optimization for the Mediterranean climate of a non-residential NZEB

using an in-house programming tool generated for dynamic evaluations of energy efficiency. A moderate heating season and a hot (and typically dry) cooling season are characterized by the Mediterranean climate. Attia (2015) compared the impact of using various zero thermal comfort models for NZEB in hot climates and study showed that compared to EN 15251, ASHRAE 55 or Givoni's model, the percentage difference of energy consumption meeting the comfort requirements varied up to 16.0%, 21.0% and 24.7%, respectively according to ISO 7730. In order to classify the collected NZEBs by climatic zones, a common method- ology was developed by Pascual and Paoletti (2016). Ascione et al. (2016) showed the net zero-energy boundary conditions, conceptions, design requirements and predicted energy efficiency construction, and planned for a traditional Mediterranean climate. Devraj et al. (2018) carried out a study to analyse the efficiency of a zero-energy building and found that such a building could be constructed. Whereas Harkouss et al. (2018) aimed to help NZEB designers to choose acceptable design options for passive and RE systems on the basis of structural evaluations in different climates. Twenty-five climates are simulated with the aim of recommending best practices for minimizing building energy demands (for cooling and heating) as well as life cycle costs (LCC). Irfan et al. (2018) targeted for developing an energy-neutral or net zero model home electricity in regions with sub-zero temperatures.

Irfan et al. (2018b) discussed about the climate change and its affects on ozone layer and increasing global warming potential. It is the one that is the hour requirement in which buildings are designed in such a way they consume less resources due to effective energy usage On-site energy design and generation for own use as well as to be used export additional electricity to utilities. They Provides a comparative electricity usage study in a Conventional architecture and the NZEB. Al-Saeed and Ahmad (2018) assessed the future efficiency in the Middle East and North Africa (MENA) region of existing buildings towards the achieve- ment of nZEB or energy-positive buildings. In order to create a guide for nZEB in the MENA region, they reviewed the existing NZEB re- quirements and definitions in hot and warm climate countries. Feng et al. (2019) provided analysis of NZEBs and their current development in hot and humid regions. The study found that in hot and humid cli- mates, passive layout and technologies such as natural ventilation and day lighting were adopted for NZEBs. Using historical weather data, the current NZEBs are built. The current weather data of the NZEB may vary significantly from the historical weather data because of climate change. Chai1 et al. (2019) examined the impacts of climate change on the en- ergy balance of the NZEB in different climate regions, and also assessed the effectiveness of various interventions in mitigating the related im- pacts of climate change using Morphing method. Raniga (2019) gave an understanding of zero energy, its relevance and urgency with regard to global commitments to reduce the effects of the building and construc- tion in promoting emissions reductions in the built environment. Summa et al. (2020) described the climate change impact on energy and comfort performance of NZEB by conducting hourly dynamic simulations on a reference building. A broad range of technologies, systems and solutions with varying degrees of complexity are needed to implement in NZEBs. Doust et al. (2013) explored the case of a house in a temperate environment with a warm climate in northern Italy. McLauchlan (2020)

focused on the weather Risk Management Emission reduction and achievement of net zero goals in Scotland by reducing emissions. Similarly, Firląg and Piasecki (2018) carried out a survey on the possible approaches and metrics that could be applied to the NZEB concept of existing single-family homes in heating dominated climate. Kashiyani et al. (2013) researched the NZEB idea where his work explained that about 40% of the world's primary energy usage is used by buildings. In the context of climate change, the scarcity of energy supplies and the decline in global energy use, energy efficiency was a significant topic.

The NZEB principle of both energy use and building output is seen as one of the solutions that could change the image of energy use in the building sector and thus lead to reducing the global usage of energy.

After overall review, here are the some figure examples of design of NZEB worldwide:

Photo by Halkin | Mason Photography (Hailey Hinton (2020))
Photo credit: John Petersen, Oberlin College (Voss and Musall (2012)
Photo by Kyle Caldwell (Hailey Hinton (2020)
Photo by Edward Caruso (Hailey Hinton (2020)

Fig. 6(A) is the first energy positive building situated in Lehigh, which has PV array on the top of the roof in order to achieve net zero office design. Fig. 6(B) is located on the Oberlin college campus in Ohio, the examples of NZEB. Fig. 6(C) is the current largest NZEB in US which has 220,000 sq. ft. of area. Fig. 6(D) is a single family residence of Charlotte, which is designed to eliminate all the fossil fuel burning on site. Fig. 6(E) represents the first NZEB of India from the Indian Green Building Council. Fig. 6(F) represents NZEB that consists of 40 solar panels on its roof to cover the homes annual energy use. Fig. 6(G) is designed by Sasaki, Technological solutions and green buildings strategies were set into place to achieve NZE. Fig. 6(H) is the largest NZEB in Southern Ontario region making it perfect example how to turn NZEB to positive teaching tools. These are some of the examples of existing NZEB design.

Fig. 6a. Sustainable Energy Fund (SEF) office building Schnecksville, Pennsylvania.

Fig. 6b. Oberlin college lewis center, oberlin, Ohio.

Fig. 6c. Nrel research support facilities building (Voss and Musall (2012)).

10

Fig. 6d. Charlotte Vermont house, charlotte, Vermont, United States (charlotte Vermont house. (n.d.)).

Fig. 6e. First net zero energy building in India (Godrej & Boyce (2016)).

Fig. 6f. Net zero home in Lexington, Massachusetts.

Fig. 6g. John J. Sbrega health and science building at bristol community college in Massachusetts.

Fig. 6h. the Joyce Center for Partnership and Innovation at Mohawk College's Fennell Campus Hamilton, Ontario Photo courtesy of B + H Architects (Hailey Hinton (2020)).

5. Recommendations and future strategies

Based on the brief study carried out in this study, following recom- mendations can be made:

- Optimization and Holistic plan to capture the complexity of the building behaviour (AbuGrain and Alibaba, 2017).
- Use of plug in loads as building is being more energy efficient along with their reducing the energy consumption (Chandanachulaka and Khan- ngern (2016)).
- Energy retrofit of residential buildings to the NZEB level is the best practice for substantially reducing energy demand and fossil fuel dependency (Abdullah and Alibaba (2017), D'Agostino et al. (2017); Moran et al. (2020)).
- In order to increase the funds available for projects and contribute to more comprehensive participation, RE should be made a priority sector (Dehwah and Asif (2019), Santos and Rüther (2012)).
- Skill enhancement training sessions for interested individuals on renewables will encourage the generation of RE (Musall et al. (2010), Gallo et al. (2015)).
- Favourable thermal comfort conditions and optimal energy balance throughout the year through detailed energy simulations (Braun and Rüther (2010)).

Furthermore, for more energy saving potential, the following guidelines should be studied:

- Integration of automatic shading systems into window construction.
- Daylight sensors must be built into the lighting system for proper energy consumption.
- Installing new energy-efficient lighting and HVAC systems to save even more money on electricity per year.
- The feasibility of adding RES as additional elements to the building envelope materials for insulation.
- The cost analysis of economic viability and life cycle of optimizing the current building into a definition of net-zero energy.

While the nZEB objective is technically possible, there is a 30% cost difference between the nZEB solution and the cost-optimal option. This is crucial since it implies that the existing nZEB standard is inferior than the optimum financial option (Salem et al. (2020)). The possibilities of reducing energy use and construction costs are investigated, and evi- dence is provided that wooden nearly-zero-energy buildings (nZEB) are technically possible at affordable construction costs through the use of novel design processes and procurement models that enable scalable and modular production (Aruma¨gi and Kalamees (2020)). Pikas et al. (2017) concluded that the nZEB investments are expected to become cost- optimal without subsidies, due to the increasing efficiency and decreasing costs of PV systems. Buildings account for a large proportion of the world's total energy and carbon emissions, and play an important role in formulating strategies for sustainable growth. In recent years, there has been a growing interest in NZEBs.

To this end, smart systems implement applications with numerous and interdisciplinary features: stable additional renewable energy inte- gration, network distribution, efficient delivery systems, control and monitoring in order to reach zero energy goals by demand response. The incorporation of intelligent technologies requires a holistic approach that takes all aspects of sustainability into account. The introduction of highly efficient smart buildings is possible through the incorporation of smart metering and renewable systems, serving as storage/generators and energy control by tracking in-house devices, smart sustainable buildings can have a better quality of life. With the help of a mobile app, such platform-based configuration technology has the potential to improve comfort, healthcare, safety and security, as well as energy conservation at home and at work. The general pictorial representation of net zero building towards smart Sustainable building is shown in Figure (7).

A more comfortable built environment can be generated by smart construction while simultaneously reducing the carbon footprint of a site.

In order to change water quality and increase energy efficiency, Green building blends technology and living practices. Optimized en- ergy efficiency, additional commissioning measurements and verifica- tion, and continuous monitoring of carbon dioxide would benefit from the use of environmentally friendly materials and creative procedures.

The Green Building Concept has become popular. Purbantoro and Siregar (2019) defined the principles of green construction. Green ship rating tool composed of six groups: Acceptable Site Construction (ASD),

Energy Management & Conservation (EEC), Water Conservation (WAC), Indoor Air Health & Comfort (IHC), Material Resources & Cycle (MRC), and Building & Environments management (BEM). The conclusions demonstrated that the introduction of the green building concept will also improve energy efficiency. Purbantoro and Siregar (2019) focused on the nature of Net Zero's technological and financial viability of NZEB from an existing building.

Overall Smart sustainable building is the integration of Net Zero Energy Building, Smart building, Green building and energy efficient building which is shown in Figure (8). And commonality of green and smart building is shown in Figure (9).

Sustainable sites, Water efficiency, Energy and atmosphere, Mate- rials and resources, Indoor environmental quality, Innovation and design process.

5.1. Green building

Data network, Video surveillances, Access control, HVAC Control, Power management, Lighting control, Facilities management, wireless systems.

5.2. Smart building

Optimize energy performance, additional commissioning measure- ment and verification, CO2 monitoring, Innovation in design.

Commonality of Smart Building and Green buildings. The advantages of having Smart Sustainable Building are.

Fig. 7. NZEB towards smart sustainable building.

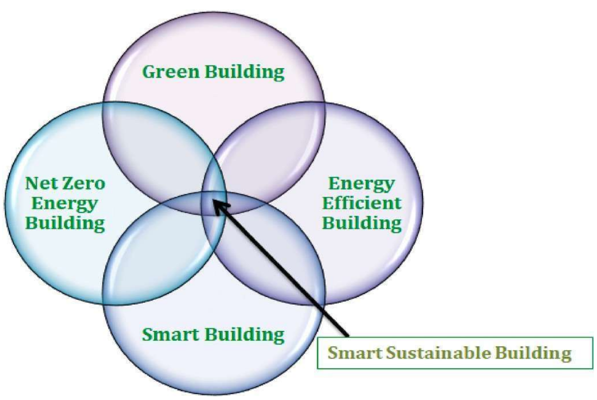

Fig. 8. Smart sustainable building integration.

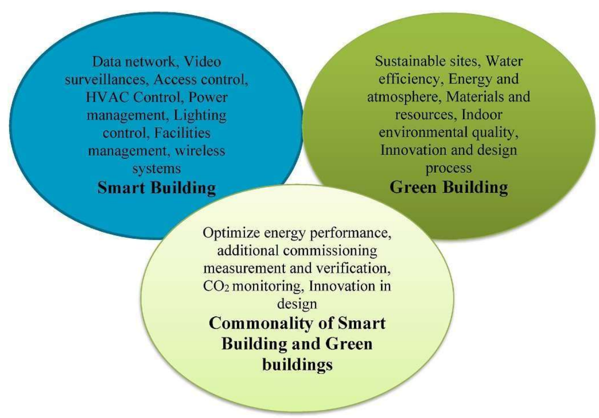

Fig. 9. Commonality of Smart and Green buildings. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

- Self sufficient
- Sustainable
- Energy efficient
- Renewable powered
- Smart
- Mitigation of Pollution
- Water management
- Waste to wealth
- Economic

In general, the most significant characteristics of smart and sus- tainable buildings are intelligent monitoring systems (like home auto- mation implementation with IoT that uses a smart microcontroller configured in Arduino and using sensors such as LDR as light sensor and LM355 as temperature sensor with mobile app to achieve; in three different modes of operation and maintenance of buildings, such as the fresh air supply, lifts and escalators. Acoustic, indoor green, and social atmosphere are considered as secondary features.

6. Conclusions

This analysis explains the viability of the NZEB. By building NZEBs instead of conventional ones, energy for buildings can be generated by own and can reduce the energy crisis, and the country's environmental emissions. The guidelines to be followed for the NZEB has been studied and the following the NZEBs' benefits has been concluded.

- Reduction in energy consumption which reduces the energy crisis.
- Carbon emission reduction which reduces the environmental pollution.
- Energy cost will be very low or near to zero, also generate revenue by selling extra energy.

Here, this study explored how net-zero energy in existing buildings can be achieved. The different NZEB policies and guidelines to be fol- lowed. The work defines and classifies NZEB's broad range of perfor- mance metrics, thus initiating a phase towards the implementation of a new high performance building standard in different European countries.

This paper has presented how to show improvement on energy ef- ficiency, optimize the comfort of occupants and reduce dependency on both the grid and the municipal supply of potable water by the means of implementation of sustainable policies. Consequently, the investigation discusses the question of load match and grid interaction at building level, taking into account on-site energy usage and generation and has analysed the contribution of solar PV and compare the generation of electricity in buildings with the demand for the buildings. In the context of climate change, the scarcity of energy supplies and the decline in global energy use, energy efficiency are discussed. Similarly, various applications for smart systems are discussed.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Building Envelope & Services.

CASE STUDY-1

BedZED (Beddington Zero Energy Development) – Hackbridge, London, UK

Owner/Client - The Peabody Trust

Architect - Bill Dunster Architects

Structural Engineers - Ellis & Moore Consulting Engineers

Mechanical/Electrical Engineers - Ove Arup and Partners

Construction Managers - Gardiner & Theobald

Sustainability Consultants - The BioRegional Development Group

Location - Borough of Sutton, London

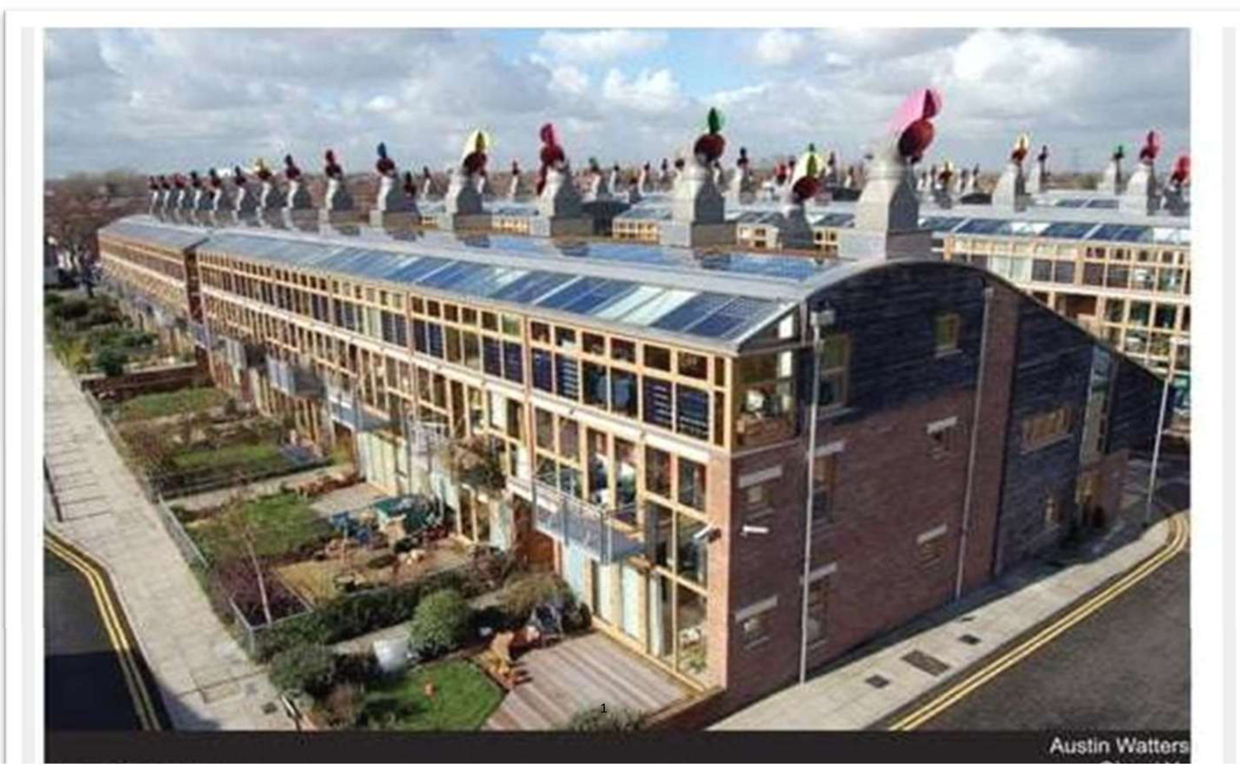
Area - 4 ac.

Completed - 2002

Unites - 82 homes, 18 work/live units, 16,800 ft² of workspace

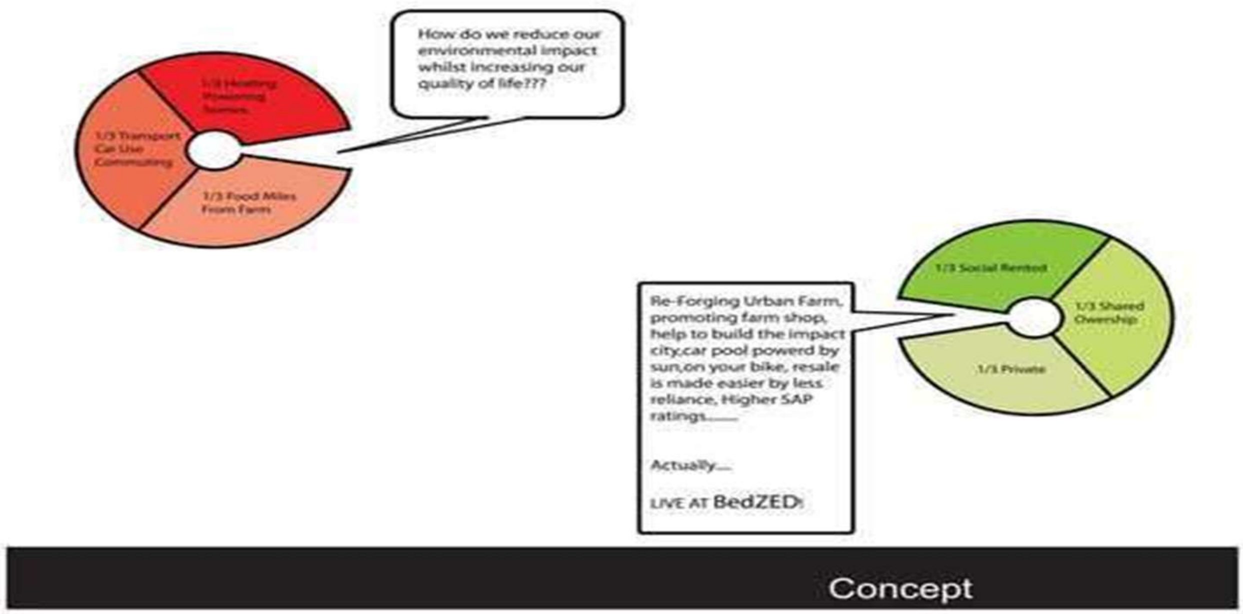
Parking - 84 spaces

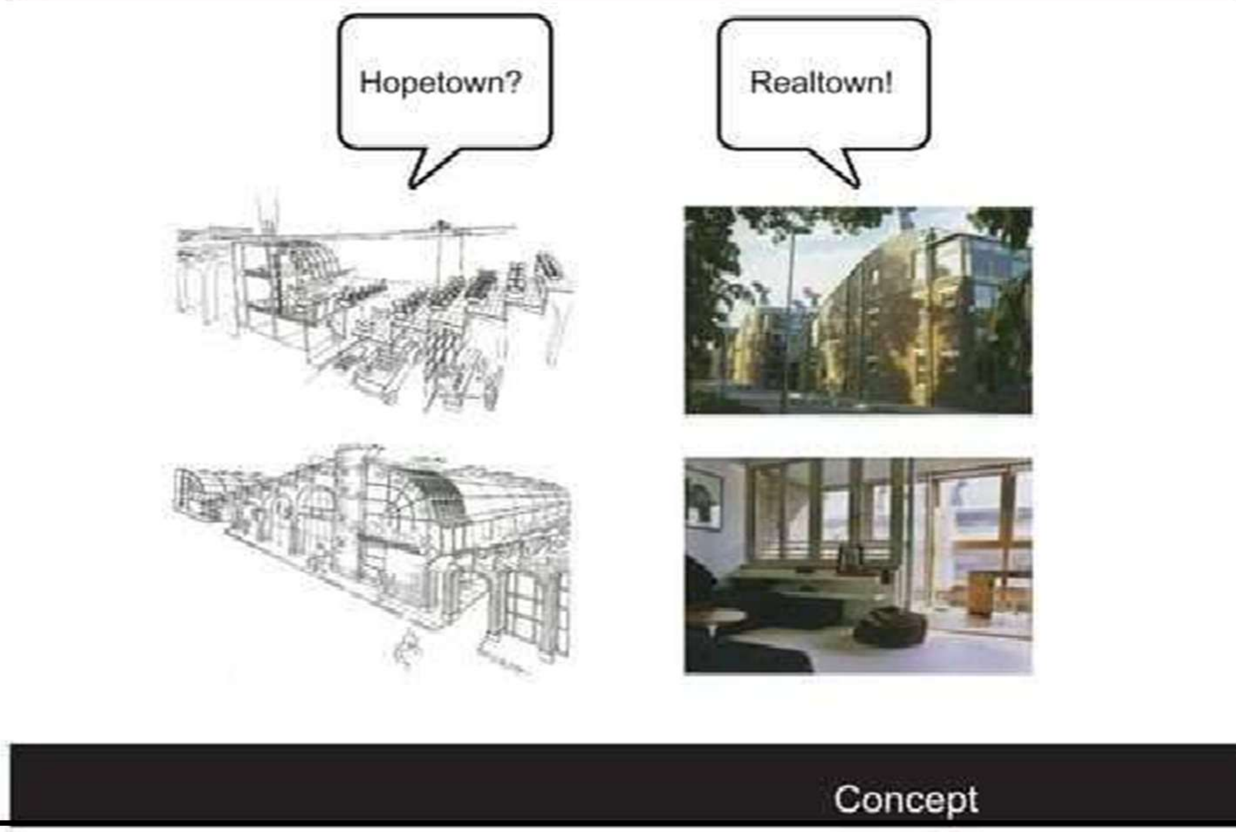
Density - 50 dwellings per hectare



Overview:

BedZED is the UK's first large-scale, mixed-use sustainable community, completed between 2000 and 2002. Located in the London Borough of Sutton, it comprises 82 homes and 1,405 m² of workspaces. The project was initiated by Bioregional and developed by Peabody Trust in partnership with ZEDfactory architects, Arup, and others.studylibfr.com+4bioregional.com+4g





secop26casestudies.org.uk+4en.wikipedia.org

Key Features:

- **Energy Efficiency:** Achieved 88% reduction in space heating requirements and 57% reduction in hot water consumption compared to UK averages. en.wikipedia.org
- **Renewable Energy:** Solar panels provide 11% of electrical power; the remainder is generated by a biomass wood chip combined heat and power (CHP) plant, though the CHP faced operational challenges. en.wikipedia.org
- **Water Conservation:** Implemented rainwater harvesting and greywater recycling systems, reducing mains water consumption by 50%.
- **Sustainable Materials:** Utilized local and recycled materials, including FSC-certified timber and reclaimed bricks, to minimize embodied carbon.
- **Community Engagement:** Features a car club, shared green spaces, and communal areas to foster a strong sense of community. gsecop26casestudies.org.uk+1neighbourhoodguidelines.or g+1

Performance Metrics:

- **Ecological Footprint:** Residents' ecological footprint averaged 4.67 global hectares, 89% of the baseline, aiming for 1 planet living. en.wikipedia.org

- **Car Mileage:** Residents' car mileage was 65% less than the UK average, promoting sustainable transport options. en.wikipedia.org

Challenges:

- **Biomass Boiler:** The biomass CHP plant faced reliability issues, leading to a switch to a gas boiler from 2005–2017. en.wikipedia.org
- **Water Recycling System:** The 'Living Machine' water treatment facility struggled with water quality, affecting its viability. en.wikipedia.org

Breathe Architecture – Melbourne, Australia Overview:

Breathe Architecture is an Australian architectural firm known for its commitment to sustainable and socially responsible design. Their projects focus on creating environmentally friendly and community-oriented spaces.

Notable Projects:

- **The Commons:** A multi-residential building in Melbourne that integrates sustainable design principles, including passive solar heating, natural ventilation, and the use of recycled materials.

- **Nightingale 1:** A pioneering affordable housing project that emphasizes sustainability, affordability, and community engagement.

- **Edgars Creek House:** A private residence designed with a focus on energy efficiency, using passive design strategies and sustainable materials.

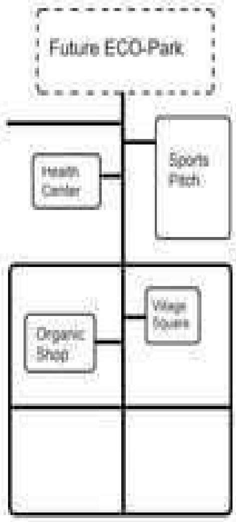
Design Philosophy:

- **Sustainability:** Prioritizes energy-efficient designs, use of renewable materials, and integration of green technologies.
- **Community Engagement:** Involves residents in the design process to ensure that the spaces meet their needs and foster a sense of community.
- **Affordability:** Strives to make sustainable living accessible to a broader population through cost-effective design solutions.

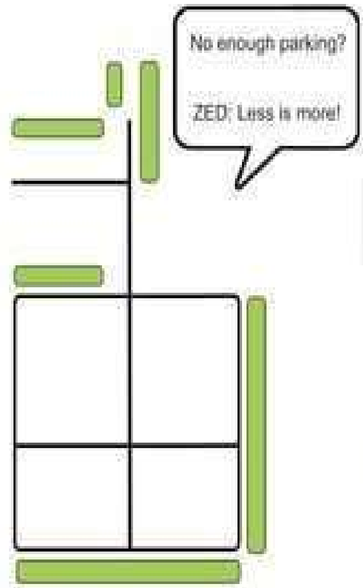
Impact:

Breathe Architecture's projects have set benchmarks in sustainable design and have influenced the development of environmentally conscious communities in Australia.

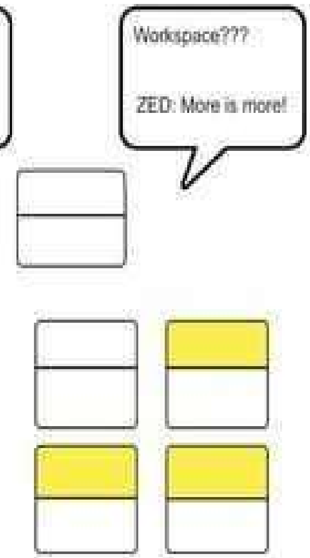
Site



Circulation/Program

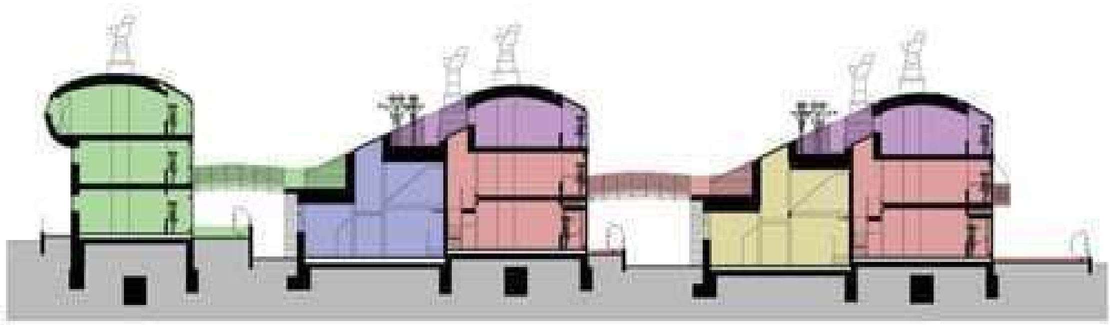


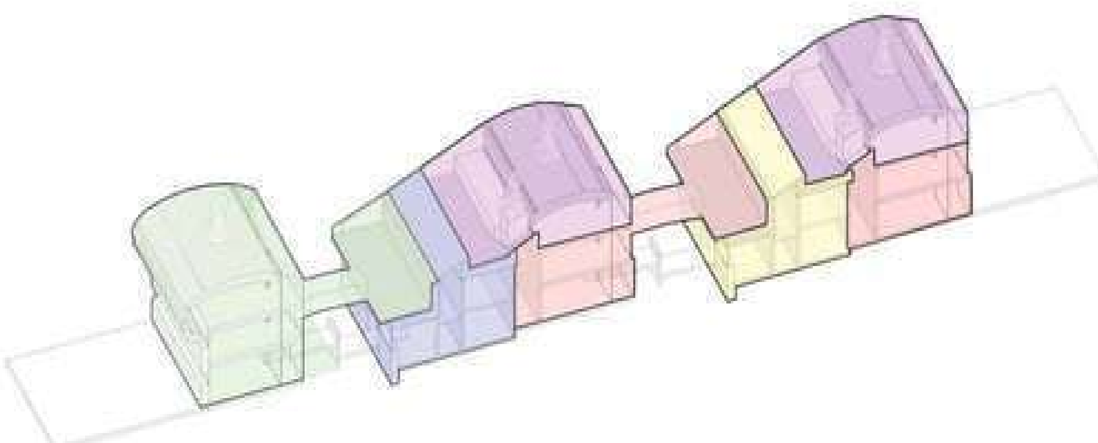
Parking



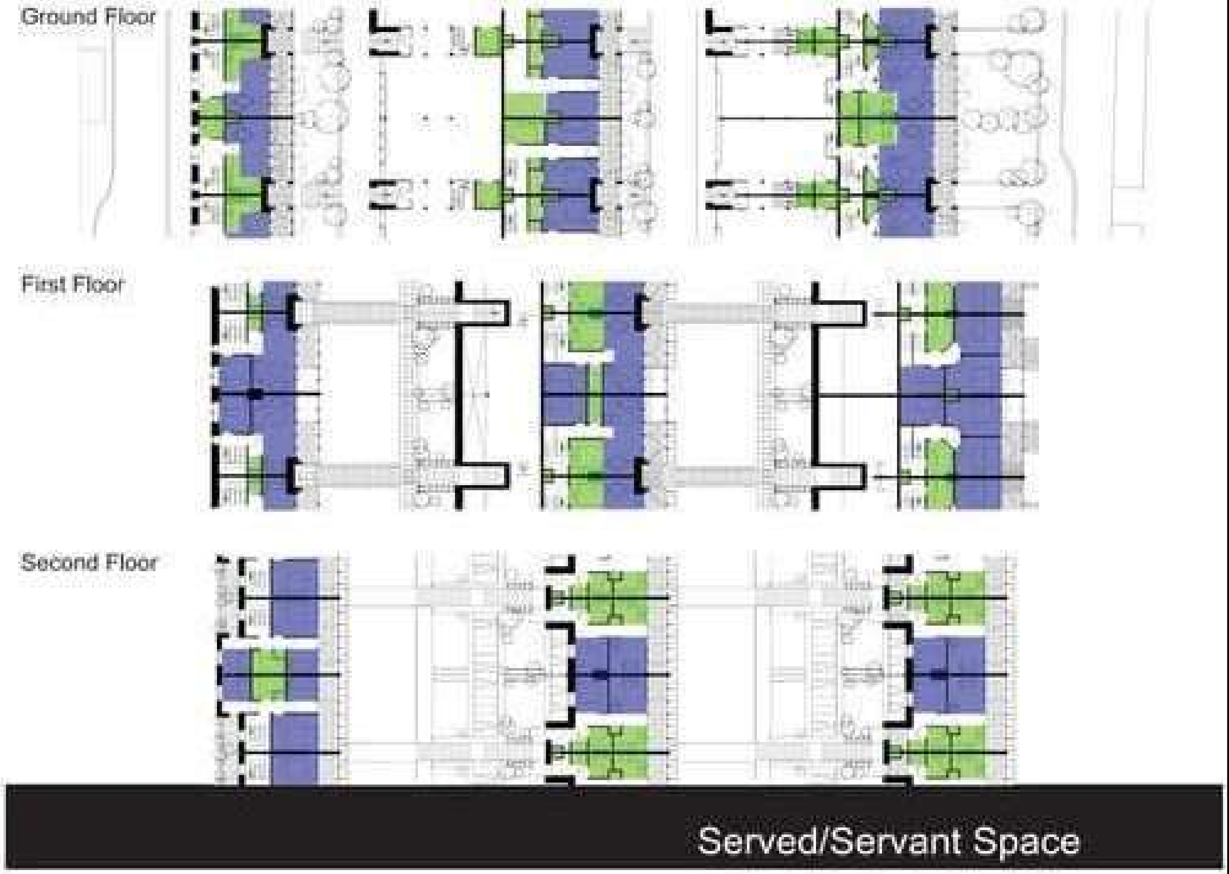
Workspace

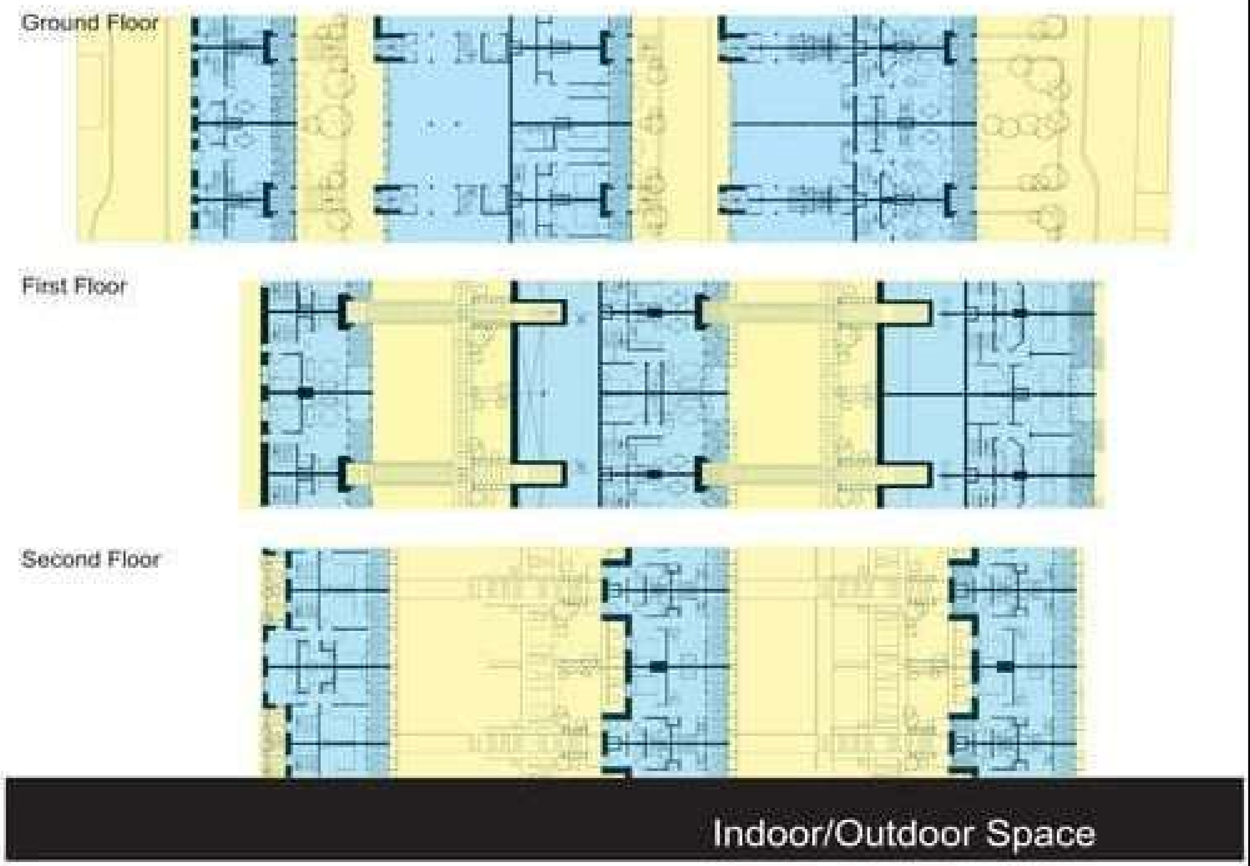
Site Diagram

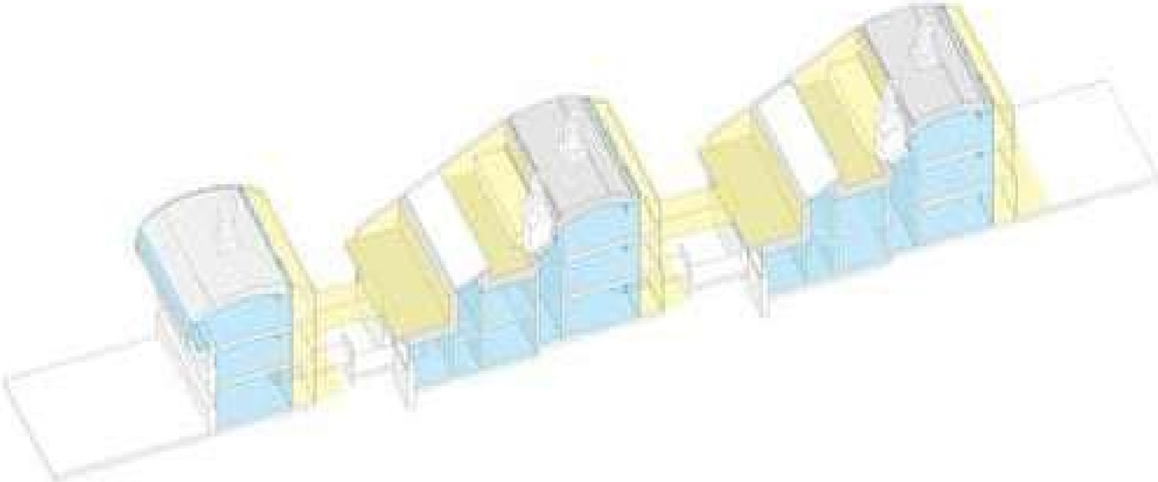




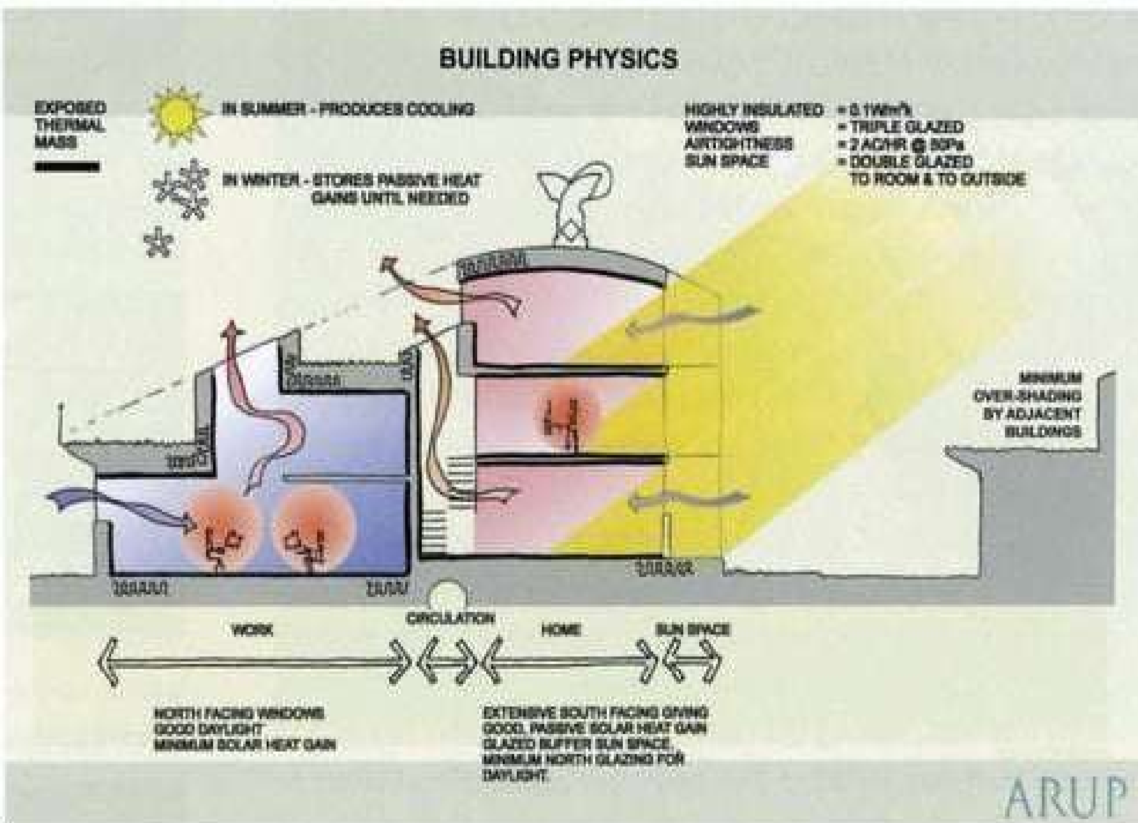
Section/Ownership


Ground Floor
First Floor
Second Floor
Served/Servant Space

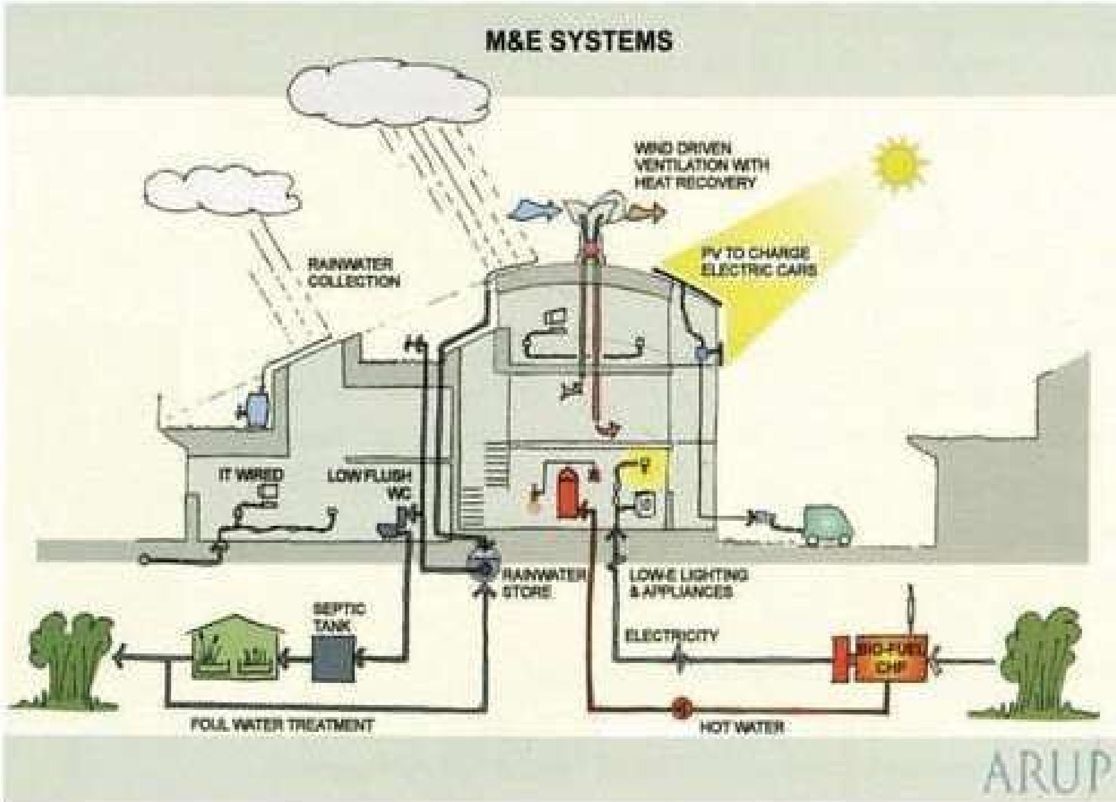

Ground Floor
First Floor
Second Floor
Indoor/Outdoor Space



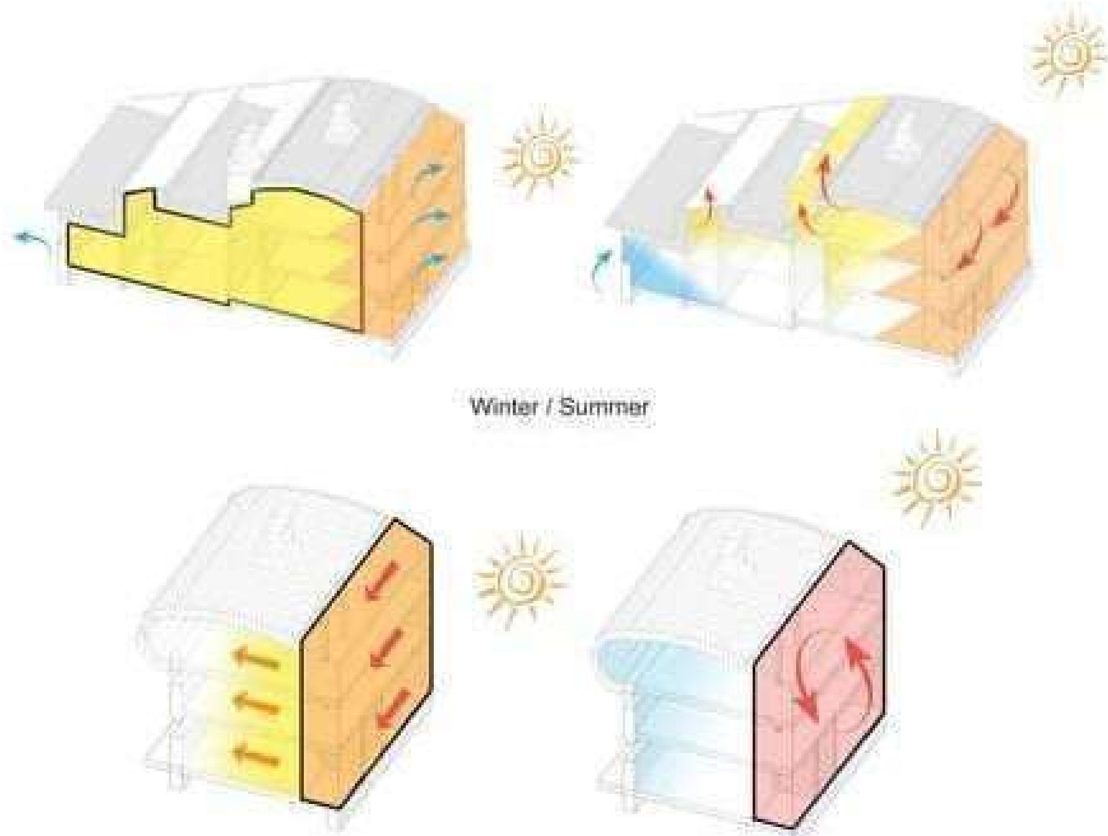
Indoor/Outdoor Space



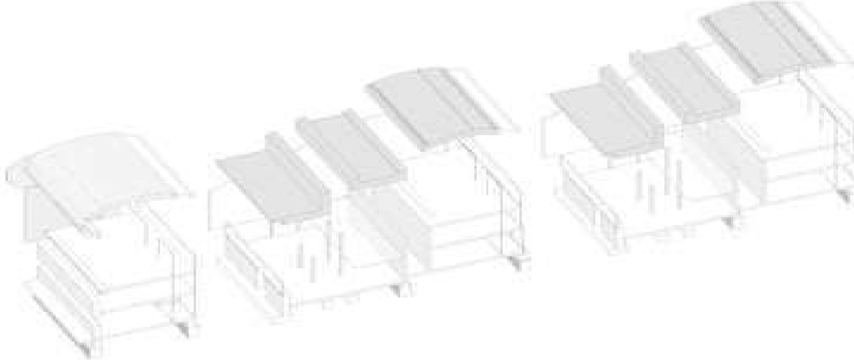
Thermal Distribution

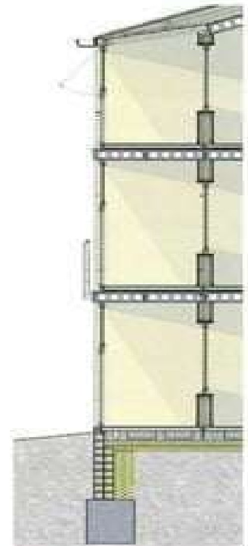


Active Technology

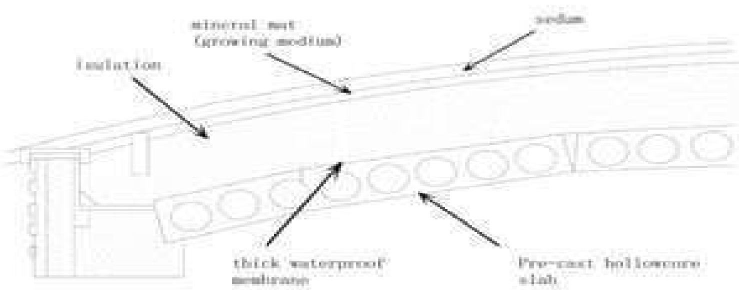


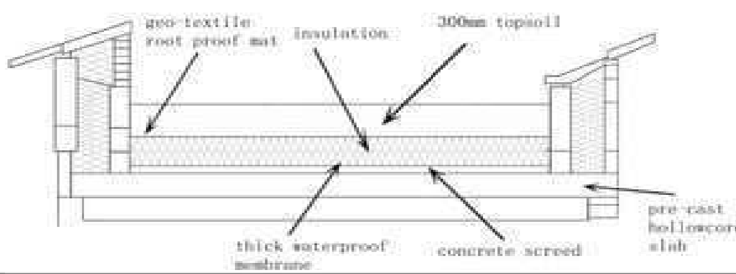
Thermal Distribution



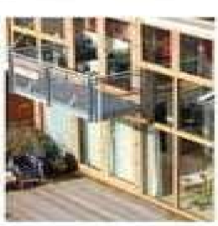


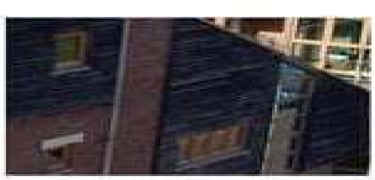
Structure





Structure





Materials

CASE STUDY-2

INDIRA PARYAVARAV BHAVAN

JOR BAGH NEW DELHI

INDIRA PARYAVARAN BHAVAN

INTRODUCTION

- THIS IS A PROJECT OF MINISTRY OF ENVIRONMENT AND FORESTS FOR CONSTRUCTION OF NEW OFFICE BUILDING AT NEW DELHI.
- THE BASIC DESIGN CONCEPT OF THE PROJECT IS TO MAKE THE NET ZERO ENERGY GREEN BUILDING.
- PLOT AREA:9565sq m
- MAXIMUM GROUND COVERAGE:30%
- F.A.R: 200
- HEIGHT:35m
- Built-up area : 3,1400 m2
- (18726 m2 – superstructure & 12675 m2 • - Basement)
- Year of completion : 2013
- **ARCHITECTURAL DESIGN: CPWD (MR. R.K.KOSHAL)**
- **LANDSCAPE DESIGN: CPWD (MR. SODHI)**
- **CONCEPT : BASIC DESIGN CONCEPT OF THE PROJECT IS TO MAKE A NET ZERO ENERGY GREEN BUILDING.**

SITE

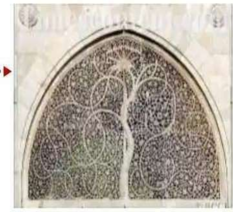
SITE PLAN

- PRESERVATION OF THE LOCAL ECOLOGY,
- TREE CUTTING APPROVALS FOR 46, BUT ONLY 19 CUT
- 11 TREES TRANSPLANTED
- EXCAVATED SOIL REUTILIZED AT OTHER CONSTRUCTION SITES AND THE ZOO

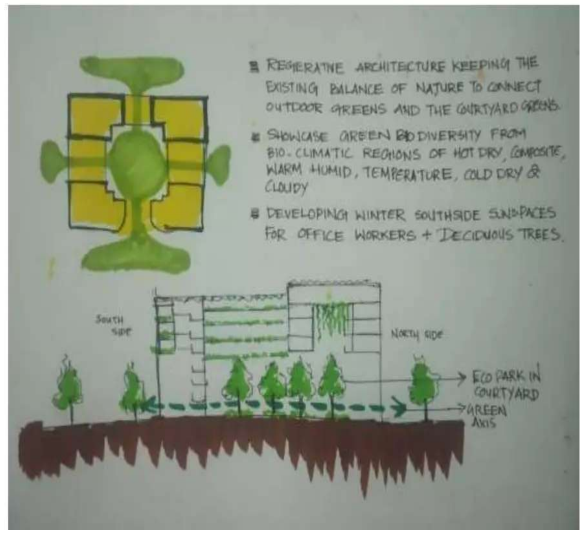
BUILDING ALLIGNMENT

-WIDER FRONT SETBACK (22M) TO PROTECT FRONT TREE LINE
-PRESERVE THE INTEGRITY OF THE GREEN STREET

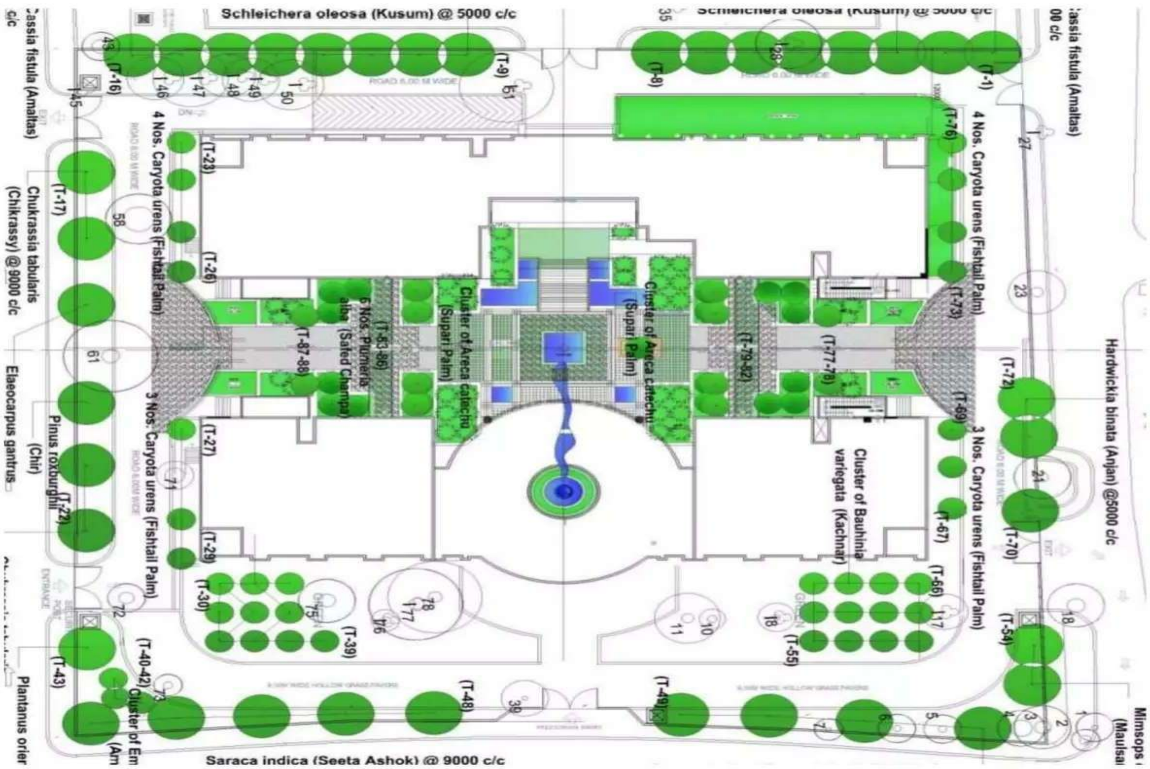
ENVIRONMENTAL RESPONSE

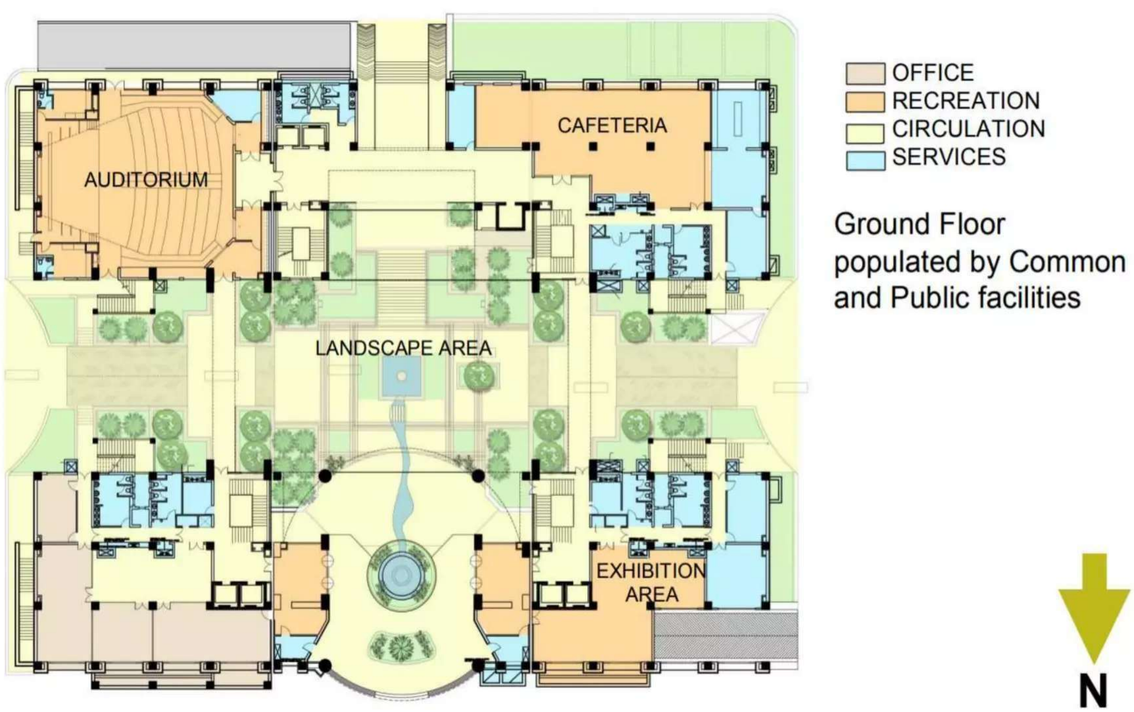


jalis

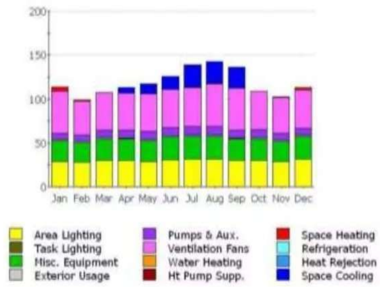


- MAXIMUM GROUND COVERAGE USED (30%) TO KEEP BUILDING HEIGHT COMPARABLE TO THE SURROUNDINGS

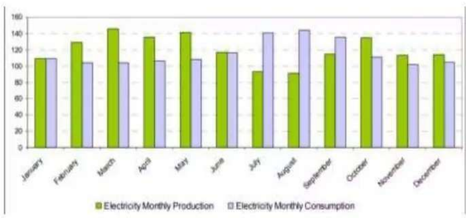

Schleichera oleosa (Kusum) @ 5000 c/c
Saraca indica (Seeta Ashok) @ 9000 c/c


AUDITORIUM
CAFETERIA
LANDSCAPE AREA
EXHIBITION AREA
OFFICE
RECREATION
CIRCULATION
SERVICES
Ground Floor populated by Common and Public facilities
N

ZERO ENERGY



ENERGY CONSUMPTION ON SITE

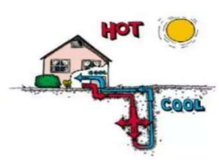


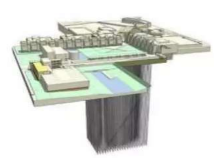
ANNUAL ENERGY PRODUCTION & CONSUMPTION (MWH)

- IPB REDUCES ENERGY REQUIREMENT BY 70% OVERALL
- N-S ORIENTATION – LIMITING WWR – INSULATION ON WALL & ROOF– EXTENSIVE GREENERY TO REDUCE HEAT LOAD
- MAXIMIZING DAY LIGHTING TO REDUCE LIGHTING LOADS
- EXTREMELY LOW LIGHTING POWER DENSITY – 5W/SQM
- PLANNING TO MINIMIZE AC LOADS (KEEPING OPEN ATRIUM FOR CROSS VENTILATION, NON CONDITIONED LOBBIES)
- EFFICIENT HVAC WITH SCREW CHILLERS, VFD'S, CHILLED BEAMS
- GROUND BASED HEAT EXCHANGE FOR CONDENSER WATER REMOTE COMPUTING - THIN CLIENT SERVERS
- ENERGY EFFICIENT APPLIANCES (5 STAR BEE)
- SPV'S FOR THE REMAINING LOAD

GEOTHERMAL COOLING

- Condenser water heat shall be rejected to earth by boring at suitable depth & sending hot water at 100°F (37.8° C) & back at 90^0 F (32.2° C).
- Enormous water saving since no make up water is required.
- Make up water pumping & treatment cost get eliminated.
- Saves cooling tower fan energy.





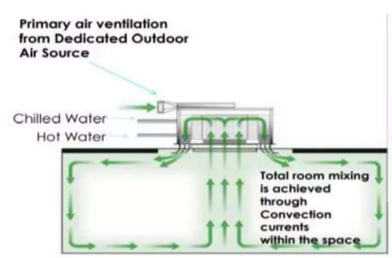
ACTIVE CHILLED BEAMS

Working Principle

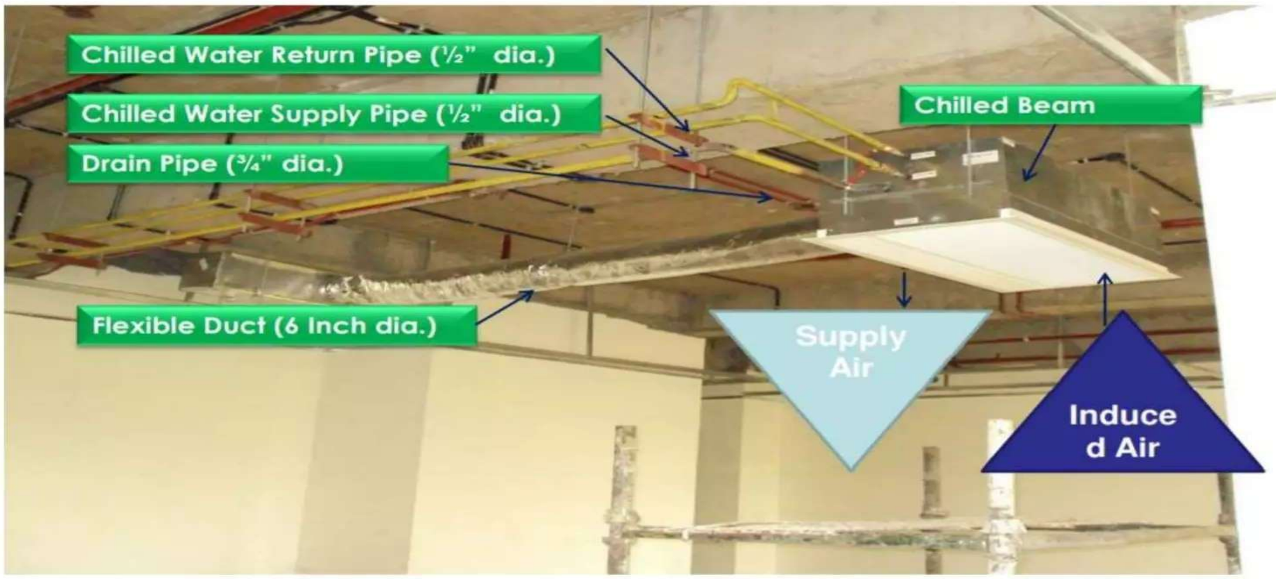
Supply air flows through nozzles in small air jets which induce room air to flow around the coil & air gets cooled.

Design / Constructional / operational advantages

- Reduces power consumption
- Easy Installation
- No noise as no moving parts
- Easy Air balancing activity
- No filters maintenance
- Save architectural space height



CHILLED BEAM INSTALLED AT SITE:



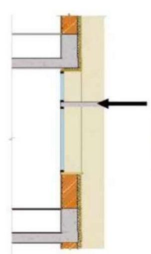
MATERIALS

Cool Roofs with high SRI tiles- high strength, hard wearing

Terrazzo Flooring

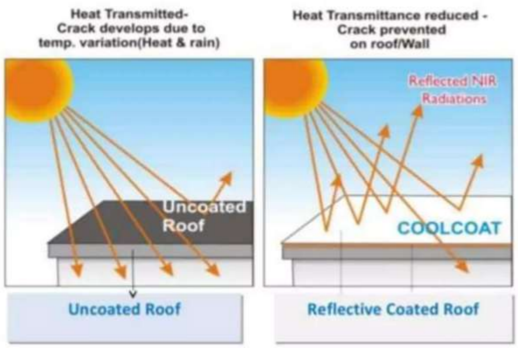
USAGE OF MATERIALS WITH LOW EMBODIED ENERGY

- STONE AVAILABLE IN NEARBY AREA FOR FLOORING
- TERRAZZO FLOORING WITH LOCALLY AVAILABLE STONE MATERIALS.
- FLY ASH BRICK.
- AAC BLOCKS.
- JUTE BAMBOO COMPOSITE FOR DOOR FRAMES & SHUTTERS.
- UPVC WINDOWS WITH HERMETICALLY SEALED DOUBLE USING LOW HEAT TRANSMITTANCE INDEX GLASS.
- USE OF HIGH REFLECTANCE TERRACE TILES FOR LOW HEAT INGRESS.
- AVOIDED ALUMINUM AS IT HAS HIGH EMBEDDED ENERGY
- SANDSTONE JALIS.
- STONE AND FERROCEMENT JALI
- BAMBOO JUTE COMPOSITE DOORS AND FRAMES & FLOORING
- HIGH EFFICIENCY GLASS, HIGH VLT, LOW SHGC & LOW U-VALUE,
- OPTIMIZED BY SHADING
- LIGHT SHELVES FOR BRINGING IN DIFFUSED SUNLIGHT
- USE OF MATERIAL AVAILABLE HAVING RECYCLED CONTENT



COOL ROOF

- A cool roof is one that has been designed to reflect more sunlight and absorb less heat than a standard roof.
- Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles.
- Nearly any type of building can benefit from a cool roof, but consider the climate and other factors before deciding to install one.



TERRAZZO FLOORING

- Terrazzo flooring is composed of composite material.
- It contains any variety of mixture of aggregate chips like stone or marble and either epoxy resin or concrete.
- It can be used both indoors and outdoors and can be poured as concrete or laid in tiles.

FLYASH BRICK

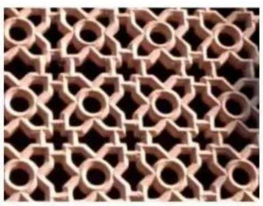
UTILIZATION OF FLY-ASH IN BUILDING STRUCTURE- READY MIX CONCRETE WITH PPC HAVING MORE THAN 30% FLY ASH CONTENT.

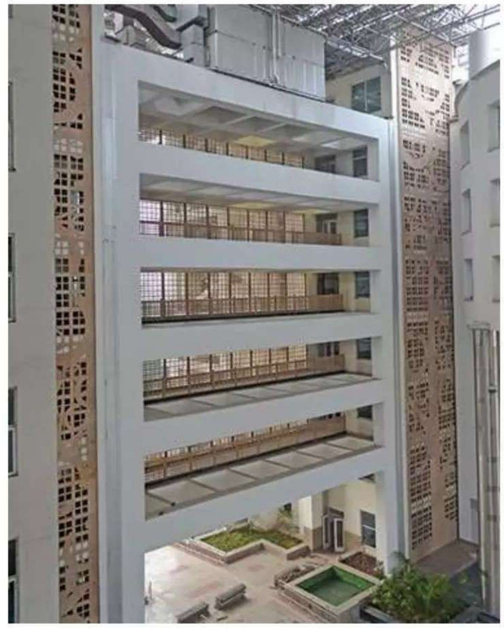
- FLY ASH CAN BE A COST-EFFECTIVE SUBSTITUTE FOR PORTLAND CEMENT IN MANY MARKETS.
- FLY ASH IS ALSO RECOGNIZED AS AN ENVIRONMENTALLY FRIENDLY MATERIAL BECAUSE IT IS A BYPRODUCT AND HAS LOW *EMBODIED ENERGY*, THE MEASURE OF HOW MUCH ENERGY IS CONSUMED IN PRODUCING AND SHIPPING A BUILDING MATERIAL.
- BY CONTRAST, PORTLAND CEMENT HAS A VERY HIGH EMBODIED ENERGY BECAUSE ITS PRODUCTION REQUIRES A GREAT DEAL OF HEAT. FLY ASH REQUIRES LESS WATER THAN PORTLAND CEMENT.

REDUCE VOLUME, WEIGHT, AND CONSTRUCTION TIME BY ADOPTING EFFICIENT TECHNOLOGIES (SUCH AS PRE-CAST SYSTEMS) ON SITE RENEWABLE ENERGY SYSTEM WITH SOLAR PHOTOVOLTAIC CELLS TO MEET TOTAL ENERGY DEMAND.

JAALIS (SANDSTONE)

- A PERFORATED STONE OR LATTICED SCREEN
- THE *JALI* HELPS IN LOWERING THE TEMPERATURE BY COMPRESSING THE AIR THROUGH THE HOLES.
- WHEN THE AIR PASSES THROUGH THESE OPENINGS, ITS VELOCITY INCREASES GIVING PROFOUND DIFFUSION.





Natural stone Jalli and connecting corridors

ECO-FRIENDLY SYSTEM

- REGENERATIVE LIFTS FULLY AUTOMATED CAR PARKING IN BASEMENTS
- BUILDING ORIENTATION IN E-W DIRECTION
- BLOCKS CONNECTED WITH CORRIDORS AND CENTRAL COURTYARD
- BUILDING ENVELOPE DESIGNED TO ENSURE DAYLIGHT IN 75% OCCUPIED AREAS
- PLANTATION AND GRASSING IN MORE THAN 50% AREA
- GRASS PAVERS IN CIRCULATION AREAS
- TERRACE GARDEN
- ENERGY EFFICIENT AIR CONDITIONING SYSTEM AND LIGHTING
- CONVERSION OF BRAKING ENERGY INTO ELECTRICITY IN LIFTS
- CHILLERS AND AHUS WITH VFDS, HEAT RECOVERY WHEELS AND THERMOSTAT CONTROLS FOR HVAC
- LED LIGHTS, OCCUPANCY AND LUX LEVEL SENSORS
- 930 KWP ROOFTOP SOLAR POWER PLANT
- LOW DISCHARGE WATER FIXTURES
- LANDSCAPING WITH NO HARD PAVING ELIMINATING HEAT ISLAND EFFECT
- FLY ASH-BASED PRODUCTS IN CONSTRUCTION
- SEWAGE TREATMENT PLANT OF 30 KLD CAPACITY.
- **FEATURES:**

i. CHILLED BEAM SYSTEM OF HVAC
ii. GEOTHERMAL HEAT EXCHANGE

ACHIEVEMENTS:

- 40% SAVINGS IN ENERGY
- ZERO ELECTRICITY BILLING
- 55% SAVINGS IN WATER
- ZERO NET DISHARGE
- LARGEST ROOF TOP SOLAR POWER SYSTEM IN ANY MULTISTOREYED BUILDING (930KWP)
- FIRST IN GOVERNMENT SECTOR TARGETED FOR BOTH RATINGS OF GREEN BUILDING (5STAR GRIHA LEED India PLATINUM)

Renewable EnergyThe Indira Paryavarn Bhawan met the energy demand with the green and clean energy solution, Efficient Solar PV systems. The building has a solar PV system installed in a 6000 m2 area of 930 kW capacity. The total area covered by the panel is 4650 m2 by 2844 solar panels which generate 14.3 lakh unit annually which is huge in amount. This is the first govt. building in the country to achieve the landmark of net-zero energy building and one of the very few fullfledged multifunctional office buildings in the world to do so on a tight urban site.

INTRODUCTION

India is facing intimidating challenges in meeting its energy needs. If India continues with a sustained growth rate of 8% per annum, its primary energy supply will need to grow by 3 to 4 times, and electricity generation capacity/ supply by 5 to 6 times compared to 2003-04. It is estimated that by 2031-32, the country's power generation capacity of 800,000 MW would be required as against the installed capacity of 160,000 MW inclusive of all captive plants in 2006-07. It has been estimated that the country is currently facing an electricity shortage of 9.9% and a peak demand shortage of 16.6%. Domestic and commercial sectors account for approximately one-third of total electricity consumption and these sectors are likely to consume around 37% of electricity in 2020-21.Building sector energy consumption continues to increase, the primary reason is that new buildings are constructed faster than old ones are retired. Per capita energy consumption has increased in India due to the improved urban living standards and advanced means of energy consumption from households to the industrial sector. The Indian building sector consists predominately of the residential and the commercial sector like building the city of Chicago Nearly, 700 - 900 million sqm of commercial and residential space is projected to be built each year until 2030.Buildings are also prime generators of Green House Gases (GHG), thus posing a threat to the environment. This is an alarming issue and hence it is necessary to develop energy- efficient buildings that would facilitate minimization of energy consumption and reduces GHG.

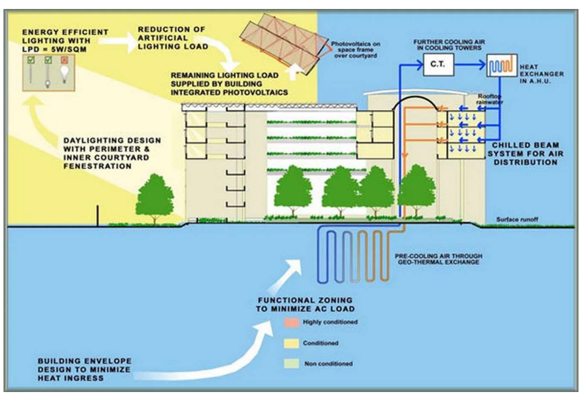
INDIA’S FIRST NET ZERO ENERGY BUILDING: INDIRA PARYAVARAN BHAWAN

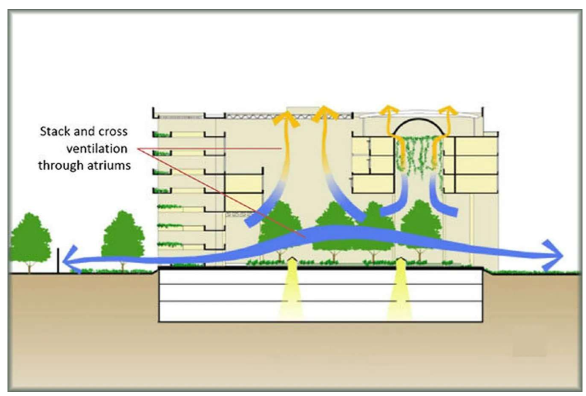
This is a project of the ministry of environment and forests for the construction of new office buildings at Aliganj, Jor Bagh Road, New Delhi. The project has been designed to make the net-zero energy building. First in government sector targeted for both ratings of green building (5 STAR GRIHA LEED India Platinum) The building has won awards such as the Adarsh/GRIHA of MNRE for ideal illustration of Integration of Renewable Energy Technologies. This new office building has been constructed in a composite zone. This building sets revolutionary change into conventional building design. The building has been designed by CPWD by using an integrated design approach with the help of multi-disciplinary fields experts like Architect, Electric Consultant, HVAC Consultant, Plumbing Consultant, Green Building Consultant, Commissioning Authority, Landscape Consultant, Structure Consultant, and other project team members. The project team emphasized on the energy conservation measure at every step of building design and construction for reducing energy demand by using passive design strategies by providing windows with shadings which again provide adequate natural light with that landscape to reduce ambient temperature and for outdoor greenery access with that energy-efficient active systems. All the possible energy-efficient and conservation practices were adopted to lessen the energy load of the building and the remaining demand load was met by an onsite solar PV System of 930 kW capacity to make the building Net Zero Energy building. The energy consumption of Indira Paryavaran Bhawan is 67.3% less in comparison to the GRIHA benchmark. The project adopted numerous green building concepts for occupants' wellbeing and eco-friendly approaches like water conservation and rainwater harvesting. The building orientation set in the manner that it favors optimum solar access and shading. Two blocks facing northsouth direction have been arranged parallelly having a linear open court in the middle. Building front is a wider setback so that it can protect tree lines for occupant’s outdoor view access.

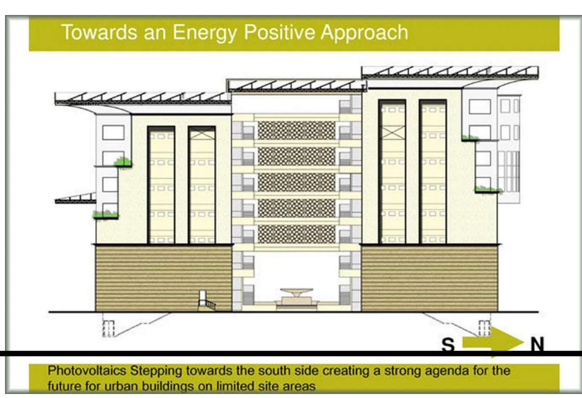
Authorities have got permission to cut 46 trees but only 19 trees were cut, and 11 trees were planted to make up for it. Native plants/trees were planted, and sprinklers and drip irrigation provided to reduce further water requirement. Local ecology was preserved as much as possible to maintain cooler microclimatic. Hard green spaces provided to elevate the greenery. Onsite STP with FAB/MBBR technology constructed to recycle the total water amount to create zero wastewater. Water consumption has been reduced by 64% by providing water-efficient fixtures. Building top, courtyard, and edges fully covered by the Solar PV panels which gives shading and create a cooler microclimate. Onsite solar energy capacity provides sufficient energy to meet the demand capacity of the building which plays an essential role to make the building Net Zero Energy Building. This is the first govt. building in the country to achieve this landmark and one of the very few full-fledged multifunctional office buildings in the world to do so on a tight urban site.

DESIGN FEATURE OF INDIRA PARYAVARAN BHAWAN:

Building design plays a vital role in the energy consumption of the building. Indira Paryavaran Bhawan was designed in three stages by using an integrated design approach. All three stages -Passive design, Active design, and Renewable Design, elaborated below which helped in achieving the net-zero energy consumption of buildings. Detailed submission guidelines can be found on the author resources Web pages. Author resource guidelines are specific to each journal, so please be sure to refer to the correct journal when seeking



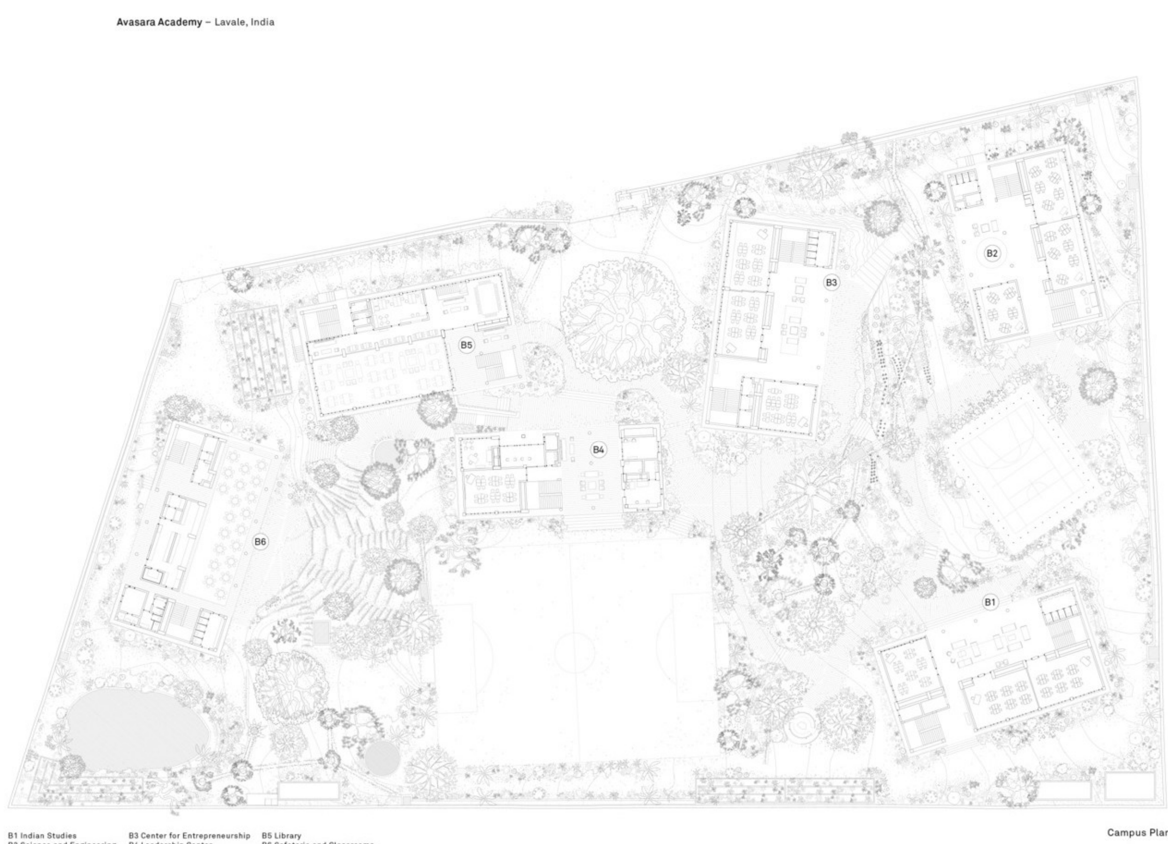




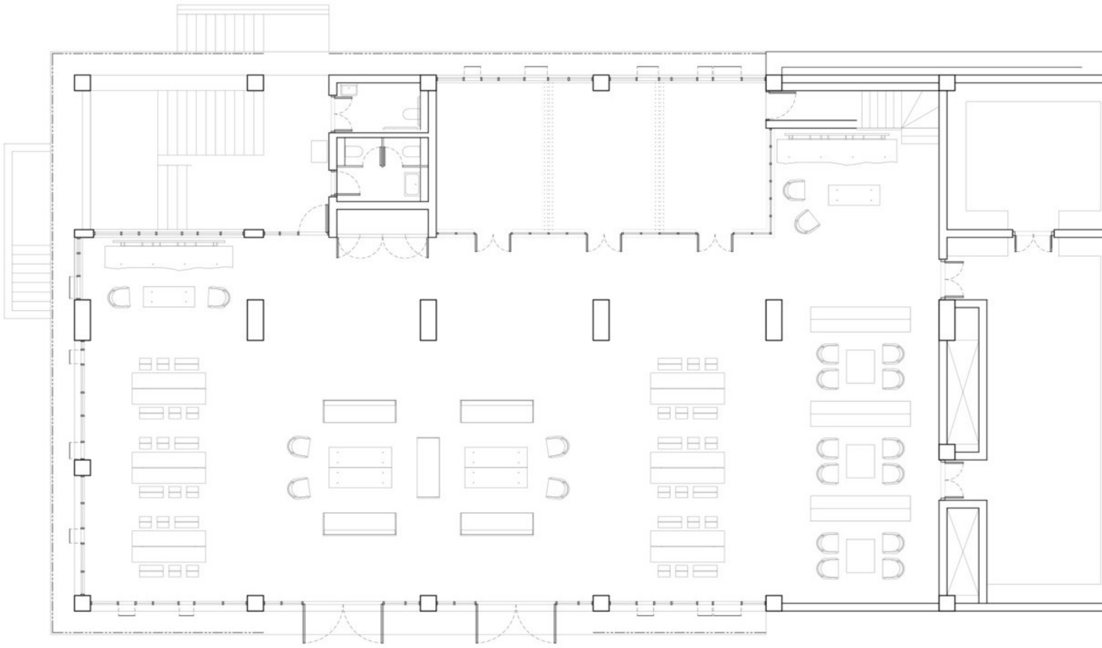
CASE STUDY-3

Avasara Academy

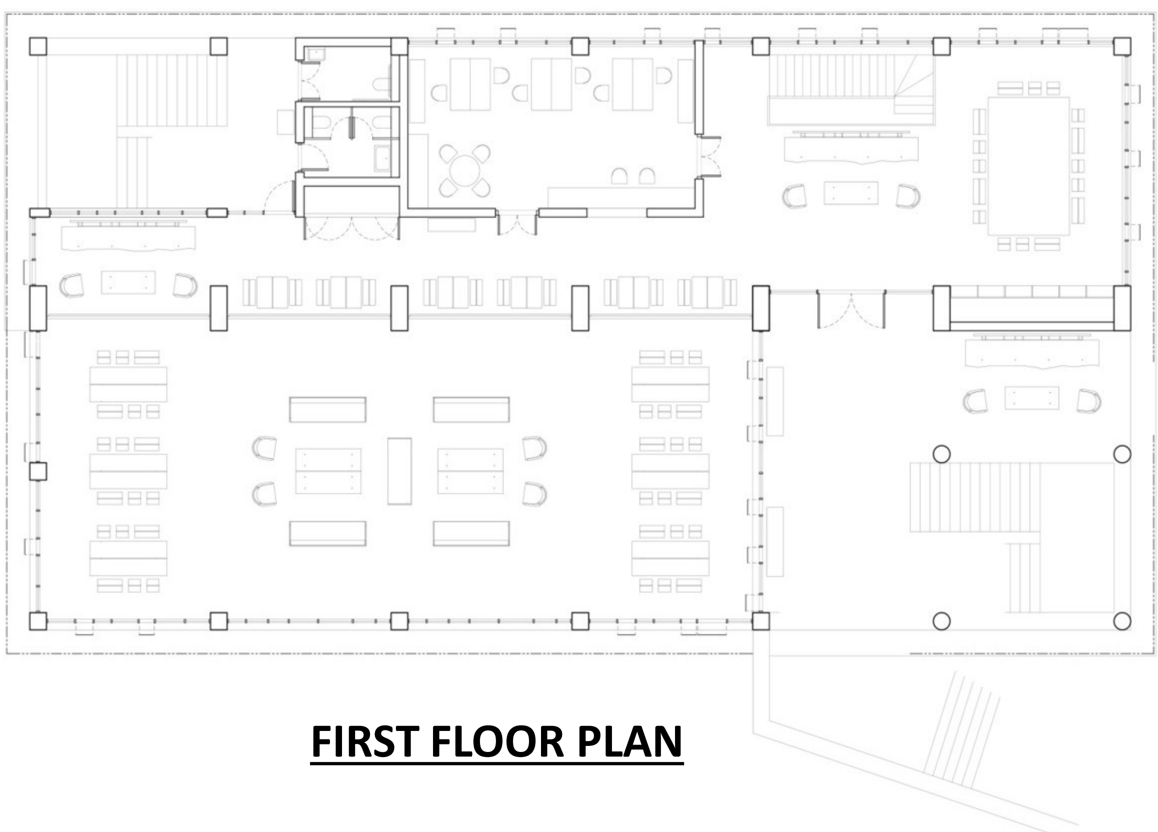
Location- PuneCoordinates 18° N, 73° EOccupancy Type AcademicTypology New ConstructionClimate Type Warm and HumidProject Area 11,148 m2Date of Completion 2020Grid Connectivity Grid-connectedArchitect Case DesignEnergy Consultants Transsolar KlimaEngineering



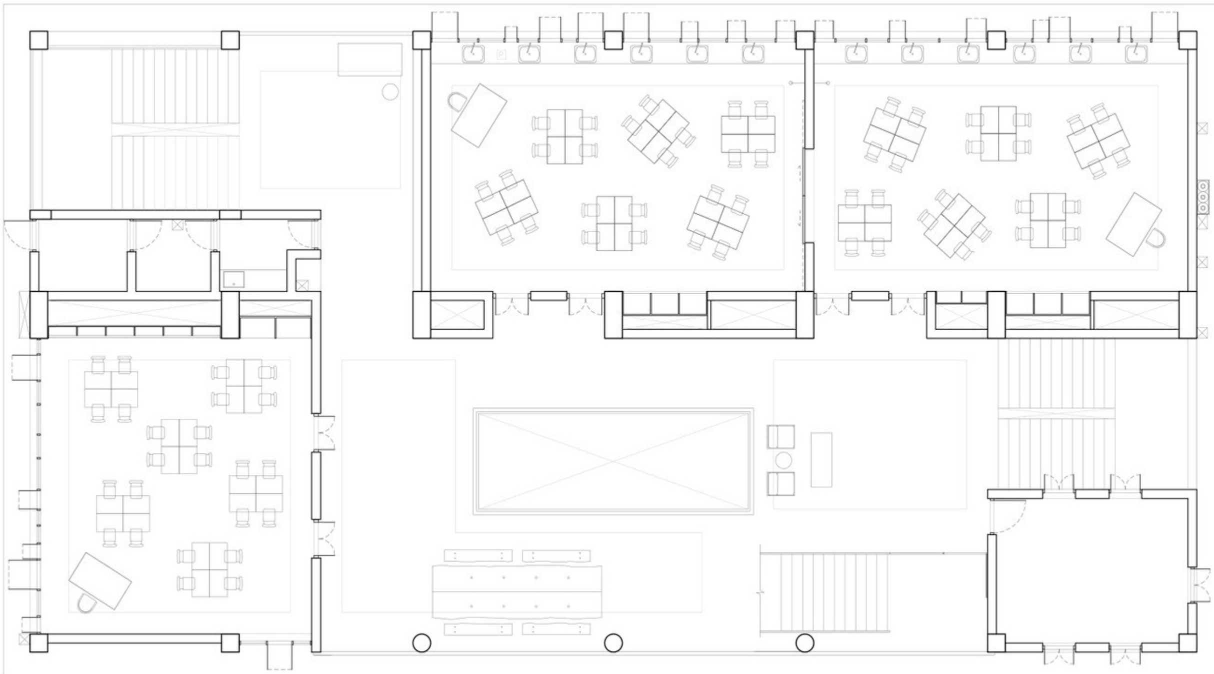
PLAN



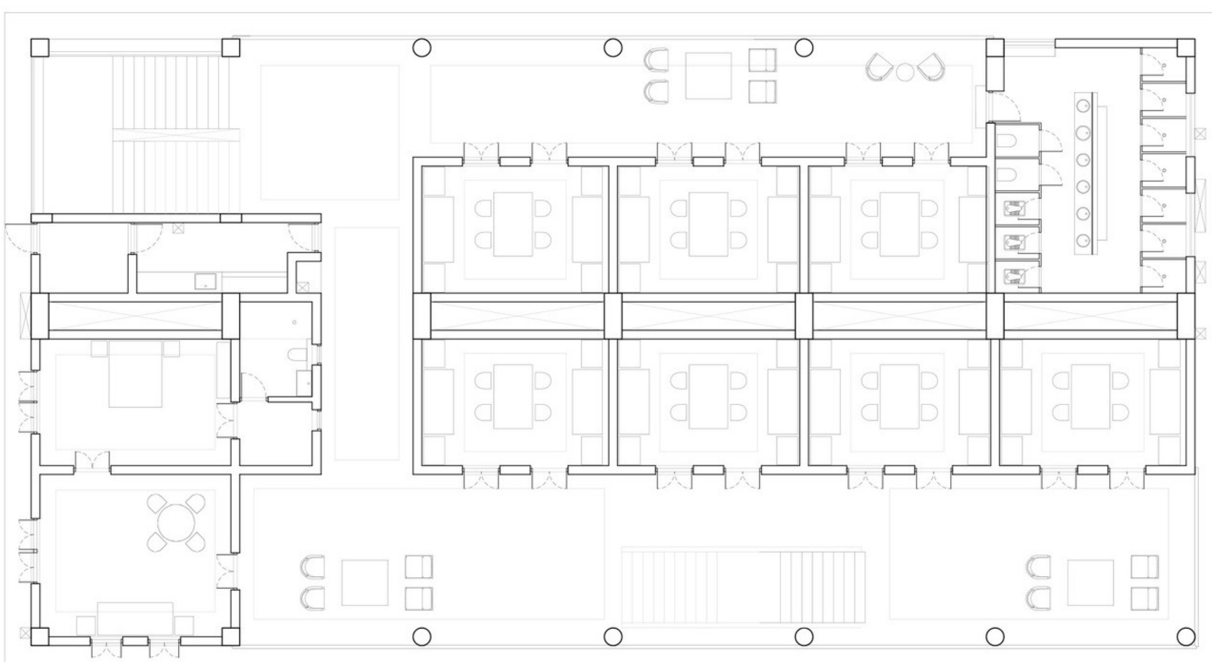
GROUND FLOOR PLAN



FIRST FLOOR PLAN

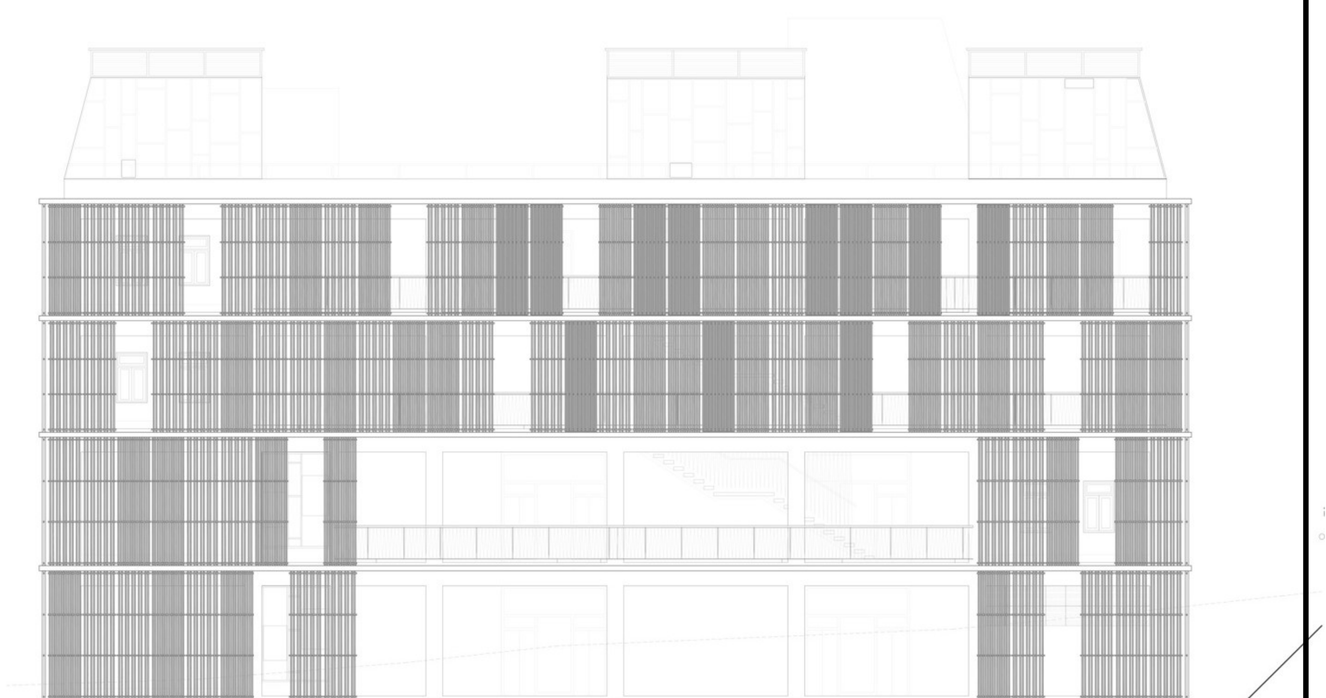


SECOND FLOOR PLAN

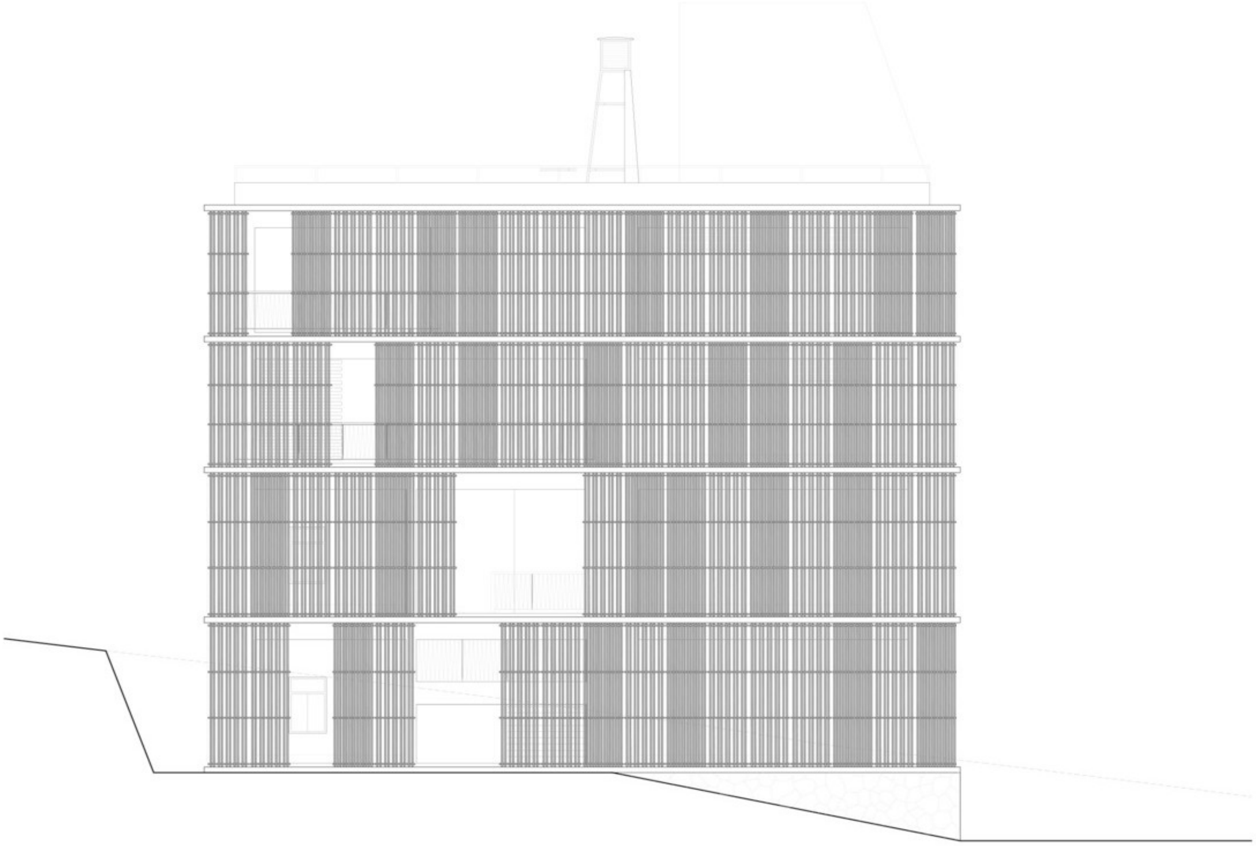


THIRD FLOOR PLAN

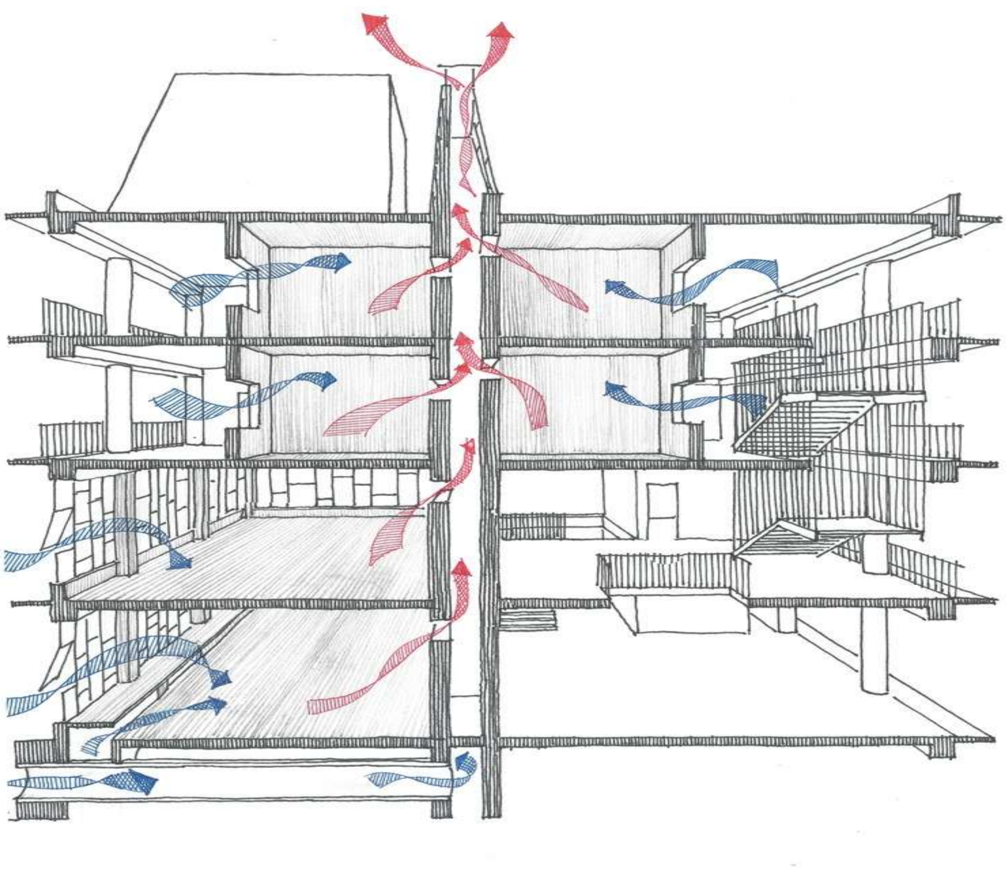
ELEVATION



SIDE ELEVATION

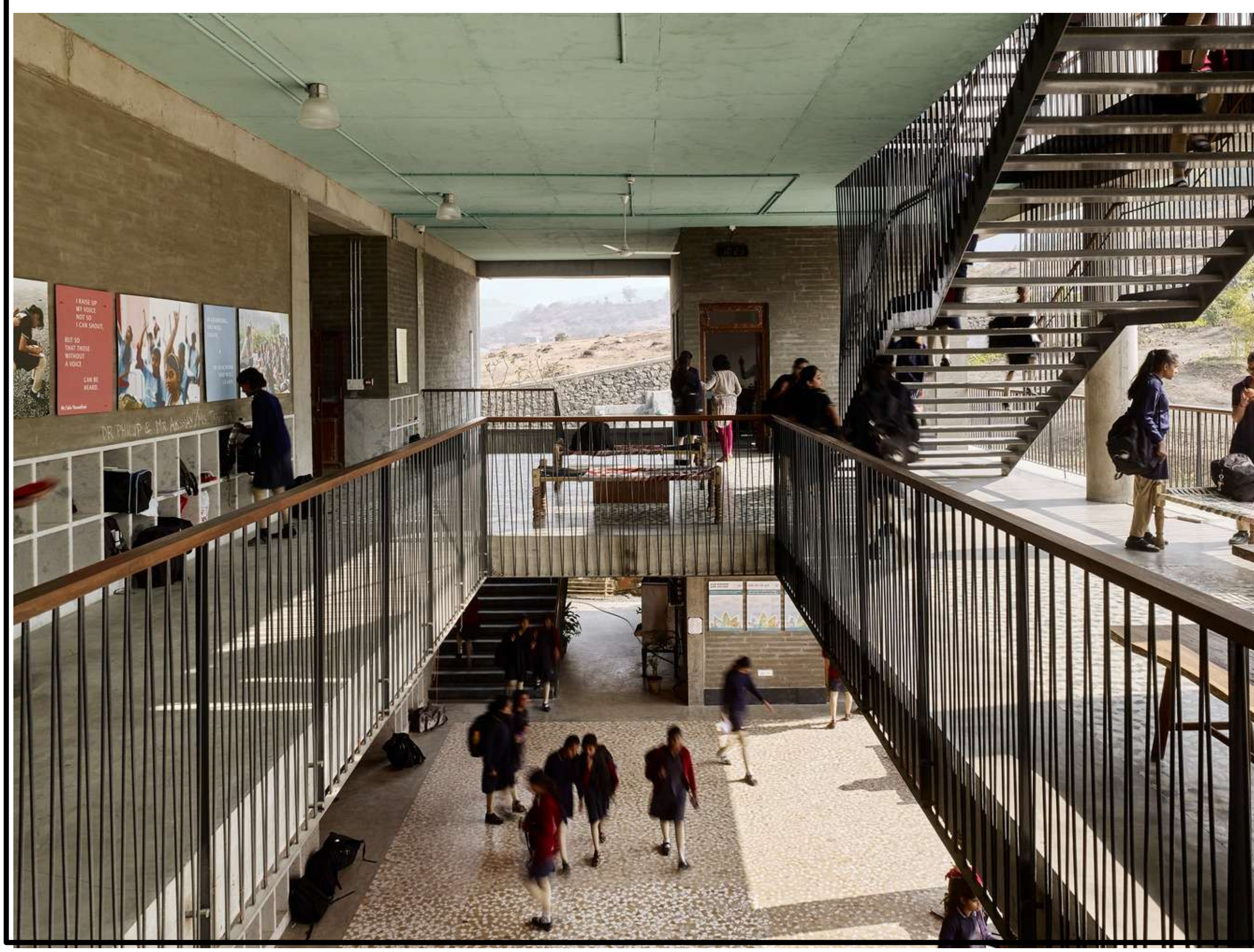


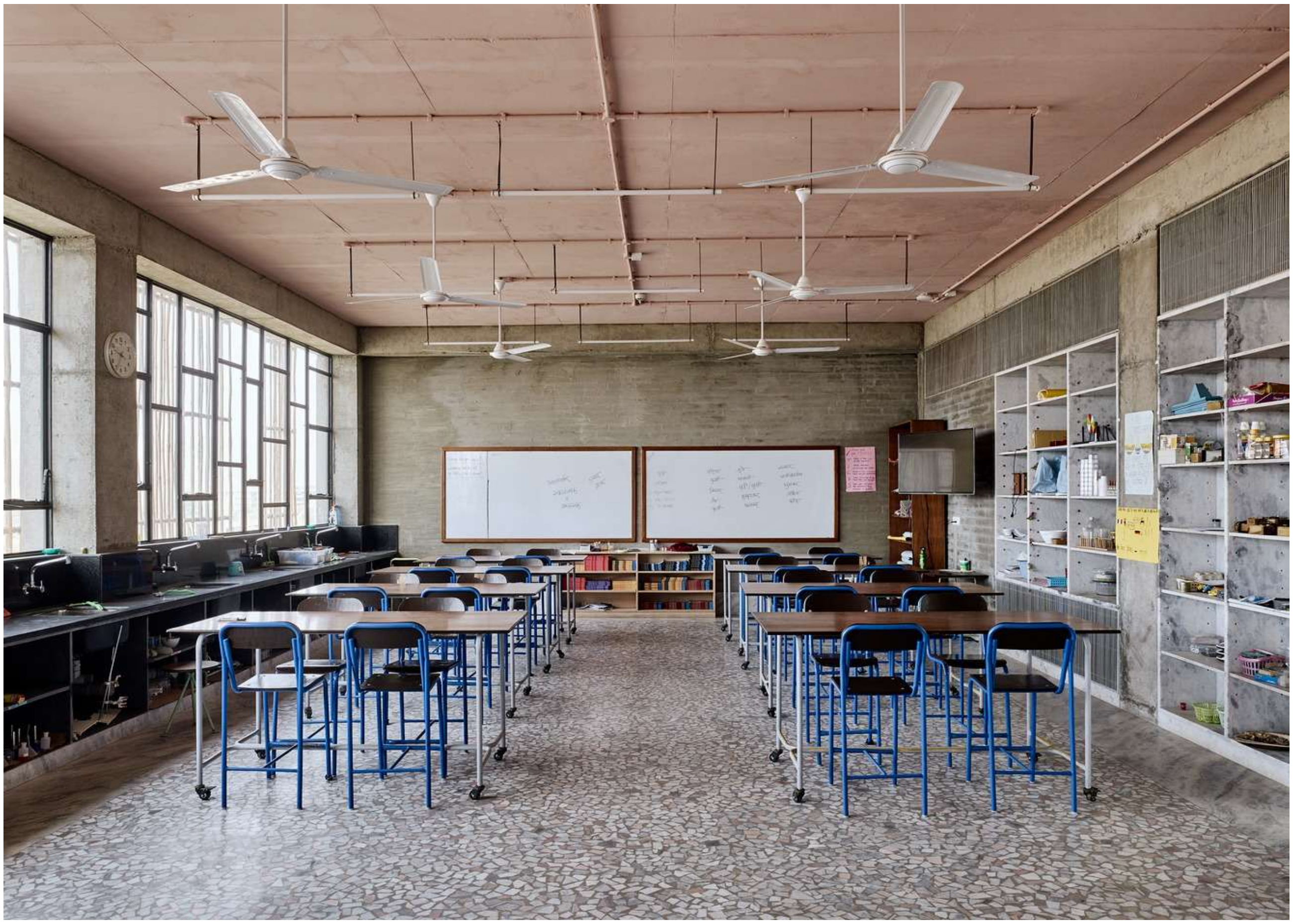
REAR ELEVATION

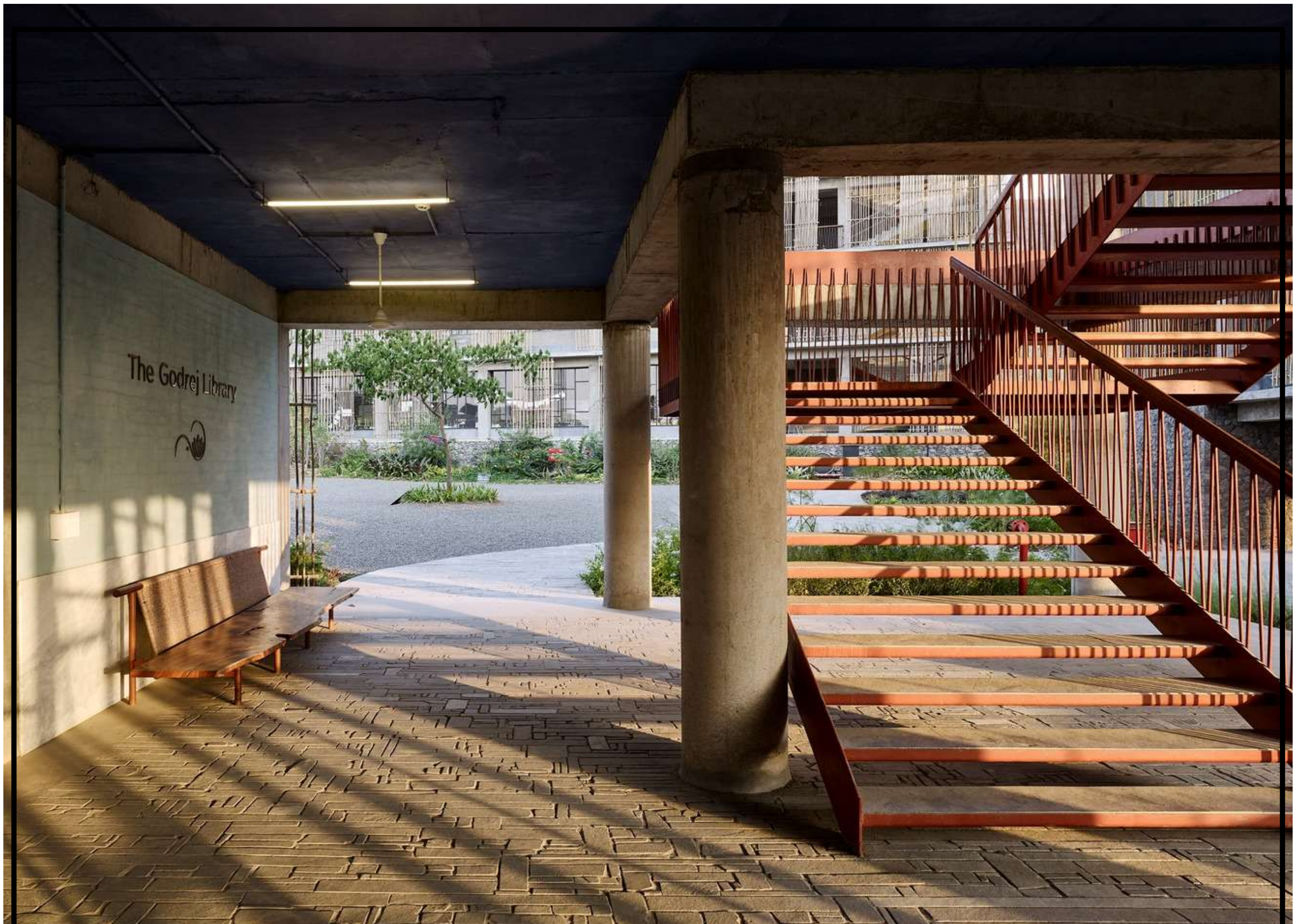


SECTION

SITE IMAGE


I RAISE UP MY VOICE NOT SO I CAN SHOUT,
BUT SO THAT THOSE WITHOUT A VOICE
CAN BE HEARD.





Avasara Academy is a residential school campus for girls located in Lavale (near Pune, India).

The campus design is an example of modern architecture meets vernacular design using passive design principles achieving net-zero energy.The six simple structures on the 4.3 acres site are planned such that the academic and residential areas are provided within every building block. This approach ensured all areas on the campus was being used throughout the year and dead zones were avoided. The priority of the design team was to conserve all available resources and integrate it an efficient and sustainble manner. We learn more about the high performance design strategies and resource management details from the project architect – Samuel Barclay (Founder, Casedesign) in this webinar.The first critical resource that was examined in detail was the use of water. The team studied an existing excavation of an artesian well over a span of a year and designed a system to replenish the water levels by rainwater harvesting. On the other hand, the wastewater from the building undergoes series of filtration through reedbeds (bioremediation) and carbon filters on its way to a polishing pond where it is exposed to UV from the sun. This water is then used for watering the landscape and is distributed throughout the campus via pumps and aqua ducts.

The simplistic design of the building was referred by the architect as “intelligent dumb boxes”. At its core, the structure is a simple grid of beams and columns using cast in-place concrete. Use of post-tensioned prestressed slabs reduced the number of columns giving the spaces an open look and feel. The partition walls were constructed using flyash blocks. The team reclaimed old teak wood doors from abandoned buildings and refurbished them for use in the campus. Composite marble created using waste glass was used in various interior applications. The pavement was designed using waste stone pieces procured from quarries in a beautiful mosaic pattern that naturally emerged due to the irregular shape of the stones. All these elements give the buildings and the campus a lot of character

Considering the large open spaces in the building, adequate shading and rain protection was imperative. This was achieved by designing a smart layout. The dorms are planned with large exterior public areas that form a verandah preventing direct sunlight from reaching the rooms. Vertical bamboo screens used on the periphery diffuses sunlight and provides rain protection.Also, most of the classrooms are planned on the north side of the building to avoid direct sun. The light coloured walls and roofs ensure the depth of daylight penetration reducing the need for electrical lighting. The buildings are fitted with LED light fixtures.

The team from Transsolar KlimaEngineering designed earth ducts and solar chimneys in the building which is integral to the passive solar design strategy. Outdoor air enters a series of earth ducts located underneath the building where it cools down and then enters the classrooms. Warm air exits through the opening closer to the ceiling into the central duct of the building. The glazing of the solar chimney is exposed to sun which in turn heats the air inside the duct creating a large temperature difference between the duct and the classroom spaces. This creates a suction pulling the air out from the classroom resulting in natural ventilation in the space. The thermal mass of the exposed stone floors drives the process through the night once it starts radiating heat.

These passive design strategies sharply reduce energy consumption by an estimated 85%. With rooftop photovoltaic system offsetting the electricity demand and solar water heaters providing all water heating requirement, Avasara Academy is a high-performance NZEB.This project proves that passive design strategies can provide thermal comfort even in a large building while sharply reducing the energy demand. The residual demand can be offset by a renewable energy system to achieve Net Zero Energy goal. Other thoughtful approaches in overall planning, smart water management and low energy material selection showcase that sustainability is a matter of choice and not a result of budget constraint

PASSIVE STRATEGIESSite Layout & Planning

The six four-storeyed rectangular blocks, organized as per the most favorable orientation, follow the undulating hillside acknowledging contours and seeking the best vistas.

The campus is characterized by an inter-connected yet informal arrangement around pathways, courts, gardens and terraces.

Façade, Envelope & Climate Responsive Massing

The building design articulates simple reinforced concrete structures, skilfully organising the volumes in combination with shades & overhangs, and setting the stage for passive climate strategy.

Articulated concrete construction includes the skeleton structure with reinforced concrete floors and the prefabricated structural ceilings. This raw concrete along with the locally sourced stone interior acts as an inert thermal mass; absorbing the solar thermal energy during the day and releasing it again after a delay overnight, resulting in a moderate, more consistent radiant temperature inside the building.

The reinforced concrete floors / ceilings project outwards a little, creating generous overhands which not only provides the facades horizontal articulation but also acts as a form of brise soleil.

The façade is shrouded in bamboo screens with variations in the patterns based on the façade orientation. These locally sourced and skilfully designed screens serve as sun protection, thus preventing excessive heating of the interior from direct sunlight.

The projection / overhang results in spaces being slightly stepped back. The spaces are attached to open corridors, deep verandas, generous semi-outdoor spaces, stairwells and atrium, resulting in an extremely airy structure supported only in part by columns.

Daylighting

The building is partly covered in bamboo screens, partly by glass surfaces, or it remains open, rendering a blur line between the sense of enclosure and openness.

The bamboo screen and the lightly woven blades placed on the overhangs deploy a second skin that provide privacy, reduce glare, and give a textural quality to the interior and exterior through a delightful play of daylight and shadows, while unifying the architectural scheme.

Passive Ventilation Design

The building is naturally ventilated using a combination of passive heating-cooling systems, thus eliminating resource-draining mechanical systems.Passive heating-cooling systems are designed with earth ducts, structurally integrated vertical cavities and solar chimneys to induce ventilation in each building, lowering interior temperatures by 5-9°C during uncomfortably hot summer months.Earth ducts are 900 mm dia concrete hume pipes laid between the building foundation that run around 16 – 20 m in length underneath the building. Fresh outdoor air sucked in these earth ducts is passively pre-cooled and then diffused into the lower floor spaces at the floor level along the facades, enabling the air to circulate freely in the middle of the buildings.Additionally, supply air enters the spaces through the strategically designed window and the doorways.The vitiated air from all the spaces, due to convection, passively transfers through the exhaust grills located at the ceiling level into three separate centrally located exhaust cavities which are integrated in the structural core of the building and eventually extend out as solar chimneys above roof level.These chimneys are wide, glazed on three sides with their rear concrete wall almost 5m high and are capped with louvered grills. This assembly is sun-driven that leads the warm air out of the building, passively driving the entire air flow and providing natural cooling throughout the building.This meticulously designed natural air flow path through all the spaces in the building using architectural and structural infrastructure create year-round comfortable learning and living environment.

Material Palette

The building material palette highlights use of raw concrete, local stone and timber windows with large expanses of glazing rounded off by bamboo mats for shading on the exteriors, use of blockwork walls, coloured mosaic floors, teak doors, and various pastel hues on the interiors.This mix of material textures was carefully selected and meticulously crafted to complement the surroundings. The palette focused on the longevity of the materials and cost reduction by using recycled materials.The majority of timber windows are recycled from demolished structures, blockwork partition walls are burned from fly ash, floor mosaics are made from the remains of marble quarries, majority of doors are made of teak from demolition objects, and the pastel hues use natural pigments – largely contributing towards the sustainability goals of the project

Photovoltaic solar panels and solar water heaters have been installed on the roof to provide electricity and supply hot water to the building.

What is Net-Zero Energy Building?
A Net-Zero Energy home is designed to produce as much energy as it consumes over a year.These homes combine highly energy-efficient design with renewable energy sources, most commonly solar panels, which are particularly effective in sunny regions like Phoenix.The goal of Net-Zero construction is to reduce the home’s energy demands through airtight construction, insulation, and energy-efficient appliances while meeting the remaining energy needs with renewable energy.In Phoenix, where sunshine is abundant for most of the year, Net-Zero Energy homes have a distinct advantage.Solar energy can be a reliable and cost-effective solution for reducing dependency on traditional energy sources, which can lead to significant long-term savings on energy bills.The U.S. Department of Energy notes that Net-Zero Energy homes can save homeowners thousands of dollars over the lifespan of the home by generating their own energy, which is particularly valuable in areas with high utility rates like Arizona.The major downside of Net-Zero Energy homes is the upfront investment.Solar panels, energy-efficient windows, and high-quality insulation all come with a steep price tag.Additionally, the systems required to store and manage the home’s energy production, such as battery storage for solar energy, can add to the cost

Passive vs LEED vs Net-Zero Energy:

Key ConsiderationsWhen deciding between Passive, LEED, and Net-Zero Energy homes, there are several key factors to consider.First, think about the climate in your region.In Greater Phoenix, where temperatures are extreme, energy efficiency should be a top priority.Both Passive and Net-Zero homes offer significant benefits in terms of reducing energy use in hot climates, as they rely on airtight construction, high insulation, and energy-efficient homes designed to stay cool without excessive air conditioning.Cost is another critical factor. While LEED certification provides a broad approach to green architecture, it may not always be the most energy-efficient or cost-effective solution, depending on the specific project.LEED homes can be more expensive due to the wide range of sustainable building methods they incorporate, from water conservation to using eco-friendly materials.However, they are flexible and offer a comprehensive approach to sustainability, which appeals to many homeowners.For those whose primary goal is minimizing energy consumption and cutting utility bills, Passive or Net-Zero Energy homes may be the better choice.Passive homes can offer the lowest ongoing energy costs, while Net-Zero homes provide the added benefit of energy independence through solar power.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews existing literature on Net-Zero Energy Buildings (NZEBs), passive design, local-material construction, renewable integration, cost-effectiveness, and key case studies. Selected images illustrate real-world applications and prototypes of low-cost, sustainable housing.

2.2 Concept of Net-Zero Energy Buildings (NZEBs)

Net-Zero Energy Buildings are designed to produce as much energy as they consume annually through a combination of energy efficiency and on-site renewable energy generation. According to the International Energy Agency (IEA), NZEBs focus on reducing energy demand through architectural design, efficient systems, and the integration of renewable energy sources, typically solar.

NZEBs are becoming increasingly important as countries seek to meet climate goals. However, most NZEB applications are focused on high-end or institutional buildings, with limited adaptation for affordable housing in developing nations.

2.3 Low-Income Housing: Issues and Opportunities

In countries like India, low-income communities face persistent housing and energy challenges including poor thermal comfort, overdependence on artificial lighting, and lack of affordability for energy-efficient technologies. Studies by UN-Habitat (2020) and BMTPC India emphasize that addressing energy poverty is crucial alongside income poverty

2.4 Importance of Local Materials in Sustainable Housing

Using locally available materials helps reduce construction cost, carbon footprint, and enhances community participation. Renowned architect Laurie Baker advocated the use of mud, stone, bamboo, and lime for their climate responsiveness and cultural relevance.Compressed Stabilized Earth Blocks (CSEB) and lime plasters reduce embodied energy and regulate indoor temperature.Studies show fly ash bricks, laterite stone, and rammed earth as thermally stable and cost-effective.Bamboo and waste-based insulation (like rice husk, coconut coir) improve energy efficiency.

2.5 Passive Design Strategies in Affordable NZEBs

Passive design reduces energy needs significantly in hot and composite climates. Key strategies include:Orientation for daylight and windShading devices (chajjas, verandahs)Thermal mass materials (mud, stone)Courtyards and ventilated roofs
Passive design can reduce cooling loads by 40–60%, enhancing user comfort while saving energy..

2.6 Renewable Energy Integration for Low-Cost NZEBs

Renewable energy is essential for net-zero performance, especially solar photovoltaic (PV) systems. Recent innovations include:Low-cost rooftop solar panelsSolar battery banksCommunity solar microgridsImage 4: Off-grid net-zero tiny home with roof-mounted solar panels.2.7 Cost Implications and Economic Feasibility
Contrary to belief, NZEBs need not be expensive:A 10–15% increase in construction cost results in 30–40% operational savings. Payback periods can be reduced to 3–5 years with proper material selection and design efficiencies. Prefabrication and modularity lower construction time and waste.

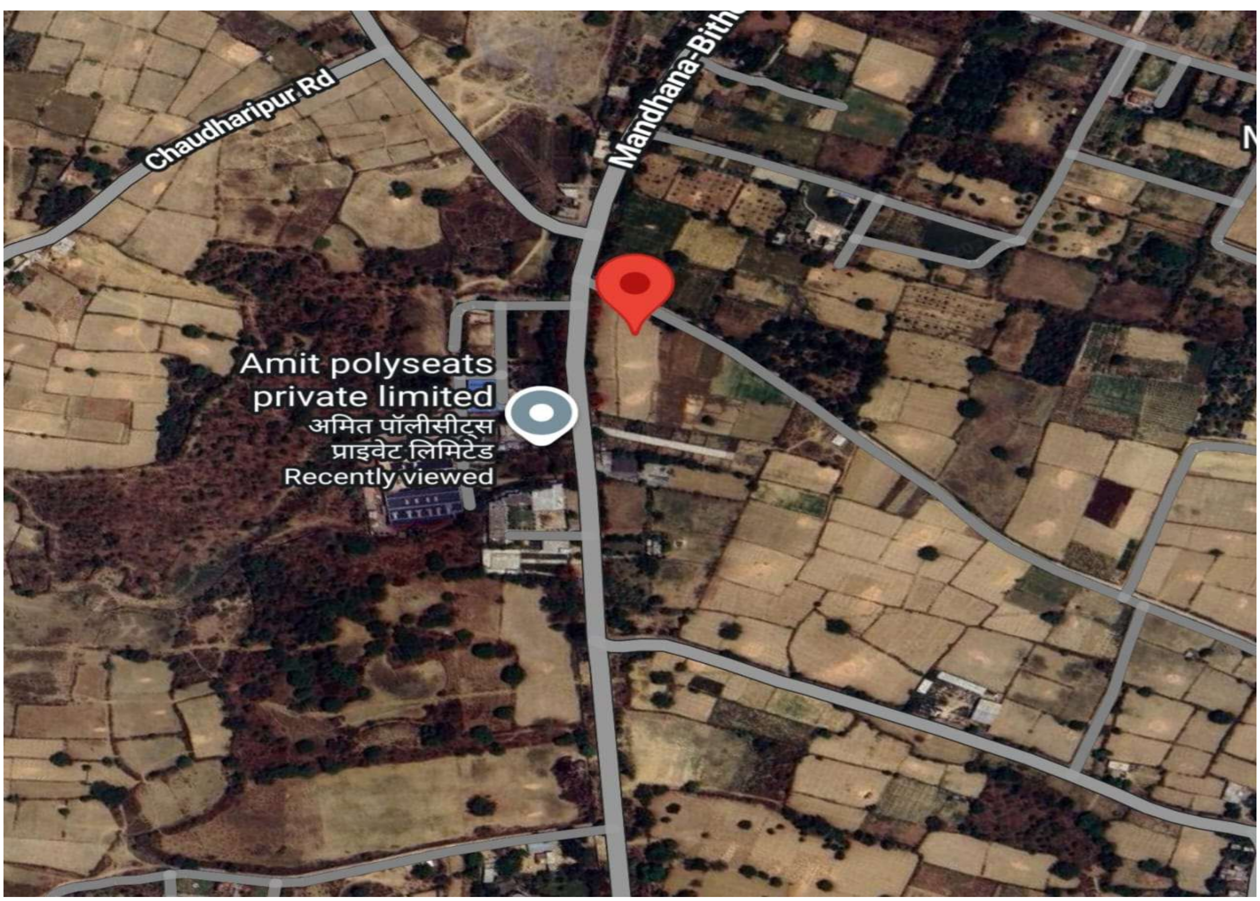
Chapter 3:

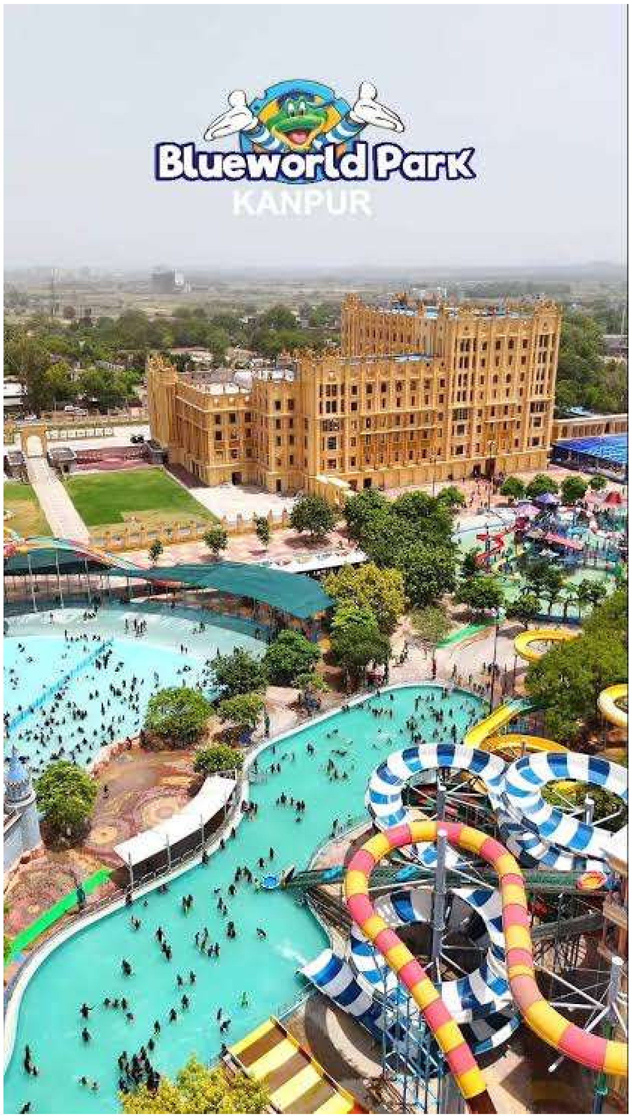
Site Analysis – Bithoor, Kanpur (For Prototype Net-Zero Housing)

This chapter examines the site context of Bithoor (also spelled Bithur)—a pilgrimage town ~25 km north of Kanpur—focusing on climate, geography, infrastructure, materials, and cultural considerations relevant to your low-cost net-zero housing prototype.

3.1 Location & Geography

Coordinates: ~26.61 N, 80.27 E, elevation ~126 m above sea level .Situated on the right bank of the Ganges River, Bithoor spans approx. 5.3–5.4 km^2 .Topography: flat alluvial plains prone to seasonal river flooding, with fertile riverine soil good for local material sourcing.Rich cultural and historical fabric—temples, ghats, pilgrimage sites—that enrich design context .





3.2 Climate Profile

Summer temperatures spike to 42–44 °C, with humidity between 50–70%, resulting in significant thermal discomfort .Heatwaves common in May–June; monsoon arrives mid-June with thunderstorms reducing peak temperatures .Annual climate:Hot dry summers (Mar–Jun)Rainy monsoon (Jun–Sep)Mild winters (Nov–Feb)

→ Passive cooling, solar shading, and heat-resilient materials are essential.---

3.3 Water & Flood Risk

Proximity to the Ganges offers water access and gravity-fed systems, but also seasonal flooding and high water table risks.Site design must include elevated plinths, permeable landscaping, and water harvesting strategies.

3.4 Local Materials & Construction

Abundant traditional materials: river sand, mud, stone, bamboo, and clay.Community familiarity with earthen construction—CSEB, rammed earth, lime mortar is common.Transport logistics favorable: road access via Kanpur, local quarries within ~30 km.Local labor experienced in vernacular techniques (mud plaster, thatch, cane), aiding affordability and sustainability.---

3.5 Infrastructure & Utilities

Electricity: stable supply (~23 hrs/day) even during heatwaves , enabling solar PV grid-tie systems.Transport: Nearby Kanpur Central Station (23 km), Chakeri airport (44 km), and road network offering regional connectivity .Limited local bus service and municipal water/sewer demands on design resilience.

3.6 Cultural & Social Context

Predominantly Hindu pilgrimage site, with seasonal pilgrimage flows—design must respect privacy, cultural norms, and community applications.Mixed demographics, literacy ~81%, moderate household incomes—affordability is key .Marathi community presence suggests adaptive, multi-cultural design acceptance.

3.7 SWOT Analysis

Strengths Weaknesses

Abundant local materials; cultural acceptance Extreme heat; high rainfall and flood risk

Stable electricity; good transport links Variable water/sewer infrastructure; pilgrim population stress

Opportunities Threats

Low-cost NZEB pilot with flood-adaptive design Flood hazard, changing climate patternsCommunity labor; government rural housing schemes Delays due to regulations or heritage site restrictions

3.8 Implications for Prototype Design

1. Climate response: High thermal mass walls (compressed earth, stone), wide eaves, cross-ventilation.
2. Flood resilience: Elevated plinths, permeable paving, rainwater harvesting.
3. Renewables: Rooftop solar PV with battery backup
4. Local materials: Mud-brick, bamboo, lime plaster
5. Cultural integration: Courtyards, shaded verandas, materials that blend with temple architecture.
6. Cost-effective construction: Modular, prefabricated CSEB panels assembled with local labor.

3.9 Summary

Bithoor’s unique setting—hot-humid climate, riverine geography, cultural richness, and access to materials/labor—makes it suitable for a climate-responsive, low-cost net-zero housing prototype. The design must balance thermal comfort, flood resilience, cultural appropriateness, and affordability to serve as a replicable model for peri-urban communities in North India.

CHAPTER 4: DESIGN BRIEF

Project Title

“Net-Zero Affordable Housing Prototype for Riverine Communities – Bithoor, Kanpur”

Project Type

Low-cost, net-zero energy residential housing with options for incremental growth, intended for economically weaker sections and flood-prone communities in peri-urban areas.

Location & Site Contex

Site: Peri-urban plot in Bithoor, ~25 km from Kanpur city, located near the Ganga riverbanks.Plot Characteristics:

Flat terrain, alluvial soil Prone to monsoon flooding (requires elevated design)Easy road access to Kanpur Rich in cultural and religious significance

Aims & Objectives

To develop an energy-efficient, climate-responsive, affordable housing prototype tailored for riverine and low-income Indian settlements.To minimize operational energy use and utilize renewable energy to meet household demands.To employ local materials and labor to support the local economy and cultural integration.To create a replicable, modular housing model adaptable to various sites and family sizes.

Target Users

Economically weaker section (EWS) and lower-income group (LIG) familiesLocal artisans, laborers, or displaced riverine households3–5 member households, possibly multigenerational

Key Design Strategies

1. Passive Design Features

Orientation: maximize natural ventilation (east-west)
Courtyard planning for daylight & air circulation
Wide roof overhangs, shaded verandas, ventilated plinth
High thermal mass using earthen/CSEB walls

2. Renewable Integration

Rooftop Solar PV: 1–1.5 kW per house
hold Solar water heaters
Battery backup or hybrid grid system

3. Flood Resilience

Raised plinth (minimum 1.2 m)
Drainage slope and rainwater harvesting
Use of flood-durable materials (lime, stone, CSEB

4. Local Materials & Systems

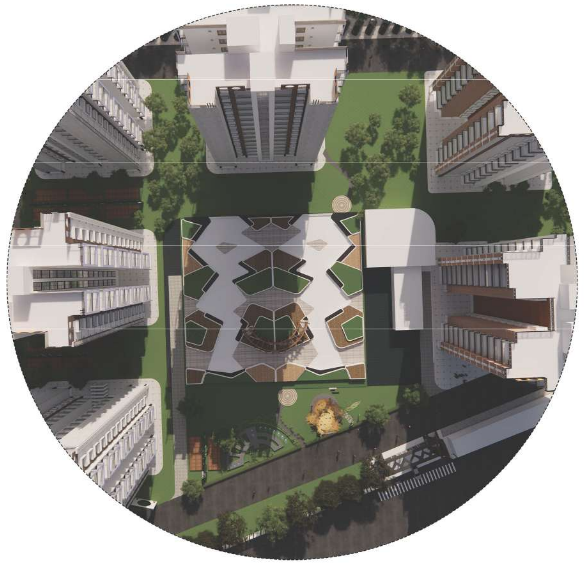
Compressed Stabilized Earth Blocks (CSEB)
Bamboo/cane reinforcement for roofing
Lime plaster, mud flooring, locally woven jute insulation
Modular toilets with bio-digester/septic tank

5. Affordable Construction Techniques

Modular layout for incremental housing
Prefabricated door-window units
Participatory construction with local labor

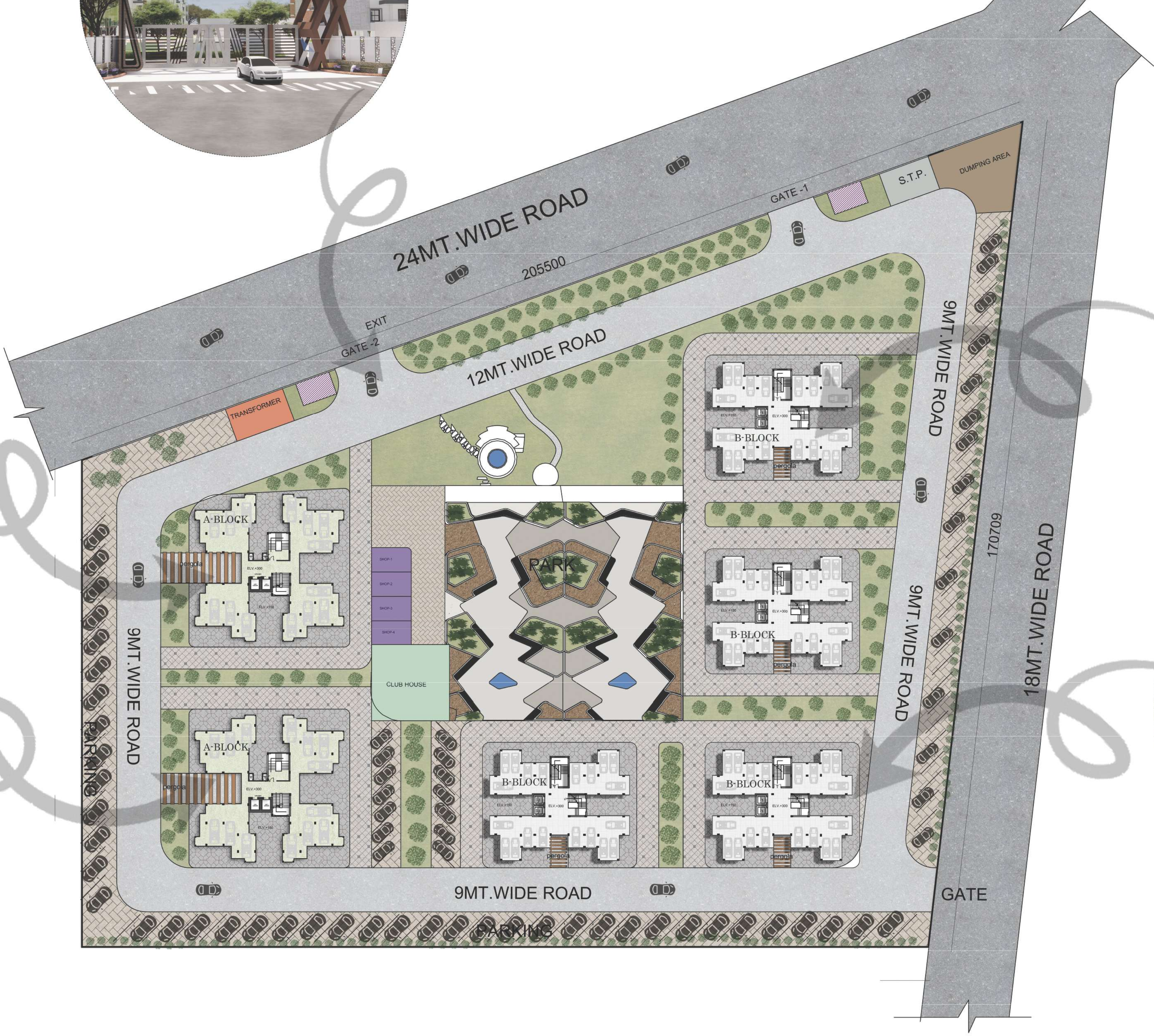
Conclusion

This design brief proposes a culturally rooted, climate-responsive, and economically accessible prototype that can pave the way for large-scale net-zero affordable housing across India’s flood-prone and resource-scarce settlements.



TOP VIEW

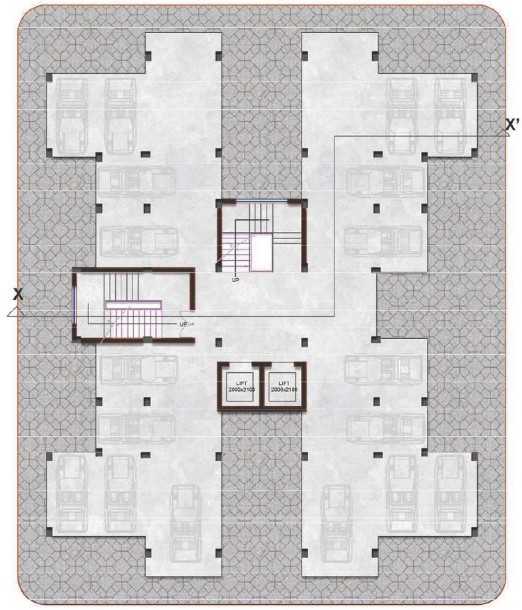
PARK VIEW



N	**DRAWING TITLE-**	NOTE: ALL DIMENSIONS ARE IN MM SCALE - 1:100 SHEET NO.- 0	**PROJECT NAME-** **NET-ZERO URBAN HOUSING: A PROTOTYPE FOR SUSTAINABLE LOW-INCOME COMMUNITIES.**	**SUBMITTED BY-** AR. ROMIL SINGH M.ARCH IV SEM. 1220109002 2024-25 BBDU, LUCKNOW **GUIDED BY-** PROF.(AR.) SAURABH SAXENA

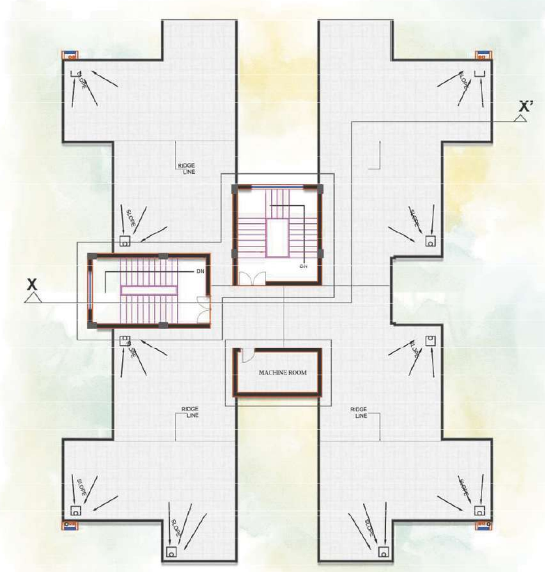
2BHK PLAN ,ELEVATION SECTION

UNIT PLAN
NOT TO SCALE



STILT FLOOR PLAN

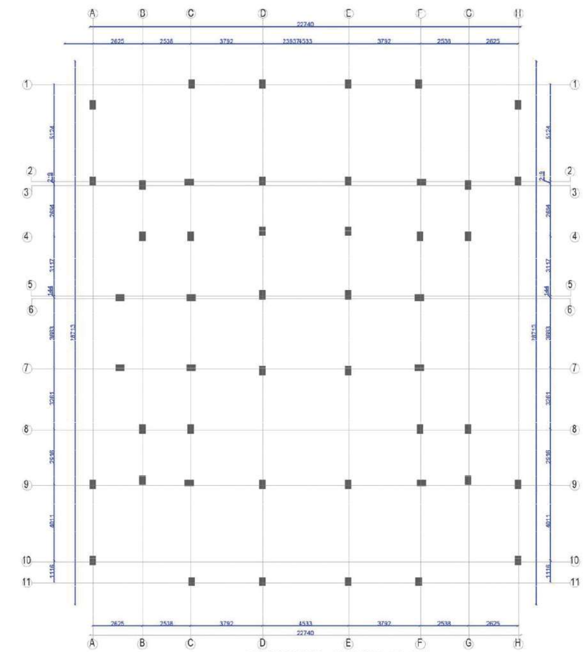
TO FOURTEEN FLOOR
TYPICAL FLOOR PLAN



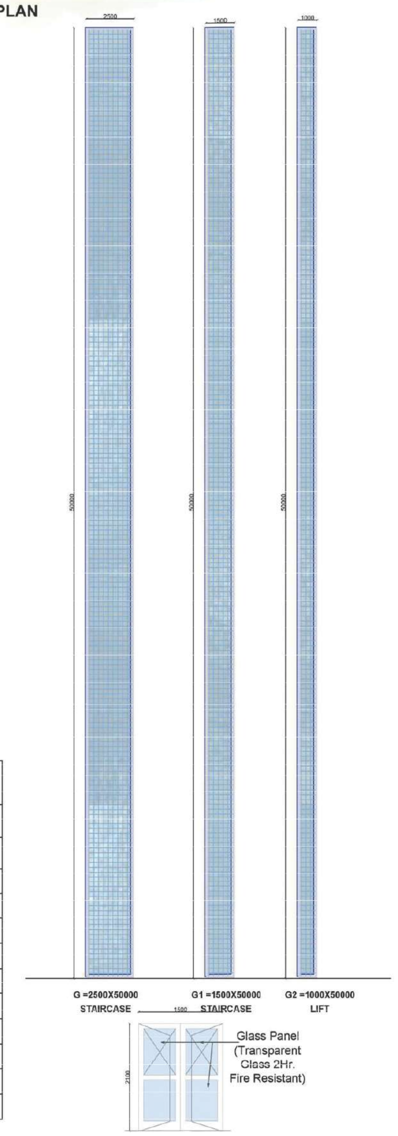
TERRACE PLAN

SECTION -XX'

ELEVATION



COLUMN LAYOUT PLAN



SCHEDULE OF DOORS & WINDOWS

S.NO.	TYPE	OPENING SIZE	LINTEL	SILL	REMARK
1	D1	1200X2100	2100	-	MAIN ENTRY FOR UNITS
2	D2	1050X2100	2100	-	BED ROOM
3	D3	900X2100	2100	-	BALCONY
4	D4	750X2100	2100	-	TOILET DOOR
5	DW	3425X2100	2100	900	BED ROOM (BALCONY)
6	W	1800X1250	2100	900	LIVING HALL , BED ROOM
7	WK	1500X1250	2100	900	KITCHNE
8	V	600X600	2550	2100	VENTILATER WASHROOM
9	G	2500X50000	-	900	STAIRCASE
10	G1	1500 X 50000	-	900	STAIRCASE
11	G2	1000X50000	-	900	LIFT LOBBY

N

DRAWING TITLE-

NOTE: ALL DIMENSIONS ARE IN MM

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1220109002
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BBDU, LUCKNOW

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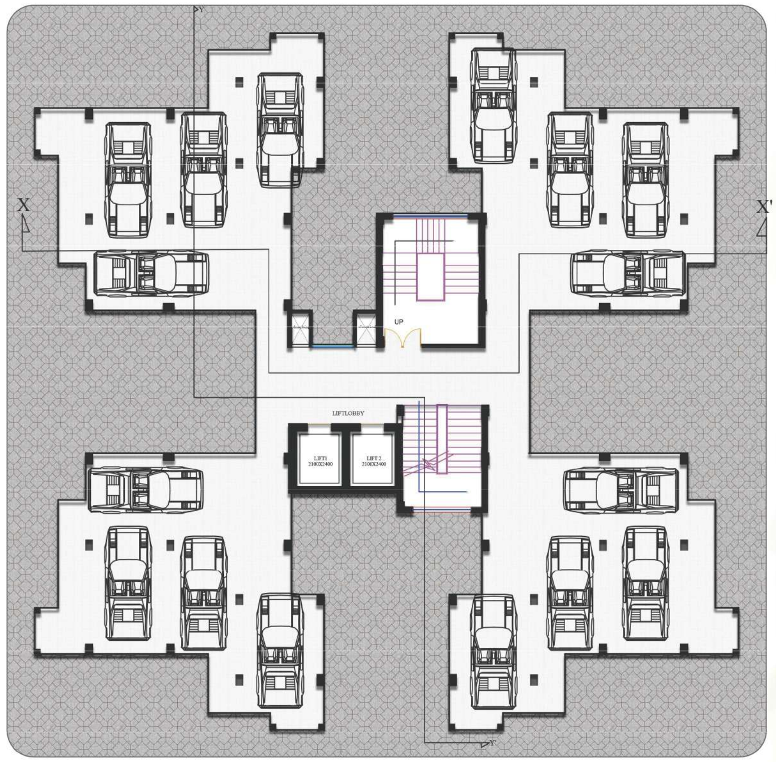
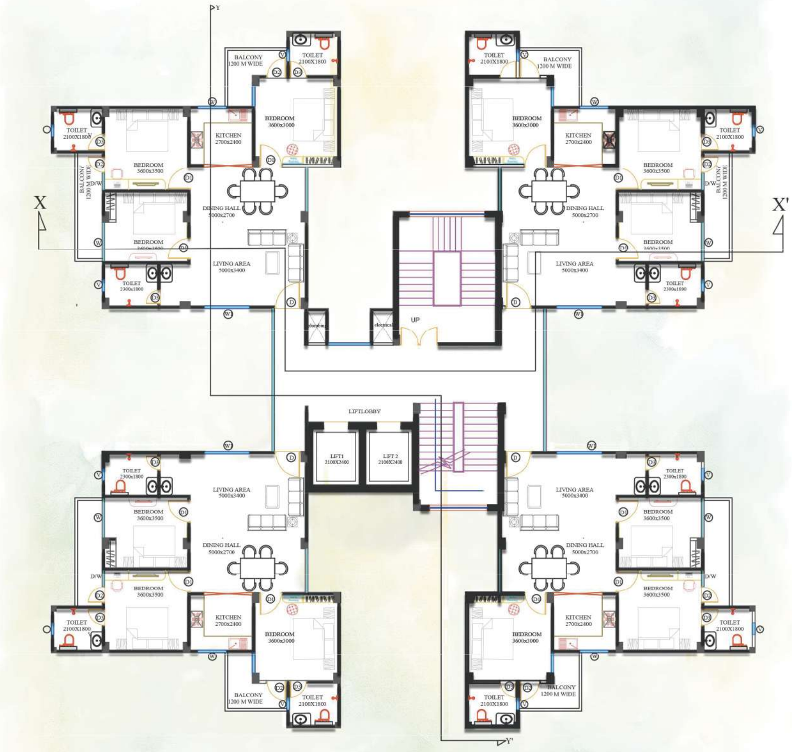
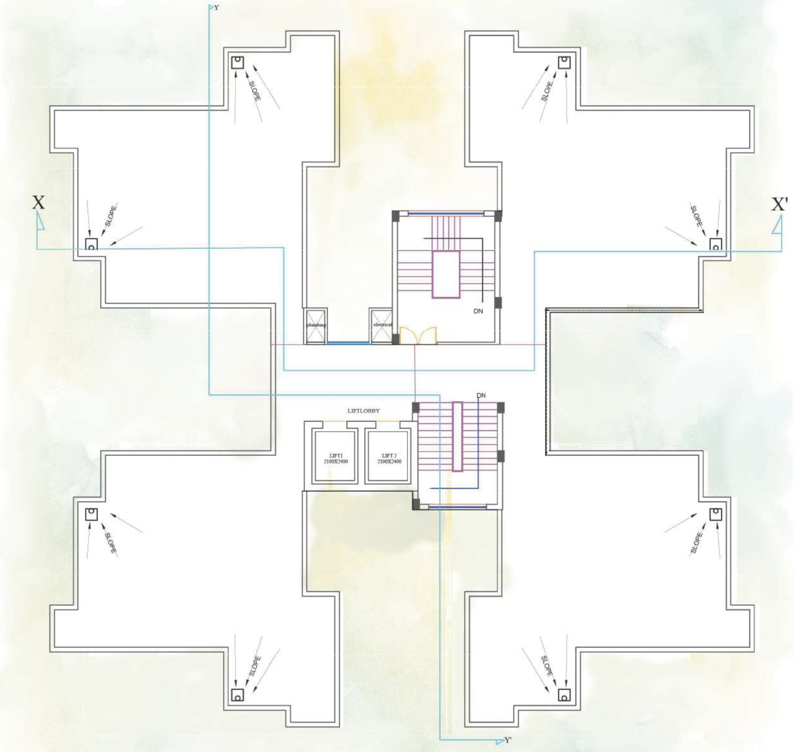
1	D	1200X2100	2100	-	MAIN ENTRY
2	D1	1050X2100	2100	-	BED ROOM
3	D2	900X2100	2100	-	BALCONY
4	D3	750X2100	2100	-	TOILET DOOR
5	DW	1470X2100	2100	900	BED ROOM
6	W	1800X1250	2100	900	LIVING HALL ,
7	WK	1500X1250	2100	900	KITCHNE
8	V	600X600	2550	2100	VENTILATER
9	G	2500X50000	-	900	STAIRCASE
10	G1	1500 X 50000	-	900	STAIRCASE
11	G2	1000X50000	-	900	LIFT LOBBY



STILT FLOOR PLAN

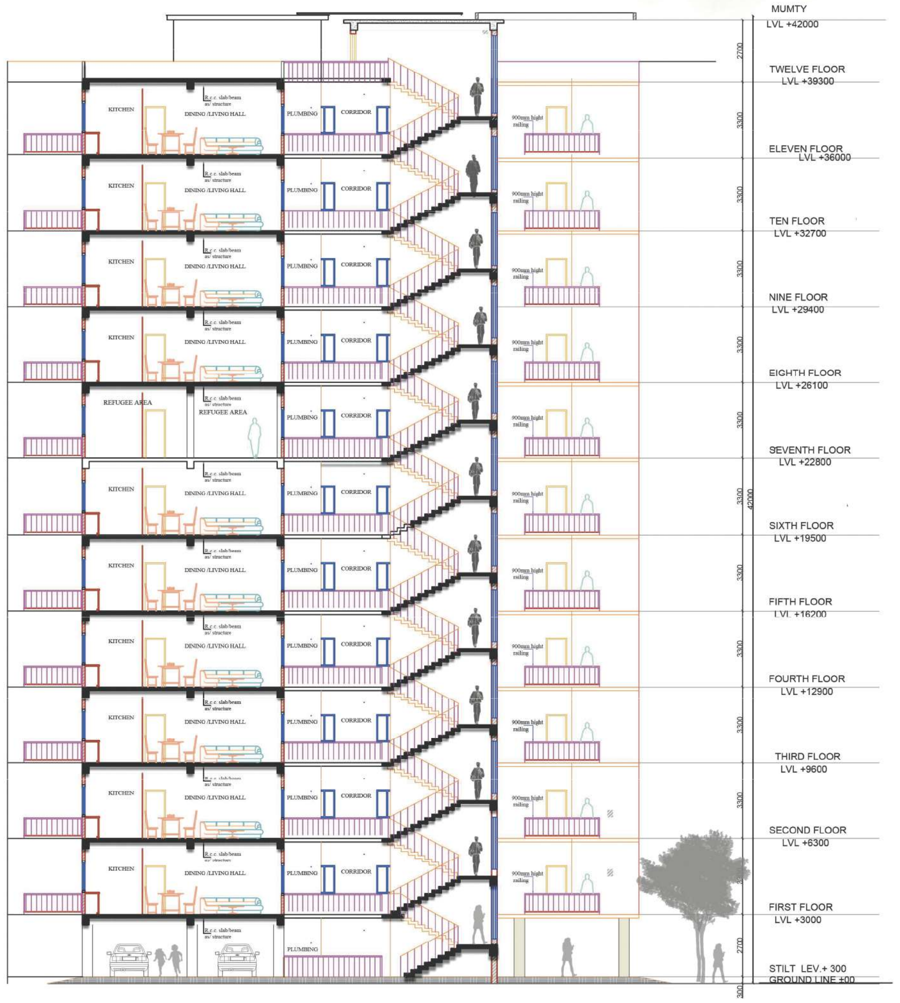


FIRST TO ELEVEN FLOOR
TYPICAL FLOOR PLAN

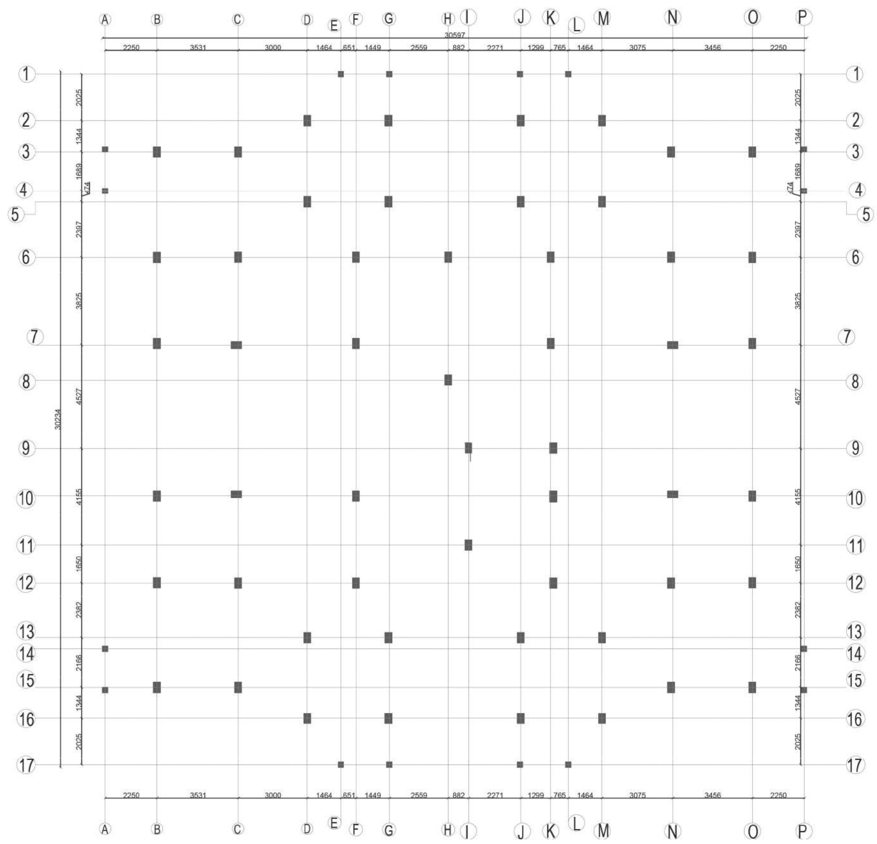


TERRACE FLOOR

SECTION -XX'



SECTION -YY'



COLUMN LAYOUT PLAN

DRAWING TITLE-

NOTE: ALL DIMENSIONS ARE IN MM

SCALE - 1:100

SHEET NO.- 0

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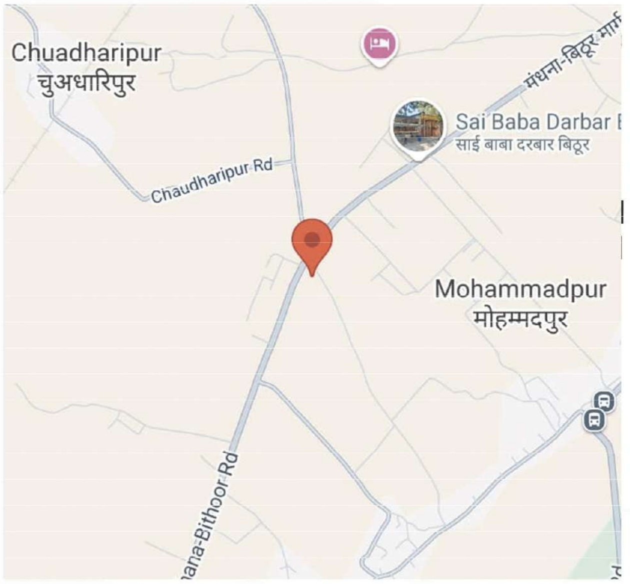
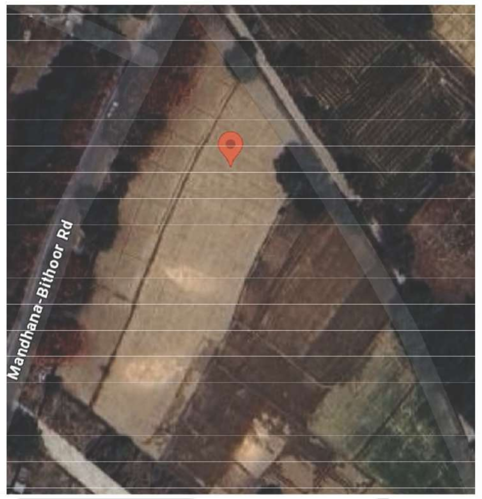
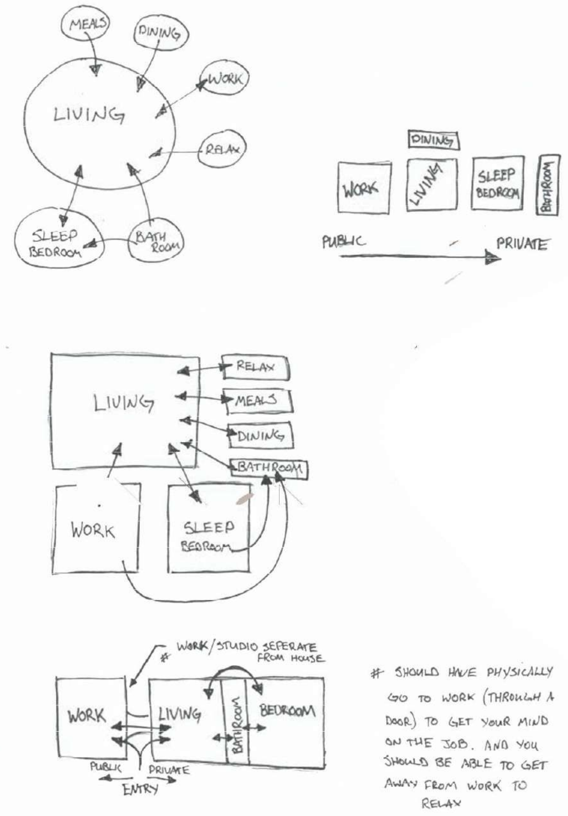
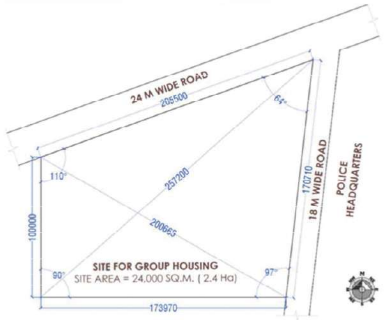
CONCEPT

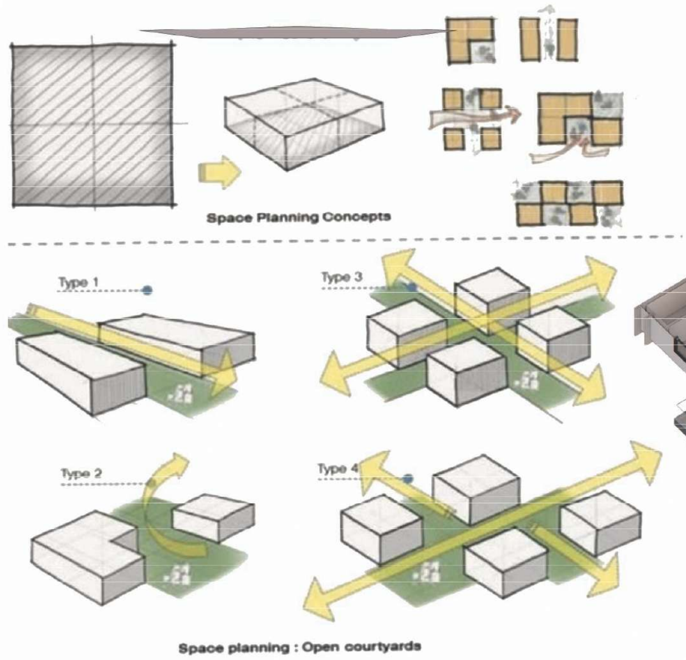


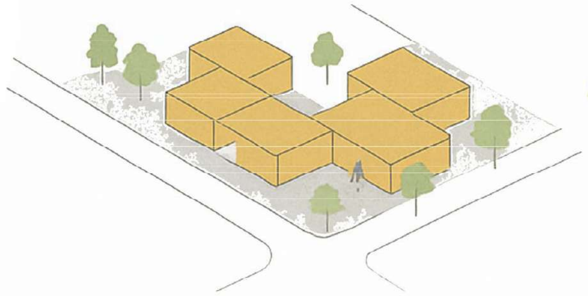


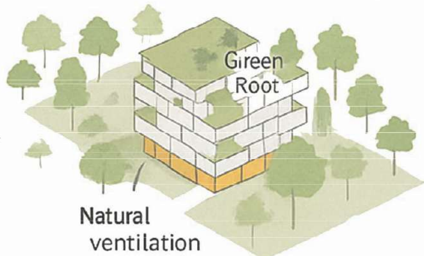


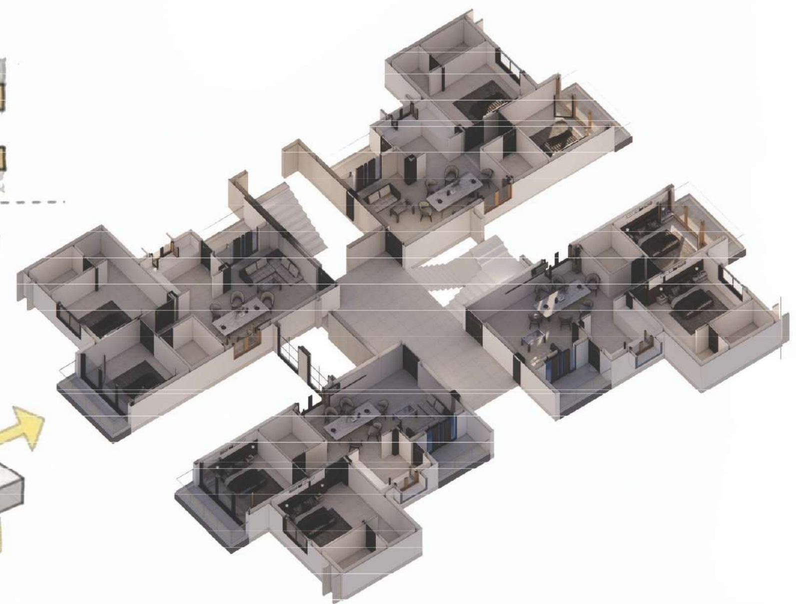
TOTAL SITE AREA 24000sq.m (2.4 hectare)				
S.NO	BY- LAWS	PERMISSIBLE	ACHIVED	UNIT
1	GROUND COVERAGE (40%)	9600	3185	sq.m
2	FAR (1.5)	36000	34000	sq.m
3	UNIT DENSITY	150units /hectare	150units /hectare	--
4	BUILT UP AREA 2BHK	80 sq.m	79 sq.m	sq.m
5	SUPER BUILT UP AREA	96 Sq.m	95 Sq.m	sq.m
6	BUILT UP AREA 3BHK	100 sq.m	99.5 Sq.m	sq.m
7	SUPER BUILT UP AREA	120 sq.m	119.5 sq.m	sq.m
8	AREA FOR COMMON FACILITIES (10%)	3600sq.m	3000sq.m	sq.m
9	AREA FOR SERVICES(5%)	1800sq.m	1000sq.m	sq.m
10	REMAINING AREA FOR (8+9)HOUSING	30600sq.m	29585sq.m	sq.m
11	TOTAL NUMBER OF UNITS	299 UNITS	296 UNITS	UNITS
12	BUILDING HEIGHT	50 MT.	49.2 MT.	
13	PARKING	300 NO	265 NO	ECS
14	PLANTATION	50 NO/ hectare	48 NO/ hectare	
15	SHOPS	6 NO.	4 NO.	











DRAWING TITLE-	NOTE: ALL DIMENSIONS ARE IN MM	PROJECT NAME-		SUBMITTED BY-	
	SCALE - 1:100		NET-ZERO URBAN HOUSING: A PROTOTYPE FOR SUSTAINABLE LOW-INCOME COMMUNITIES.	GUIDED BY-	AR. ROMIL SINGH M.ARCH IV SEM. 1220109002 2024-25 BBDU, LUCKNOW
	SHEET NO.- 0			PROF.(AR.) SAURABH SAXENA	

3D VIEW

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