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MILANO 1863

MASTER'S DEGREE THESIS

SCHOOL OF ARCHITECTURE URBAN PLANNING AND CONSTRUCTION ENGINEERING

Master of Science in Building and Architectural Engineering

Hope Horizon Academy

Primary school and kindergarten for orphans in Tanzania, Moshi

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AY 2022/2023

Acknowledges

We wish to express our sincere gratitude to our supervisor, Professor Manuela Grecchi, whose unwavering guidance, and steadfast commitment at every stage of this endeavor were indispensable. Her support was instrumental in the successful completion of this project.

We'd also like to extend our thanks to Professor Paolo Martinelli and Professor Graziano Salvalai for their valuable technical support throughout the project. Their constructive feedback challenged us to broaden our perspectives and elevated the quality of our work.

We express our heartfelt gratitude to our Family and Friends for their unwavering emotional support, which has made our journey smoother, transcending borders.

As a team, we want to recognize each other for our fantastic collaboration, outstanding cooperation, and effective communication skills. We also extend our appreciation to Politecnico di Milano for providing us with this incredible opportunity to begin, learn, evolve, and achieve.

From
Faranak
Sara

Abstract

“Hope Horizon Academy” is a comprehensive project set in the rural area of Moshi, Tanzania. Initially conceived as a kindergarten, our research and local surveys have revealed a critical need for a primary school to cater to the region's orphaned children. The availability of adjacent vacant land provided the opportunity to expand the project's scope, leading to the design of a primary school.

The primary objective of this project is to create a sustainable and adaptable space suitable for Moshi's hot climate. Beyond serving as a school, the design aims to accommodate diverse activities, addressing evolving needs over time. This proposal introduces innovative modern technologies while integrating local design principles to enrich the physical and mental well-being of both orphans and the local community.

By harmonizing innovative design with local context, our goal is to provide a high-quality space that not only supports educational needs but also contributes to the holistic development of the area, reflecting the vision of Hope Horizon Academy.

Contents

CHAPTER1: PROJECT BACKGROUND

1.1. INTRODUCTION

The topic based on a competition which is an orphanage school in Tanzania. It is a special academy designed to provide education and support for children who have lost their parents or have been abandoned. It is located in a rural area and serves children between the ages of 2 to 6 years as a kindergarten and 6 to 13 for primary school. The school provides basic education in reading, writing, and arithmetic, as well as vocational training in skills such as carpentry, sewing, and agriculture.

The school also provides basic health services such as immunizations, first aid, and health education. In addition, the children receive counselling and emotional support to help them deal with the trauma of losing their parents.

The curriculum is designed to meet the specific needs of the children, and extracurricular activities such as sports and arts are also provided to promote physical and emotional wellbeing.

The main aim of this project is to create a sustainable space where kids can start their educational journey feeling like at home; A space to learn, discover, and play.

1.2. PROBLEM STATEMENT

The education system in Tanzania faces various challenges that affect the quality of education provided in schools. Some of the key problems include:

Lack of adequate infrastructure: Many schools in Tanzania lack adequate infrastructure such as classrooms, libraries, laboratories, and other learning resources. This limits the quality of education that can be provided to students.

Shortage of qualified teachers: Tanzania faces a shortage of qualified teachers, especially in rural areas. This means that many schools have to rely on untrained or underqualified teachers to educate students.

Poverty: Poverty is a major challenge in Tanzania, and it affects access to education. Many families cannot afford to pay school fees or provide basic needs such as uniforms and textbooks for their children.

Gender disparities: Girls in Tanzania are more likely to drop out of school than boys, and they are less likely to attend school in the first place. This is due to cultural beliefs, early marriage, and other factors.

Quality of education: The quality of education in Tanzania is often low, and this is reflected in the poor performance of students in national exams. The curriculum is outdated and does not always meet the needs of students or prepare them for the job market.

Improving the quality of education in Tanzania requires addressing these challenges and investing in education infrastructure, teacher training, and curriculum reform.

Strength

- Growing demand for education due to the population.
- Rau is close to Moshi town and has good road connectivity to neighboring towns and cities.
- land availability for school expansion and building.
- Tanzania has a politically and economically stable environment that encourages education investment.

Weakness

- limited access to financing and resources for school construction and maintenance.
- Lack of infrastructure and resources which might impact how well school's function.
- competition from already-established, well-regarded schools in the area.

Opportunity

- Possible collaborations with regional or global organizations to aid in the growth of schools.
- Possibility of government incentives or support for education initiatives.
- Tanzania is seeing rising demand for high-quality education, opening up opportunities for new schools to fill this gap.

Threat

- Financial instability in Tanzania that might influence the capacity of families to bear school expenses.
- Limited availability of qualified teachers in the region.
- Changes in government policies or rules that may affect the function of schools

1.3. SITE SELECTION CRITERIA

When selecting a site for a school in Moshi, Tanzania, several factors should be considered, including:

Accessibility: The site should be easily accessible to students and staff and should be located close to major roads or public transportation. Both workers and students will find it simpler to get to work because of this.

Safety and security: The site should be safe and secure, with adequate security measures in place to protect students, staff, and school property. This includes safeguards like fence, security personnel, and surveillance equipment.

Size and topography: The land needs to be big enough to fit the classrooms and accommodate the school buildings, playgrounds, and other facilities. The topography should also be suitable for construction.

Proximity to community resources: The site should be located close to community resources such as medical facilities, libraries, and recreational areas. This will provide students with access to important services and opportunities outside of school.

Availability of utilities: The location should have easy access to dependable services such as electricity, water, and sanitation. This will ensure that the school can operate effectively and provide a safe and healthy environment for students and staff.

Environmental considerations: The site should be located in an area that is free from environmental hazards such as pollution, flooding, or erosion. Additionally, the location of the site should be suitable to learning with little interruptions or distractions.

Overall, selecting a site for a school in Moshi requires careful consideration of these factors to ensure that the school can provide a safe, accessible, and effective learning environment for students and staff.

1.4.AT THE FOOT OF KELIMANJARO

Moshi is a friendly city in the north of Tanzania. It is the capital of the Kilimanjaro region and is situated at the base of Mount Kilimanjaro, the highest peak in Africa. Moshi is located approximately 200 kilometers (124 miles) east of Arusha. Between beautiful expansive coffee plantations, with an attractive mix of African and Asian influences, where the skyline of the Kilimanjaro dominates.

Location: Rau village, Uru Kusini Moshi district, Kilimanjaro Region of Tanzania
Area: 800 sqm in rectangular shape of 20 m x 40 m plus 55mx70m approximately

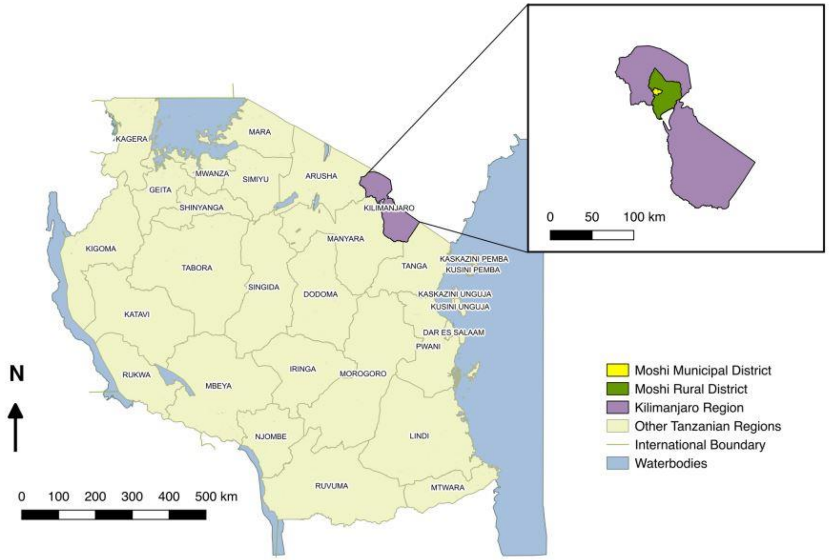


Fig 1. Map of Tanzania showing the administrative regions of Tanzania (main map) and the location of the Moshi Municipal and Moshi Rural Districts within the Kilimanjaro Region (inset). Maps were made using Quantum Geographic Information System (QGIS) open access software [19]. Shapefiles were obtained from Tanzania National Bureau of Statistics [20].

1.5. CULTURE

The culture in Kilimanjaro, Tanzania, is rich and diverse, with a strong emphasis on tradition, music, dance, and craftsmanship.

- Two-thirds of the population are dependent on agriculture for their survival.
- High level of education.
- It has a strong colonial background which is reflected in architecture.
- Coffee and corn producing center.
- Traditional Clothing: consists of a colorful kanga (a wraparound cloth), a kanzu (a long, flowing robe), and a kofia (a small cap).
- Music and Dance: Traditional music and dance are an integral part of the Chagga culture.
- Religion: The Chagga people are predominantly Christian, but they also practice traditional beliefs that involve ancestor
- Art and Craft: Many artisans in Kilimanjaro produce handmade crafts such as wooden sculptures, beaded jewelry, and woven baskets, which are sold in local markets.

1.6. POPULATION

According to the last Tanzania Population and Housing Census, the population of Moshi Rural District, which includes Rau village, was approximately 466,737, and the percentage of children under the age of 18 was 47.1%.

In Rau, the population refer to 2012 information is 9,137 ,3.817 km^2 area and 2,394/km^2 population density.

In the United Republic of Tanzania (hereinafter referred to as Tanzania), educational development has been promoted since independence in 1961. In particular, a school attendance rate of 98% was achieved for primary education in 1981. However, due to the economic slump, the downgrading of the public financial situation has affected the educational sector, and very severe educational situations such as inadequate educational facilities, shortages of teachers with adequate certification, limited budgetary funds, have continued until now. The overcrowding of classrooms is especially serious. The average number of pupils per classroom is approximately 73 at the primary schools in Tanzania. Thus, it is extremely difficult to conduct proper education. In particular, in Dar es Salaam, due to dramatic increase of population, the average number of pupils per classroom is 114 which is approximately 1.5 times the national average. The necessity of increasing the number of classrooms is urgent. In addition, due to the deterioration of educational facilities, about 70% of existing classrooms need to be repaired. The rebuilding of classrooms is indispensable for improving the educational environment.

1.7. EDUCATION

Tanzania's educational system is overseen by the Ministry of Education, Science and Technology. The system consists of three levels: Primary education, Secondary education, and Tertiary education.

Primary Education:

Primary education in Tanzania is compulsory and is for children between the ages of 6 and 14. It consists of seven years of schooling, with students receiving instruction in subjects such as mathematics, science, social studies, and English.

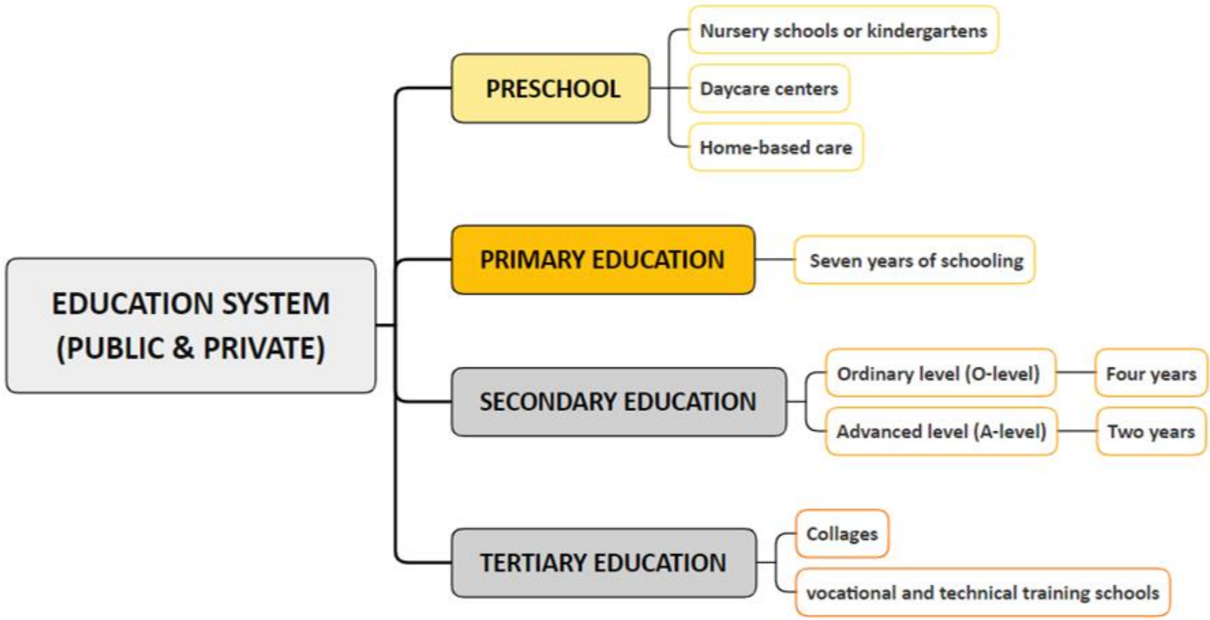
Secondary Education:

Secondary education in Tanzania is divided into two levels: Ordinary level (O-level) and Advanced level (A-level). O-level education is for four years, and A-level education is for two years. Students typically take the Certificate of Secondary Education Examination (CSEE) after O-level education and the Advanced Certificate of Secondary Education Examination (ACSEE) after A-level education.

Tertiary Education:

Tanzania has several universities and colleges that offer tertiary education. There are both public and private universities and colleges, with the University of Dar es Salaam being the oldest and largest university in the country. In addition to universities, there are also vocational and technical training schools, which provide training in areas such as mechanics, carpentry, and electronics.

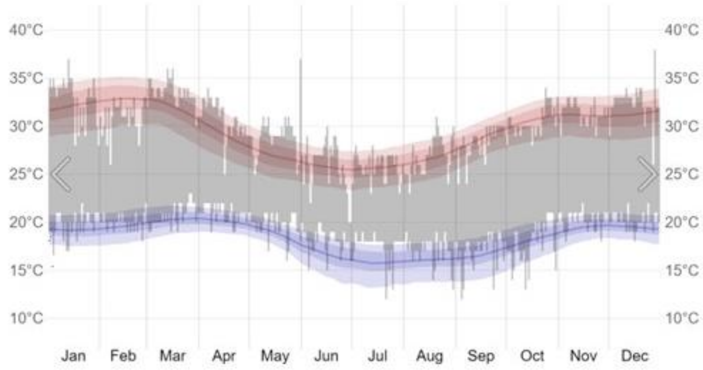
Kindergarten education in Tanzania is part of the country's formal education system and is offered to children between the ages of 2 to 6 years old. The curriculum for kindergarten education in Tanzania includes activities such as play, storytelling, singing, drawing, and other creative activities.
Many schools combine kindergarten and primary education, which can adversely affect the quality of learning for kindergarten children. As a solution, we propose separating kindergarten education from primary school.



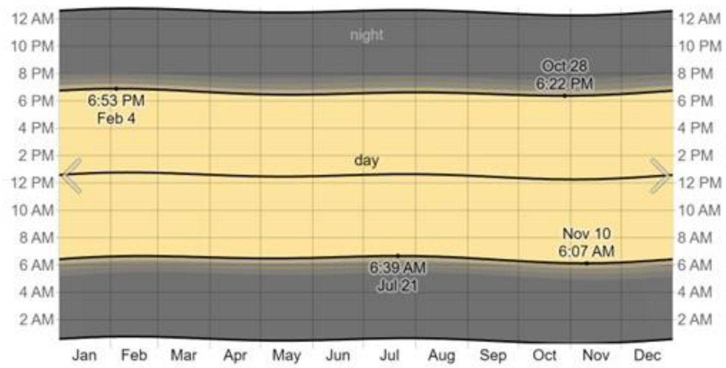
The educational system in Tanzania has made significant progress in recent years, with increased enrollment rates and improvements in infrastructure and resources. However, there are still challenges to be addressed, such as inadequate funding, shortage of qualified teachers, and the need to improve the quality of education.

1.8. CLIMATE

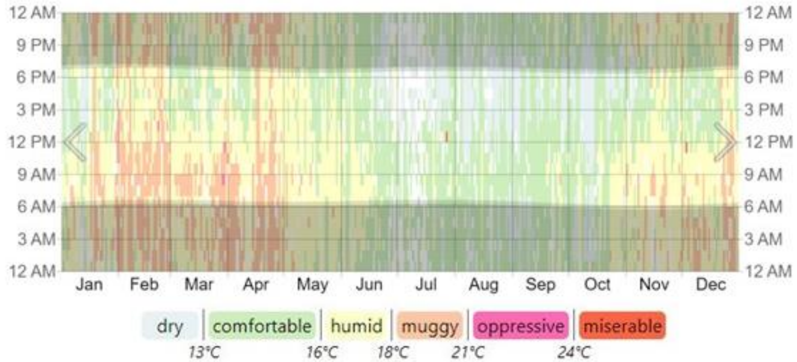
The climate in Rau, Moshi, is a mountain area with an altitude of 830 m and classified as a subtropical highland climate. Rau experiences relatively mild and moderate temperatures throughout the year. Annual temperature max is 30-35° and min 15-20°. The average annual temperature in Moshi is 23.4 degrees °C. Rau has two primary seasons - the dry season and the wet season. The short rain season: November-December and long rain season: March-May. The prevailing winds, influenced by the trade winds, are from the southeast. North-facing slopes receive far less rainfall. January to March are the warmest months. The daily humidity is 50-60% with 750-1500 mm/y rainfall.



Temperature



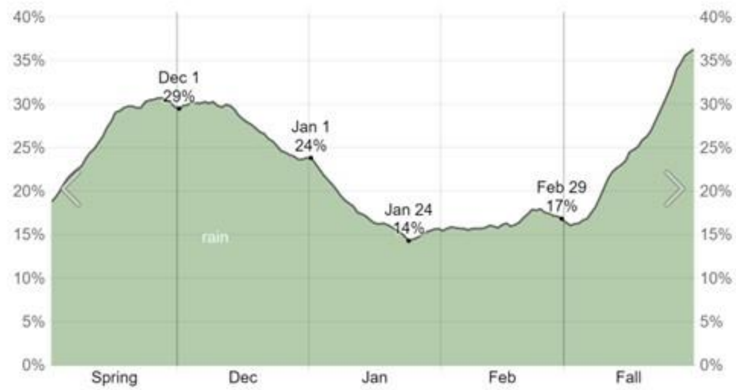
Sunrise & Sunset



Humidity Comfort Levels

Hours of Daylight

Probability of Precipitation in the Fall



Probability of Precipitation in the Summer

1.9. FOOD PRODUCTION

Tanzania has a considerable variation in farming systems due to the large variation in climatic and agro-ecological conditions. The primary crops grown in the Moshi district include coffee, bananas, maize, beans, and various vegetables such as tomatoes, onions, and peppers. Coffee production is a particularly important industry in the area.

Strategy: The school could partner with local farmers to establish a school garden or host educational events that highlight the importance of sustainable agriculture practices. It is possible to create a more sustainable, environmentally conscious learning environment that promotes a deeper appreciation and understanding of the local food system.

1.10. BIODIVERSITY

The Moshi is known for its rich biodiversity. The Moshi district is home to several national parks and protected areas, including Kilimanjaro National Park, which is a UNESCO World Heritage Site and Arusha National Park. This park is home to a variety of species, including elephants, buffalo, leopards, and several species of primates, such as the black and white colobus monkey and the blue monkey.

The Moshi district also has a diverse plant life, including several species of orchids and other rare and endemic species. The district's unique ecosystem is heavily influenced by the altitude, temperature, and rainfall patterns, which create a range of habitats for a variety of flora and fauna.

Strategy: Minimize any negative impacts on the environment. Integrate outdoor learning spaces into the school's design to provide students with opportunities to connect with nature and learn about the local biodiversity. For example, a school garden.

Wild Date Palm (Phoenix reclinata)

Phoenix reclinata can reach up to 12 m but is most often between 3 and 6 m. The flowers appear during August, September and October. The orange-brown fruits are borne during February, March and April. They are oval in shape and smaller than the commercial date.

Lighting	Water	Transplant spacing
Full sun	Every 1-2weeks	4-6 m

Acacia

The acacia tree grows in various places across the African continent. The average height is around 12 m . They are a vital part of Tanzania's ecosystem, and that is why so many of them exist in this country.

Lighting	Water	Transplant spacing
Full sun	Every 1-2weeks	Max 9m

1.11. WATER AND WASTE MANAGEMENT

Currently, water supply in Moshi district is mainly from surface water sources, such as rivers and streams, and groundwater sources. The district has two main water supply systems, namely the Moshi Urban Water Supply and Sanitation Authority (MUWSA) and the Kilimanjaro Water and Sewerage Authority (KIWASA).

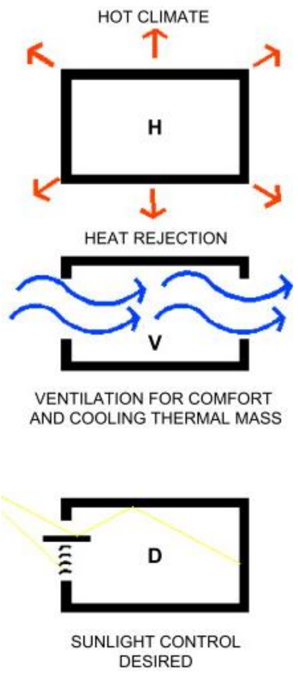
Strategy: Rainwater harvesting, Water-efficient fixtures, Greywater reuse, Water conservation education, Water-efficient landscaping

- Schools can have **separate bins** for each type of waste and educate students on the importance of proper waste segregation.
- **Composting**: Schools can incorporate composting into their design by providing compost bins and a designated area for composting. Composting can help reduce the amount of organic waste in landfills and provide a natural fertilizer for school gardens.

1.12. ENERGY PRODUCTION

Tanzania has a high and mostly untapped potential for renewable energy sources. The only resource significantly in use is hydropower at a large scale. Additionally, small hydropower has good potential and is particularly feasible in rural areas. Solar energy is abundant with initial efforts being undertaken to exploit this resource through both off-grid and grid-connected solutions. In Tanzania, 15.3% of the population have access to electricity; in rural areas this goes as low as 2-3%. In fact, Tanzania is in the lowest 10 countries globally for population access to electricity. The main energy users in Tanzania is the residential sector.

Strategy: Using active and passive strategies to reduce consumption and produce more energy. active strategies like 1. Solar Power Systems 2. Solar Water Pumping Systems 3. Solar Water Heating Systems. Passive strategies like orientation of the building, ventilation, and shading.



Electricity production	GWh
Coal	0
Oil	1381
Gas	2764
Biofuels (solid biofuels)	21
Waste	0
Nuclear	0
Hydro	2108
Geothermal	0
Solar PV	21
Solar thermal	0
Wind	0
Tide	0
Other sources	0
Electricity production	6295

Source IEA Statistics 2015

Final Electricity Consumption	GWh
Industry	1362
Transport	0
Residential	2372
Commercial and Public Services	1181
Agriculture/Forestry	178
Fishing	0
Other non-specified	156
Finale Electricity Consumption	5249

Source IEA Statistics 2015

1.13. TYPOLOGY AND MATERIAL

In rural areas, people are living in mud houses under primitive conditions. The vast majority of the houses are squared but there are still circular ones as well. Some houses are made of stone or burned bricks. As for construction materials, the choice depends on factors such as availability, affordability, and climate. Some common materials used in Moshi. It's important to note that the specific materials and typologies used in construction can vary depending on the architectural design, budget constraints, and local preferences.

Here are some typologies and materials commonly found in Moshi:

Residential Buildings, offices: Buildings designed for businesses and administrative purposes, retail stores, hotels and accommodation facilities, restaurants: Dining establishments for food service, educational Institutions: schools and universities, religious Structures: mosques, churches, temples, public Infrastructure, hospitals, government buildings and transportation hubs:

Strategy: Trying to keep the typology of the building also using pitched roof and local material such as timber

Reasons to build with timber: timber protects the climate, timber is a renewable resource, timber is nowadays a high-tech material, timber brings diversity to the cities, timber is a light weight material with a high bearing capacity, timber doesn't produce any wastage, timber offers a pleasant indoor climate.

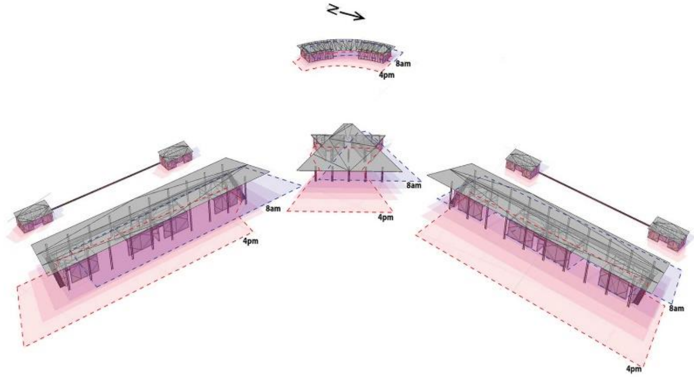
Material	Pros.	Cons.	Note	Picture
Pine	• Renewable resource • Cost-effective • Versatility • Lightweight	• Limited strength • Vulnerability to rot & decay	—	
Cypress	• Natural Resistance • Thermal Insulation • Durability • Aesthetic Appeal • Availability	• Density • Maintenance	Regular maintenance such as sealing and staining might still be necessary to ensure its longevity. Cypress wood has a lower density compared to some other hardwoods.	
Acacia	• Natural Hardness and Durability • Low Maintenance • Sustainability	• Brittleness • Staining and Finishing Challenges	In hot climates, where intense sunlight and temperature fluctuations can accelerate material deterioration, acacia's durability can contribute to the longevity of structures. The natural oils in acacia wood can make it challenging to stain or finish uniformly.	
Adobe Brick	• Reduce ecological footprint • Health benefits • Sound and thermal insulation • Better indoor quality • Does not require industrial processing. • It is not renewable, but it is a reusable material.	• Its vulnerability to extreme actions • Brittle behaviour • Low tensile strength and deterioration when exposed to moisture. • Seismic performance is poor.	Properties of adobe can be improved by mechanical compaction, chemical stabilisation with cement, lime and bitumen, and fibre inclusions such as straw.	
Bamboo	• Eco friendly • Sustainable • Durability • Cost effective • Aesthetically pleasing	• Fire risk	Bamboo is a highly flammable material, and schools in areas prone to wildfires may need to consider additional fire safety measures to ensure the safety of the building and occupants.	

CHAPTER2: ANALYSIS

2.1. CASE STUDY

2.1.1. CHIPAKATA CHILDREN'S ACADEMY

The Chipakata Children's Academy is a new primary school in Zambia, Africa designed by Frank Lupo, Randy Antonia Lott, Susan Rodriguez. It is the first initiative of the 14+ Foundation, a New York City-based non-profit organization established in 2012. The design for the new school has realized the Foundation's mission to develop, build and operate schools and orphanages in rural African communities. The site in Chipakata Village is approximately 100 kilometers east of Lusaka, Zambia's largest city. Referencing regional school planning typologies, the design of the classroom structure transforms the standard model to create a new paradigm. The design provides for ten teaching and learning spaces compared to the four rooms found in the typical prototype. This is achieved by breaking down the monolithic volume of the typical classroom bar building and introducing open space for collaborative activity between classrooms.



Conclusion and strategy:

- The project defines a sense of place and community for the Village.
- Open space for collaborative activity between classrooms.
- Agriculture fields dedicated to generate food in order to ensure long-term economic sustainability.
- Elevating the roof, upper level accessible by stairs.
- Window openings and roof canopy to maximize daylight.
- Clerestory windows with continuous roof to protect spaces from harsh solar gain.

2.1.2. CALLING ACADEMY SCHOOL

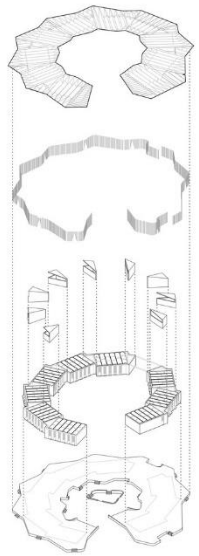
Calling Education is an NPO that was established out of identifying the need for affordable top-quality education as an imperative to South Africa's restoration designed by SALT Architects. Their first campus, rolling out their unique funding model, is Calling Academy Stellenbosch, which is located on a bucolic plot bordering the Polkadraai Road between Stellenbosch and Kuilsriver. The site was identified and set aside by the previous generation of surrounding landowners to serve the local farming community and consisted originally of six existing classrooms, a reception, and a sports field. Designing this campus is therefore an ongoing organic process aimed at maximizing the quality of the learning environment, connected to the natural beauty of the site, at the lowest possible cost, resonating with their priority of quality education over the cost of facilities.

Conclusion and strategy:

- Aim: Maximizing the quality of the learning environment with lowest possible cost
- Connected to natural beauty.
- Lowest possible cost
- Flexible functions under continues roof.

2.1.3. LYCEE SCHORGE SECONDARY SCHOOL

This school located in the third most populated city in Burkina Faso designed by Kere. The Lycée Schorge Secondary School will not only set a new standard for educational excellence in the region, it will also provide a source of inspiration by showcasing locally-sourced building materials in an innovative and modern way. The design for the school consists of 9 modules which accommodate a series of classrooms and administration rooms. One of these modules also houses a dental clinic which will provide a new source of dental care for the students. The material functions well as a wall system for the classrooms because of its thermal mass capabilities. This, in combination with the unique wind-catching towers and overhanging roofs, lowers the temperature of the interior spaces exponentially.

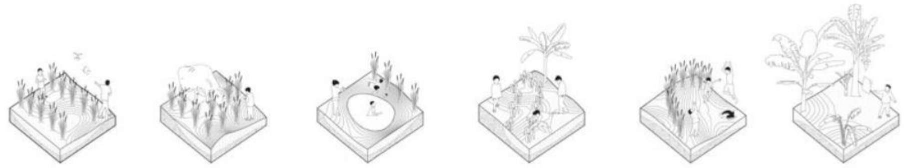


Conclusion and strategy:

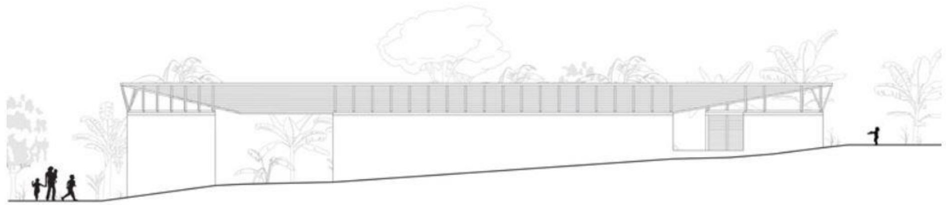
- The design for the school consists of modules.
- Locally sourced building materials in an innovative and modern way such as Laterite stone which can be shaped to bricks with Good thermal mass capabilities.
- For lowering the temperature: Unique wind-catching towers and overhanging roofs.
- Naturally ventilated and illuminated by massive undulating ceiling.

2.1.4. PLAY FOLLOWS FARM

designed as part of an international competition with the rural landscape of Tanzania's Moshi district to create a learning environment that embraces the surrounding nature and enriches early childhood development. T R radhakrishnan's proposal looks to Africa's traditional settlements, where self-sustaining communities are grounded to the land. embracing these values, the proposed school merges with surrounding farmlands to allow the actions of the farm to become activities of play. By doing so, the project anchors its value on the belief that the future lies in self-sustenance.



actions of the farm as play activities



Conclusion and strategy:

- Create a sustainable space.
- Allow the actions of the farm to become activities of play.
- Takes advantage of the open, unadulterated rural context
- The programs take the form of a boundary wall to create safe, inclusive, well lit, and ventilated spaces.
- Flexible classroom activities with louvered openings facing the farm/play area.
- The structure is conceived using interlocking compressed earth blocks along with local timber.

2.2. SITE ANALYSIS

2.2.1. ACCESSIBILITY

Rau is a suburb located in the city of Moshi, which is in the Kilimanjaro Region of Tanzania. The main roads in Rau are generally paved and in good condition. However, certain side streets and smaller roads might not be paved. Pavements are not always existent or in excellent shape. Some neighborhoods could have well-kept pavements, while others might not have any sidewalk or have pavements in poor condition.

In the case of public transports, there are a number of public transport options, including taxis, buses, and minibuses (often referred to as "daladalas" locally). However, the quality and safety of these options can vary widely, and some may not be accessible for individuals with disabilities.

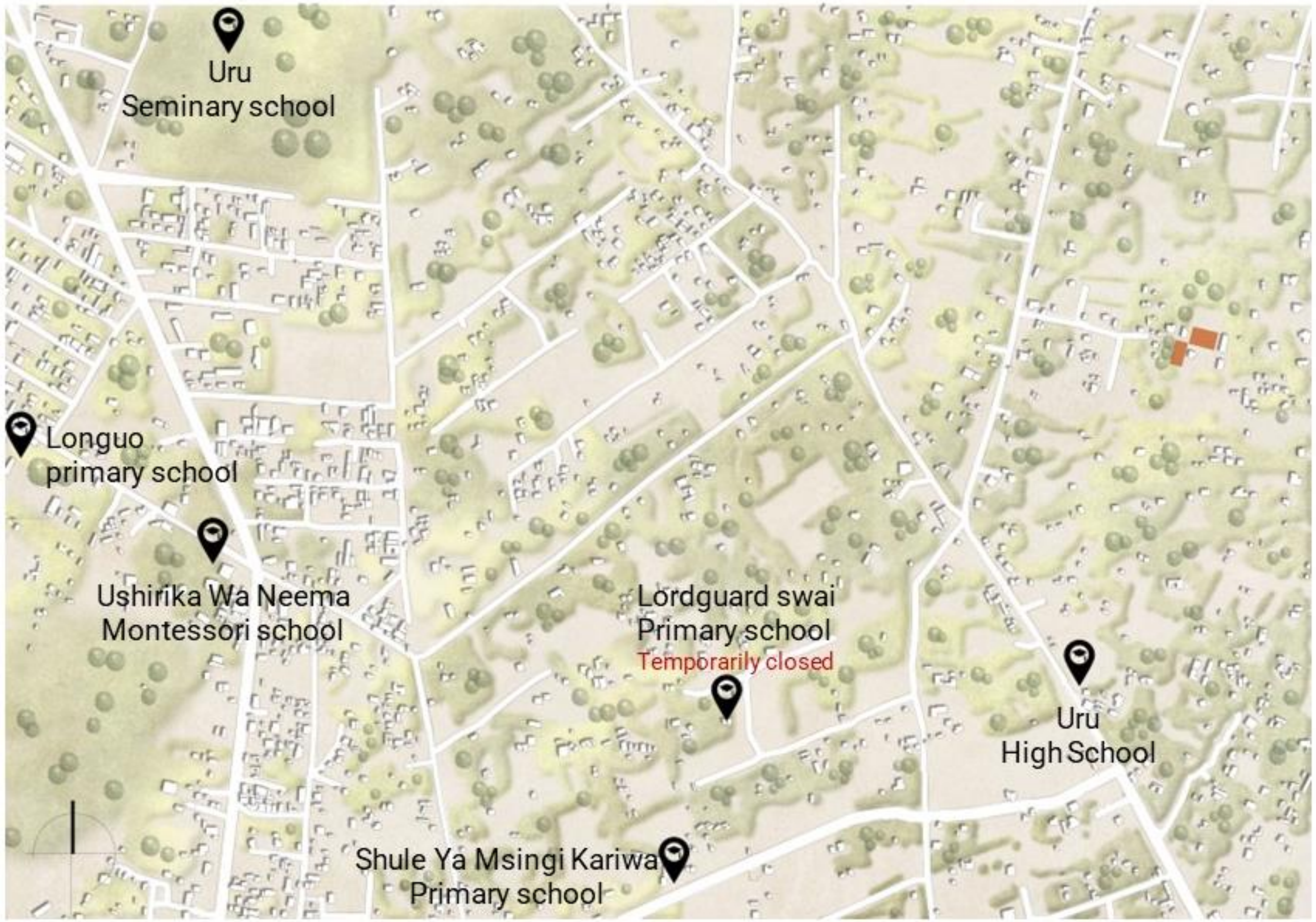
In our case there is only one bus station close to the main site which takes almost 5 and 30 minutes by car and walking respectively to reach.

2.2.2. TYPE OF USES

The Moshi suburb of Rau is active and diversified, with a variety of uses and activities. Rau is primarily a residential area, with many homes and apartment buildings. There are also educational institutions such as the Kilimanjaro Christian Medical University College, St. Joseph University in Tanzania, and the Tumaini University Makumira. It can be seen several healthcare facilities in Rau, including the KCMC Hospital, the largest referral hospital in northern Tanzania, and the Kilimanjaro Hospital. Business and commerce and religious places are other activities in this area.

Land use is about 48.7% of the total land area is arable, 21.3% is under game reserves,15.3% under grasslands, and rangelands, 12.4% under forest reserves and 2.3% under lakes, dams, and rivers. Actual land use is however highly influenced by three distinct agro-ecological zones based on altitude, soil, and climate.

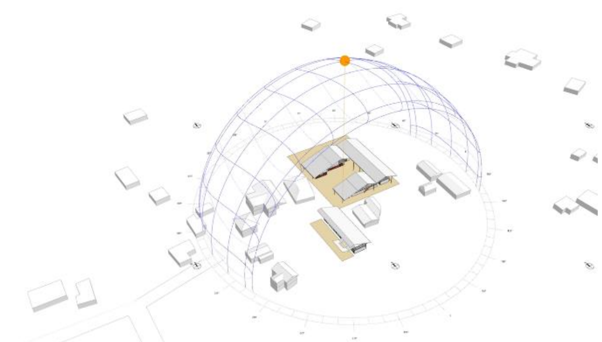
The main site is also surrounded by several schools but the need for school in the neighborhood is considerable.



2.3. CLIMATE ANALYSIS

2.3.1. SUN ORIENTATION AND WIND ROSE

Rau is located relatively close to the equator; it receives intense and constant sunshine all year round. The wind direction can vary, depending on the time of year and weather conditions.



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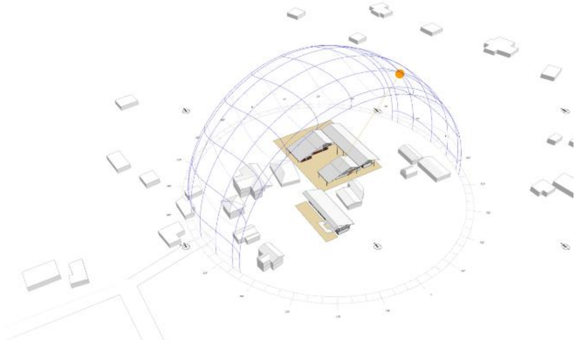

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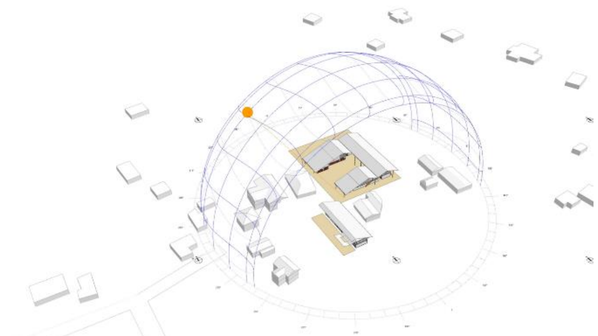

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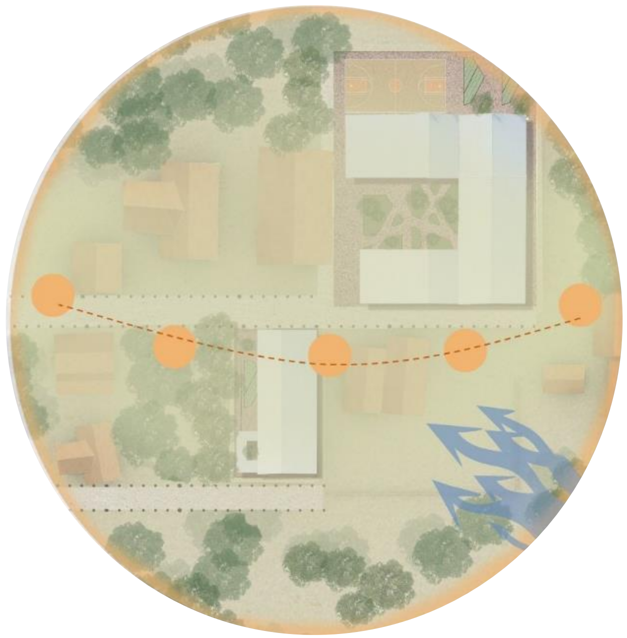
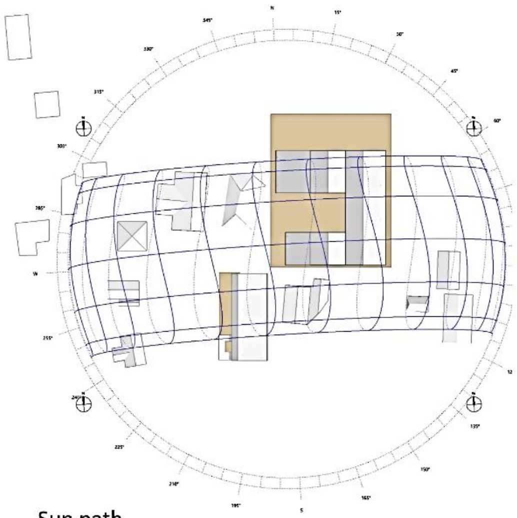
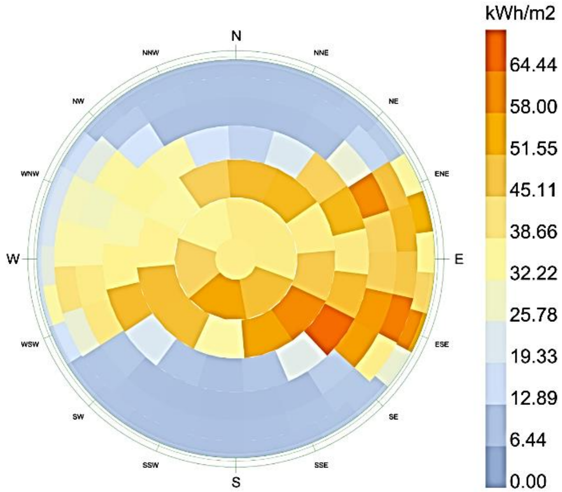
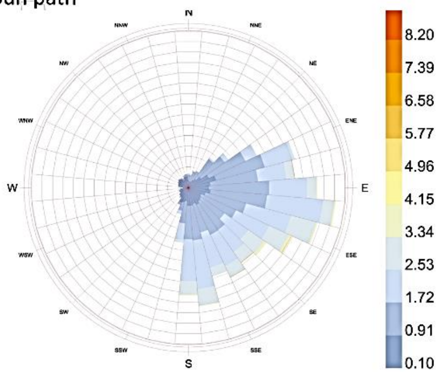




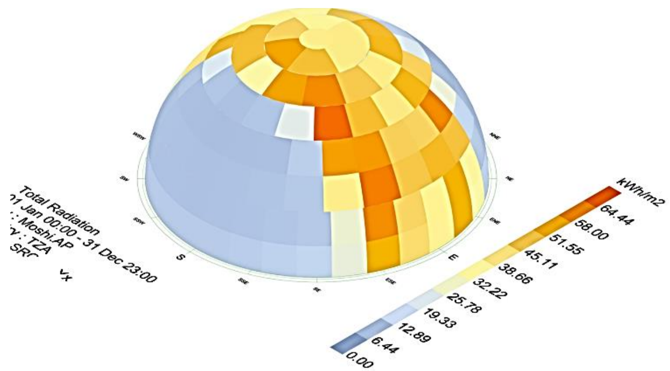
Sun path



Total Radiation
01 Jan 00:00 - 31 Dec 23:00
city : Moshi.AP
country : TZA
source : SRC-TMYx



Wind Speed (m/s)
city: Moshi.AP
country: TZA
source: SRC-TMYx
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 0.07% of the time = 6 hours.
Each closed polyline shows frequency of 0.6



21 Dec to 20 Mar

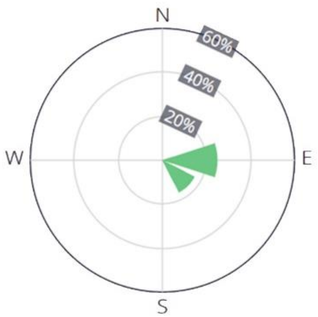
Summer - hot, light
Hot and dry to glorious

Avg min **20°C** | Avg max **33°C**

Typically calm
Often breezy, rarely strong winds

Very low precipitation
(35 mm over 9 days)

No snow



Calm 58% hrs

21 Mar to 20 Jun

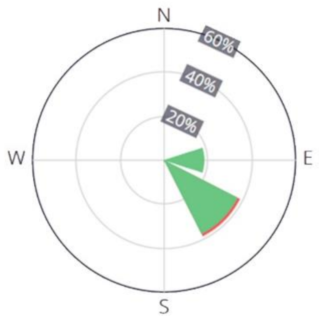
Autumn - warm
Glorious to changeable

Avg min **19°C** | Avg max **28°C**

Typically breezy
Often calm, rarely strong winds

Meaningful precipitation
(232 mm over 40 days)

No snow



Calm 42% hrs

21 Jun to 20 Sep

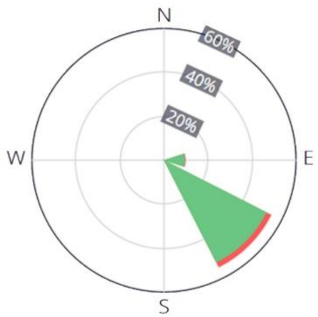
Winter - warm, dark
Glorious to overcast

Avg min **16°C** | Avg max **27°C**

Frequently breezy
Periodically calm, rarely strong winds

Very low precipitation
(43 mm over 13 days)

No snow



Calm 35% hrs

21 Sep to 20 Dec

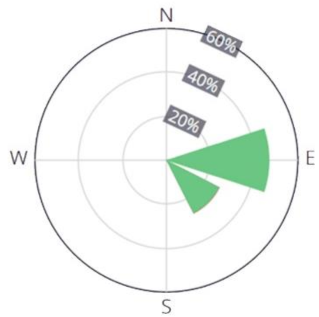
Spring - hot
Glorious to hot and dry

Avg min **19°C** | Avg max **31°C**

Usually breezy
Sometimes calm, rarely strong winds

Very low precipitation
(41 mm over 13 days)

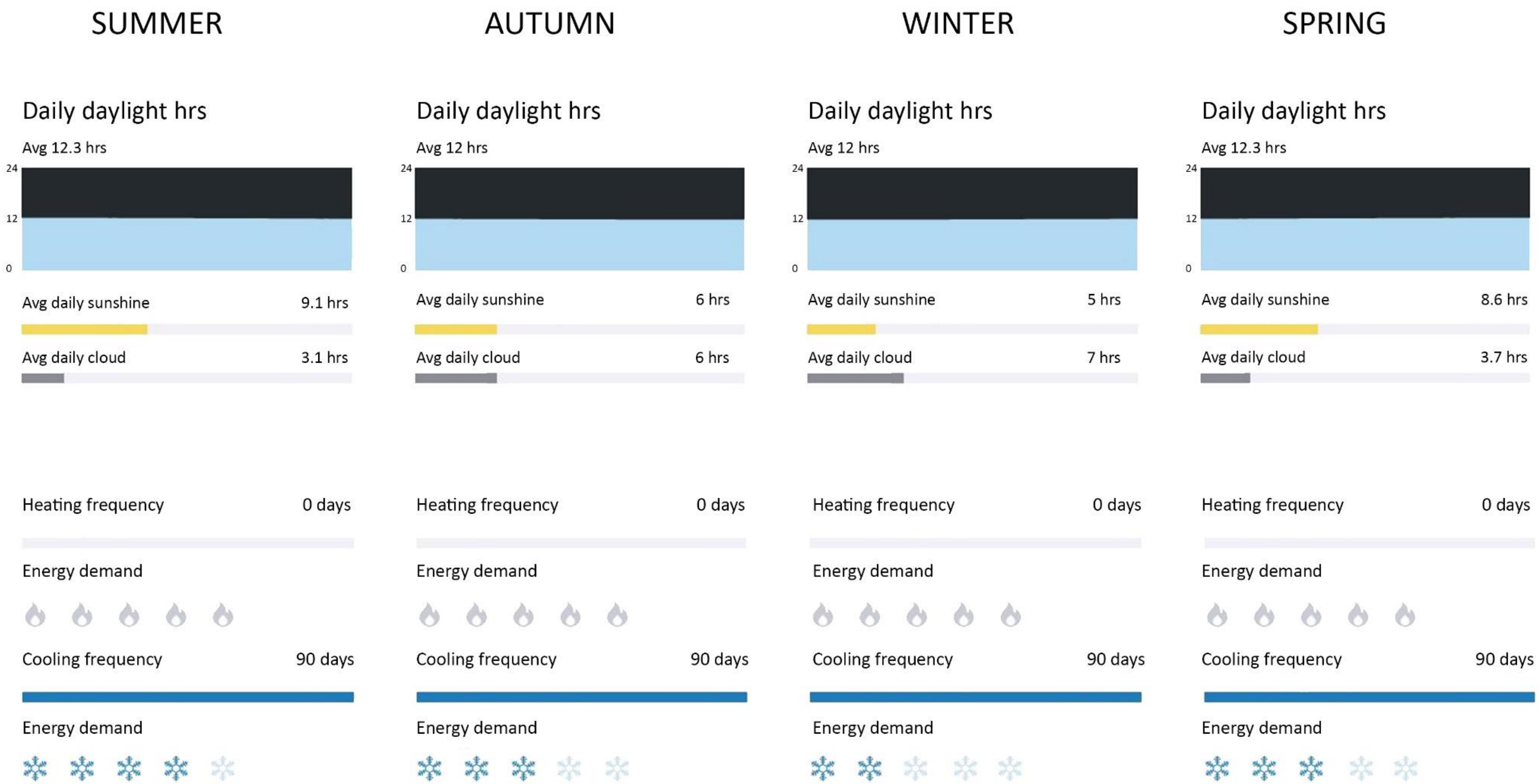
No snow



Calm 24% hrs

2.3.2. IMPACT OF DAYLIGHT & SUNSHINE ON LIKELY HEATING & COOLING NEED

The sun comes up at 6 in the morning and goes down at 6 in the evening. This means we have about 12 hours of bright daylight every day throughout the year. The sun shines differently at different times of the year. December to February usually has the most sun and heat. Because



of Rau's warm and humid climate, cooling is likely to be a more significant concern than heating. It has to be considered that the school hours are usually from 8:00 to 3 or 4 but to 12 on Fridays only.

2.3.3. IMPACT OF CLIMATE ON ARCHITECTURAL RESPONSE

The hot and humid climate with occasional rain in Rau affects the kind of buildings and architectural responses in the region. Building orientation, natural ventilation, suitable materials, roof design as pitched roof and large overhangs and passive cooling strategies are important factor which must be considered to create comfortable and sustainable indoor environments.

Frequency(Occupied hrs) 75%

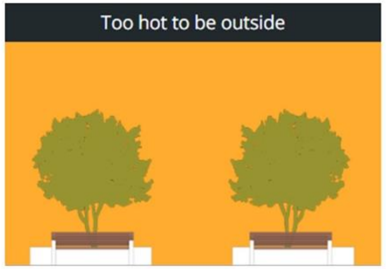
What its like:

-Pleasant or warm

-Breezy or calm, not windy

What most human want:

-To enjoy the weather



Frequency(Occupied hrs) 17%

What its like:

-Warm but windy

-Hot

What most human want:

-Protection from wind and sun

-To be cool

Frequency(Occupied hrs) 8%

What its like:

-Still but chilly

-Breezy and cool

What most human want:

-Shelter when needed

-Some connectivity with outside

Frequency(Occupied hrs) 0%

What its like:

-Breezy and chilly

-Still and cold

What most human want:

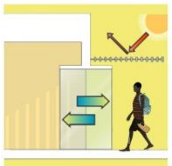
-Shelter from the wind

-Warm

Take the inside outside

- Large openings to connect inside with outside
- Shaded outside areas as alternative to inside space
- Larger glazing ratios
- Shading where needed

★★★



Provide shelter from heat

- Shaded glazing with solar control
- Limited unprotected glazing
- Efficient indoor cooling systems
- Shaded outdoor areas with fans and possibly misting

★☆☆

Bring the outside in

- Controlled openings for natural ventilation
- Sheltered outside spaces like courtyards & atriums
- Larger glazing ratios
- Shading as needed

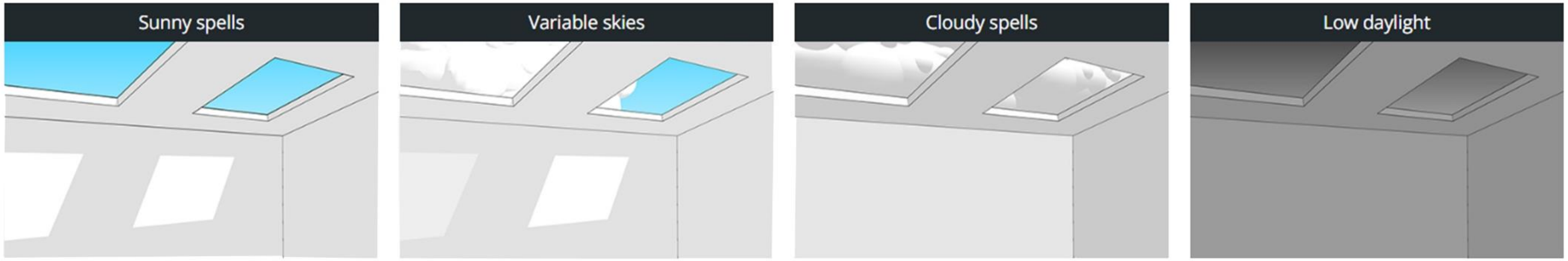
★☆☆

Provide shelter from the cold

- Well-insulated glazing and envelope
- Good control of infiltration
- Massings with limited articulation
- Efficient & comfortable heating systems

☆☆☆

2.3.4. IMPACT OF THE FREQUENCY OF SUN ON TOP LIGHTING STRATEGIES



Sunny spells

Frequency (Occupied hrs) 54%

At these times:

- 5% roof glazing may be enough for good light
- Bounce or diffuse direct sun to control glare and spread light evenly
- Expect warmer daylight colours

Variable skies

Frequency (Occupied hrs) 28%

At these times:

- 10% roof glazing may be needed for good light
- Bounce or diffuse direct sun to control glare and spread light evenly
- Operable systems may be less effective

Cloudy spells

Frequency (Occupied hrs) 18%

At these times:

- 20% roof glazing may be needed for good light
- Elements bouncing or diffusing light may reduce light as well
- Expect cooler daylight colours

Low daylight

Frequency (Occupied hrs) 0%

At these times:

- Other sources of light are needed for illumination
- Interior glazing will act like a mirror
- Privacy through glazing will be poor without blinds

This has not been used to inform the strategies below.

Different types of top lighting can be suitable for different types of spaces and applications. Factors like how much sunlight is needed, the orientation of the building and the local climate will help to decide which kind of top lighting works best. Refer to that we chose clerestory.

Baffle

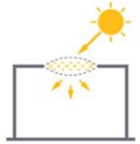
- Limits glare by diffusing overhead sun.
- Warmer daylight from diffused sunlight.
- Obstructed view of sky.
- Light levels change with time of day.

★★★

Cushions

- Limits glare by diffusing direct sun
- Warm light when sunny, cooler light when cloudy.
- Good view of the sky when cloudy.
- Good sense of time passing.

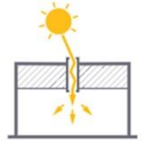
★★★



Light Pipe

- Limits glare by bouncing direct sun
- Warmer daylight from bounced sunlight.
- Virtually no view of sky.
- Light levels change gradually with time of day.

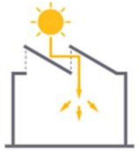
★★★



Sawtooth facing north

- Occasional glare from direct sun.
- Cooler daylight from northern sky.
- Great view of northern sky.
- Decent sense of time passing.

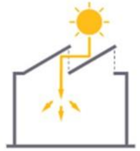
★★☆



Sawtooth facing south

- Occasional glare from direct sun.
- Cooler daylight from northern sky.
- Great view of southern sky.
- Decent sense of time passing.

★★☆



Clerestory

- Frequent direct sun may cause too much glare.
- Cooler daylight mixed with harsher direct sun.
- Great view of sky and clouds.
- Good sense of time passing.

★★☆

Reflector

- Frequent high angle sun may cause glare.
- Potentially warm light often dulled by cloud.
- Mostly obstructed view of sky.
- When sunny, reflected light shows time passing.

★☆☆

Sky Light

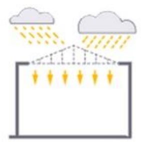
- Very hard to get diffusing material right.
- Very bright daylight.
- Heavily diffused view of the sky.
- Light levels change with time of day.

★☆☆

Roof Light

- High risk of glare from direct sun.
- Extremely bright sunlight very common.
- Excellent view of the sky and clouds.
- Enhances sense of time passing during cloudy spells.

★☆☆



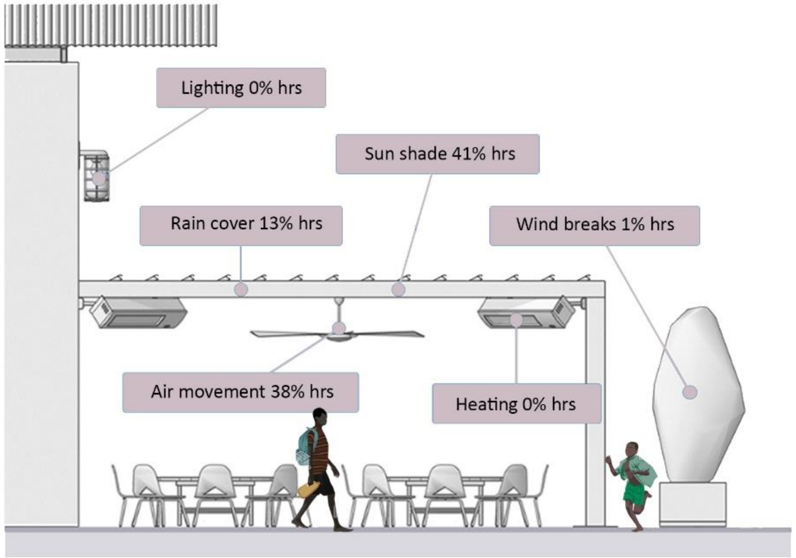
2.3.5. MAXIMIZING THE USABILITY OF AN OUTDOOR SPACE

By considering some factors such as shading, water features, plants, air movements and flexible design can create an outside space which is comfortable, inviting, and maximizes its usability.

How this strategy compares

Intervention combinations							Usability*
Selected interventions	✓	✓	✓	✓	✓	✓	100%
Best 5 interventions	✓		✓	✓	✓	✓	100%
Best 4 interventions	✓			✓	✓	✓	99%
Best 3 interventions	✓			✓	✓		98%
Best 2 interventions	✓				✓		86%
Best single intervention				✓			49%
No intervention							38%

Maximum intervention usability

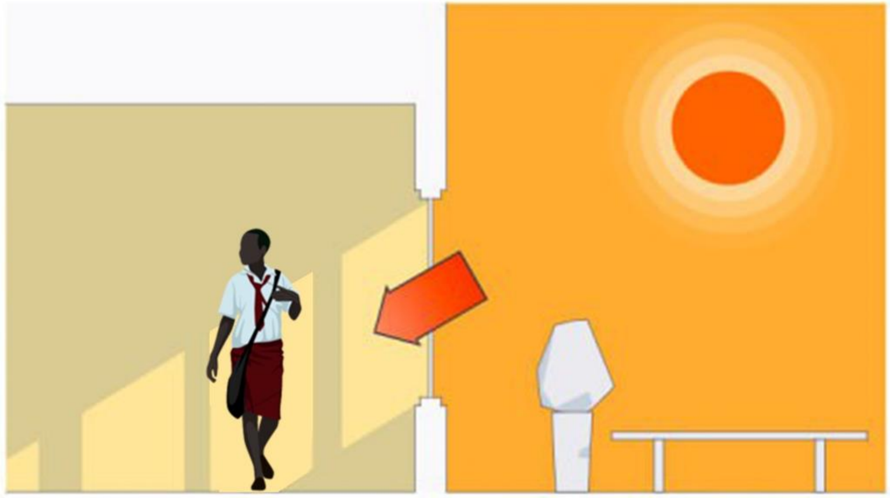


2.3.6. SHADING AND GLAZING

Given the high temperatures and strong sunlight in Rau, it is important to provide adequate shadings both for open spaces and the building. Due to the analysis the most overheating side is north-west and the least one belongs to north-east/south-east/east.

Cold weather lead to heat loss:

Heat loss potential	0 heating degree-days per year
Heat loss through glazing	Negligible
Impact on glazing ratio	Negligible

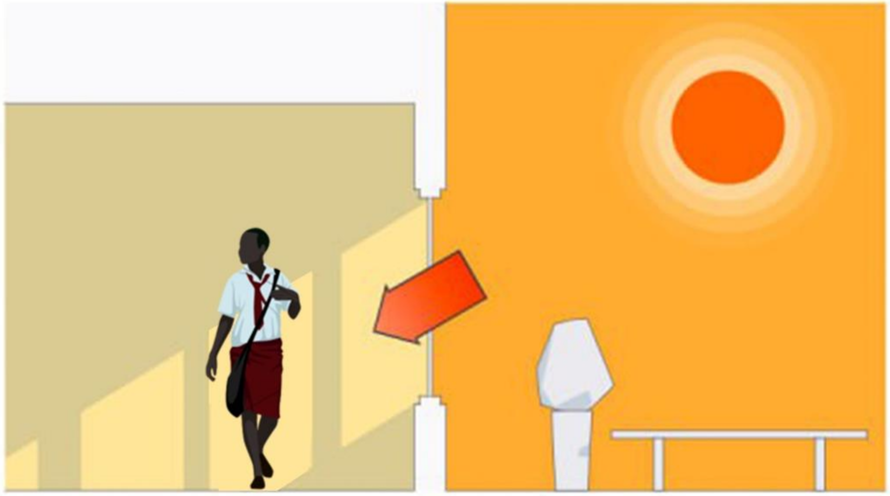


Detrimental sun leading to heat gain:

NW

Amount of overheating sun	2222 overheating hrs per year
Heat gain through glazing	Extremely significant
Impact on glazing ratio	Very high

To determine the most overheating side of a specific building, it may be necessary to conduct a detailed analysis of the building's properties. Shading can be helpful by limiting the amount of direct sunlight that enters the building and by preventing heat from being absorbed by exterior surfaces. The building's exterior can be enhanced with shading elements like awnings, louvres, or sunshades to prevent direct sunlight.



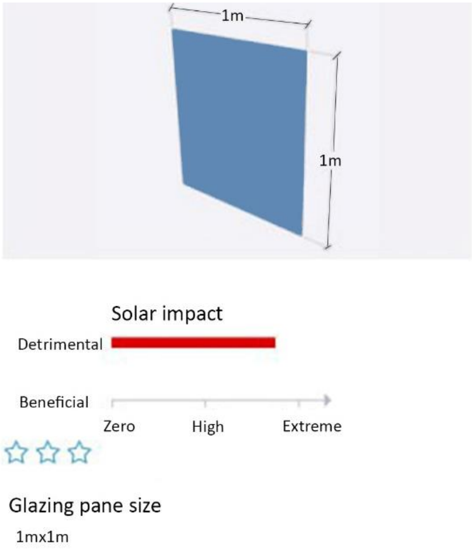
Cold weather lead to heat loss:

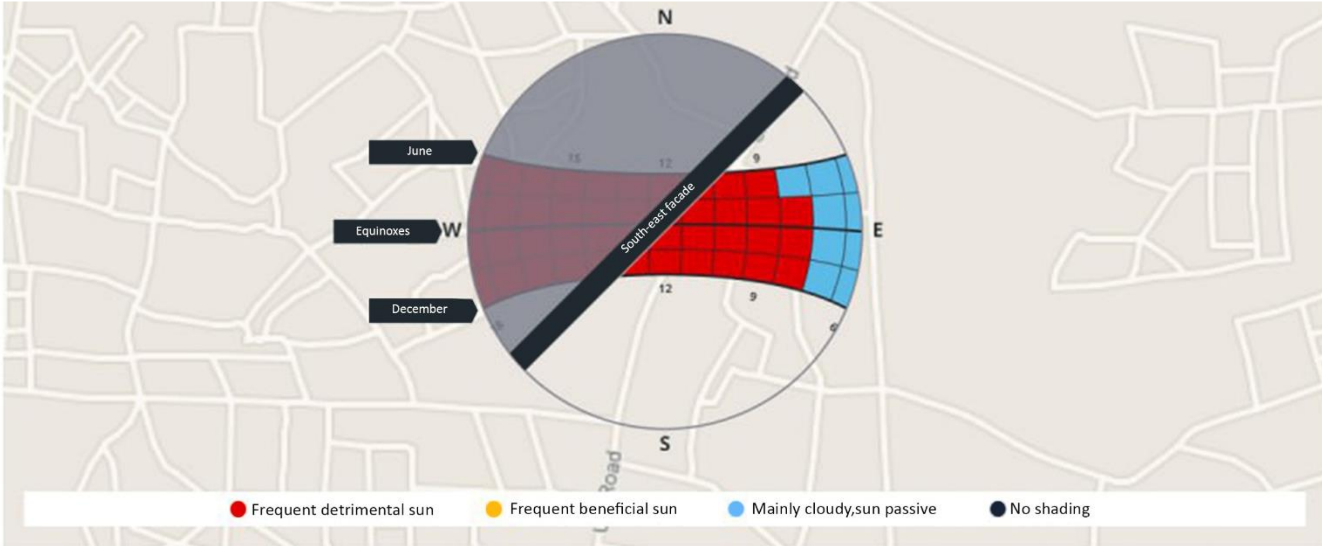
Heat loss potential	0 heating degree-days per year
Heat loss through glazing	Negligible
Impact on glazing ratio	Negligible

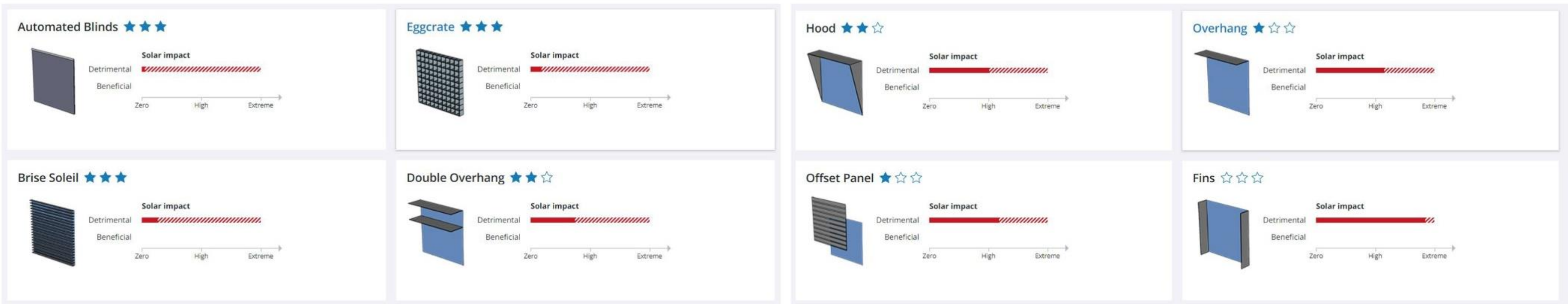
Detrimental sun leading to heat gain:

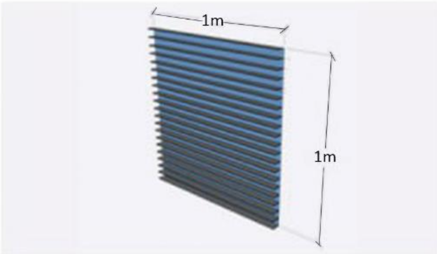
SE	Amount of overheating sun	1675 overheating hrs per year
	Heat gain through glazing	Quite significant
	Impact on glazing ratio	Very high
E	Amount of overheating sun	1769 overheating hrs per year
	Heat gain through glazing	Quite significant
	Impact on glazing ratio	Very high
NE	Amount of overheating sun	1816 overheating hrs per year
	Heat gain through glazing	Quite significant
	Impact on glazing ratio	high

Different shadings such as Automated blind, Eggcrate, Hood, Overhang, vertical and horizontal louvers have been considered to check which one can be more effective. After analysis it has been found that the horizontal shading with low spaces is the best choice to avoid heat gain on east.









Solar impact

Detrimental

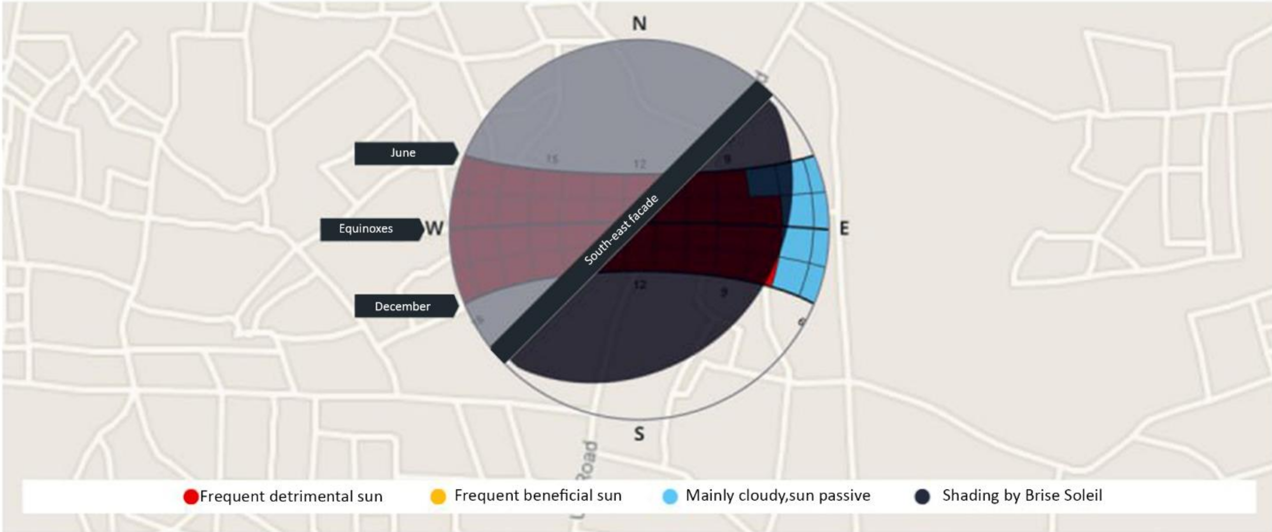
Beneficial

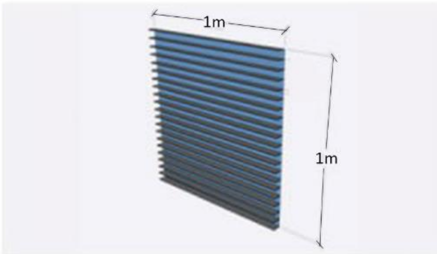
Zero High Extreme

★★★

Glazing pane size

1mx1m





Solar impact

Detrimental

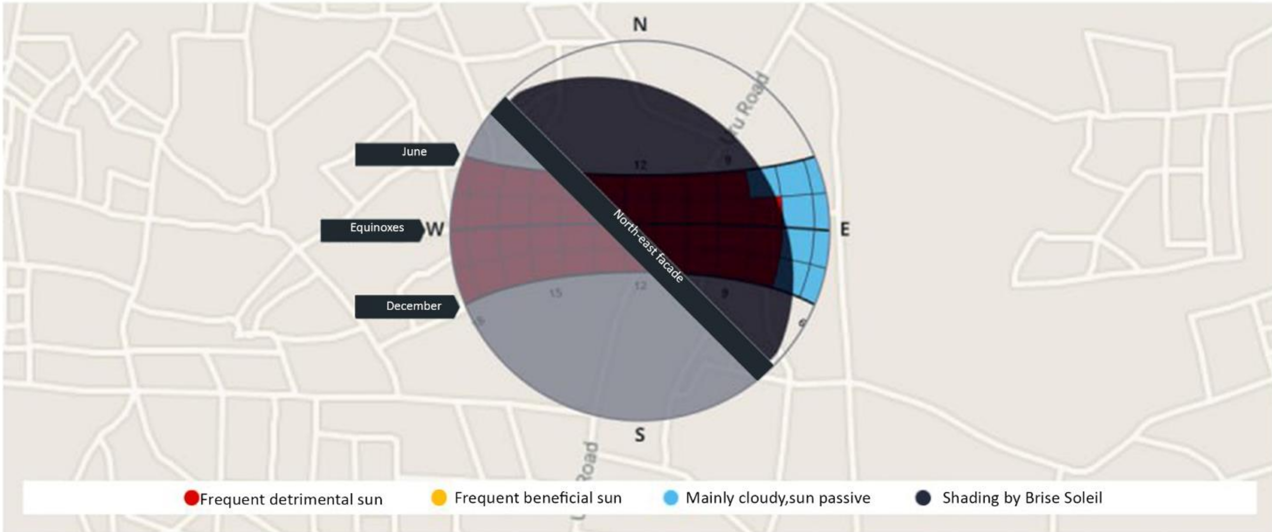
Beneficial

Zero High Extreme

★★★

Glazing pane size

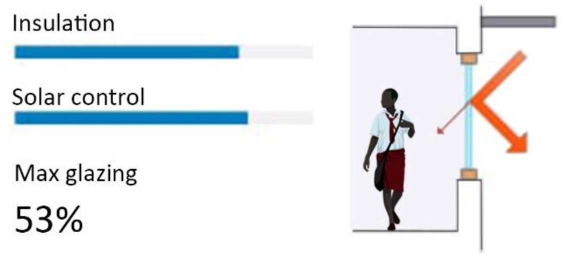
1mx1m



On the other hand, the type and amount of glazing used in a building's design can also impact its tendency to overheat. The glazing ratio, which is the ratio of window area to wall area, can have a significant effect on heating in buildings.

Double glazed low E, non metal, substantial shading , great glazing

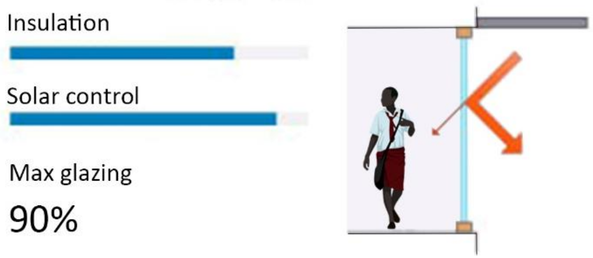
Double glazed argon, non metal, substantial shading , great glazing



Double glazed low E, non metal, extensive shading , great glazing

Single glazed , metal-unbroken, prtial shading , basic glazing

Double glazed argon, non metal, extensive shading , great glazing



CHAPTER3: DESIGN

3.1. CONCEPT

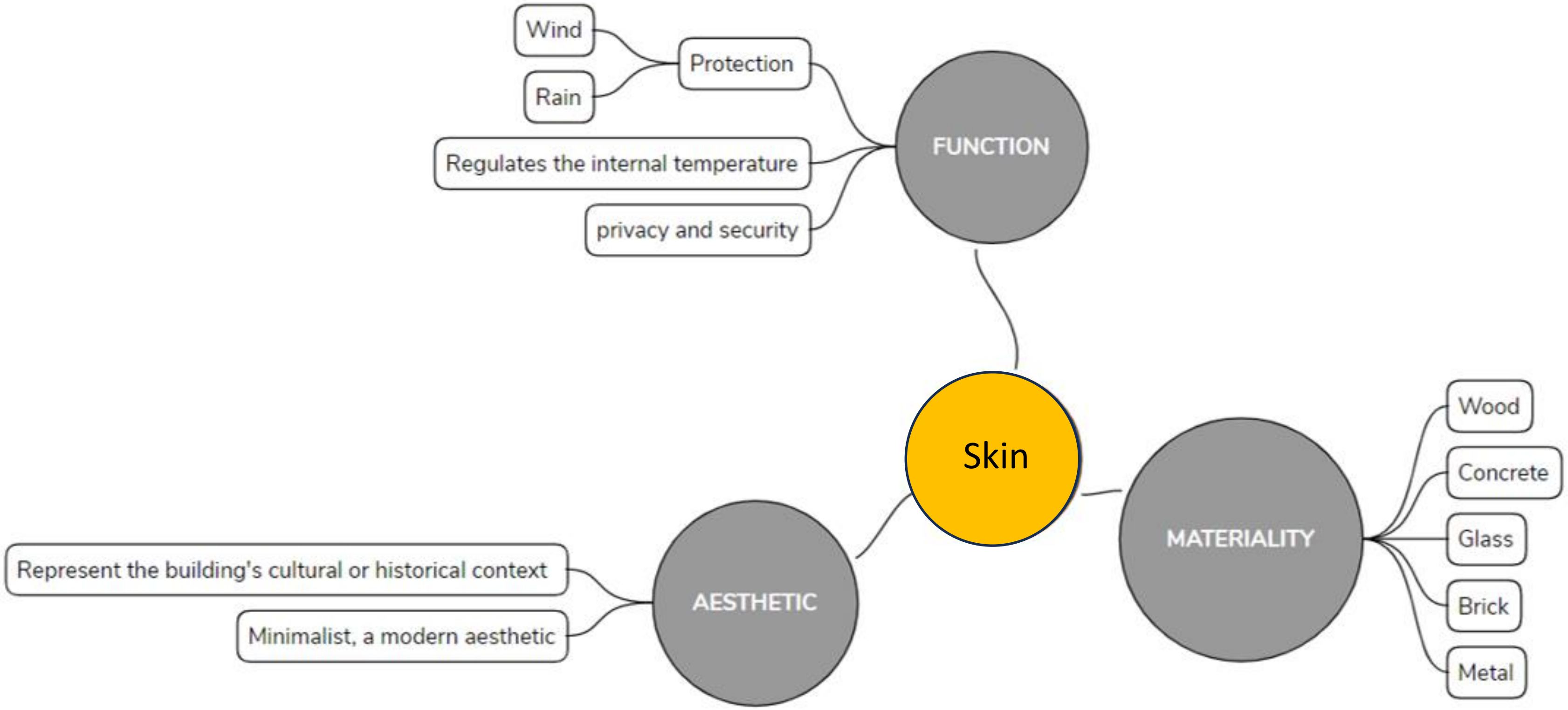
The term "skin" in architectural design refers to a building's outer layer or envelope. The building's skin is a crucial component of its design since it performs several purposes, including protecting the building from external elements, regulating the internal temperature, and providing an aesthetic appeal. There are various methods to explain the idea of skin in architectural design, including:

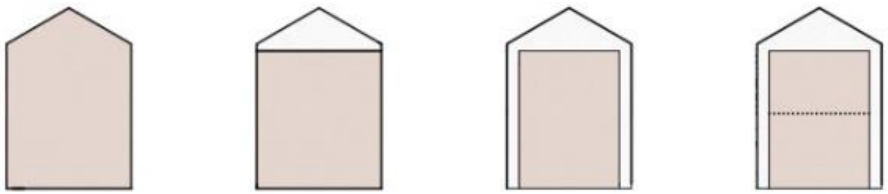
Function: The skin of a building serves several functions, such as protecting the building from weather elements such as wind, rain, and snow. The skin also regulates the internal temperature of the building by controlling the amount of heat that enters or exits the building. Additionally, the skin provides privacy and security to the building's occupants.

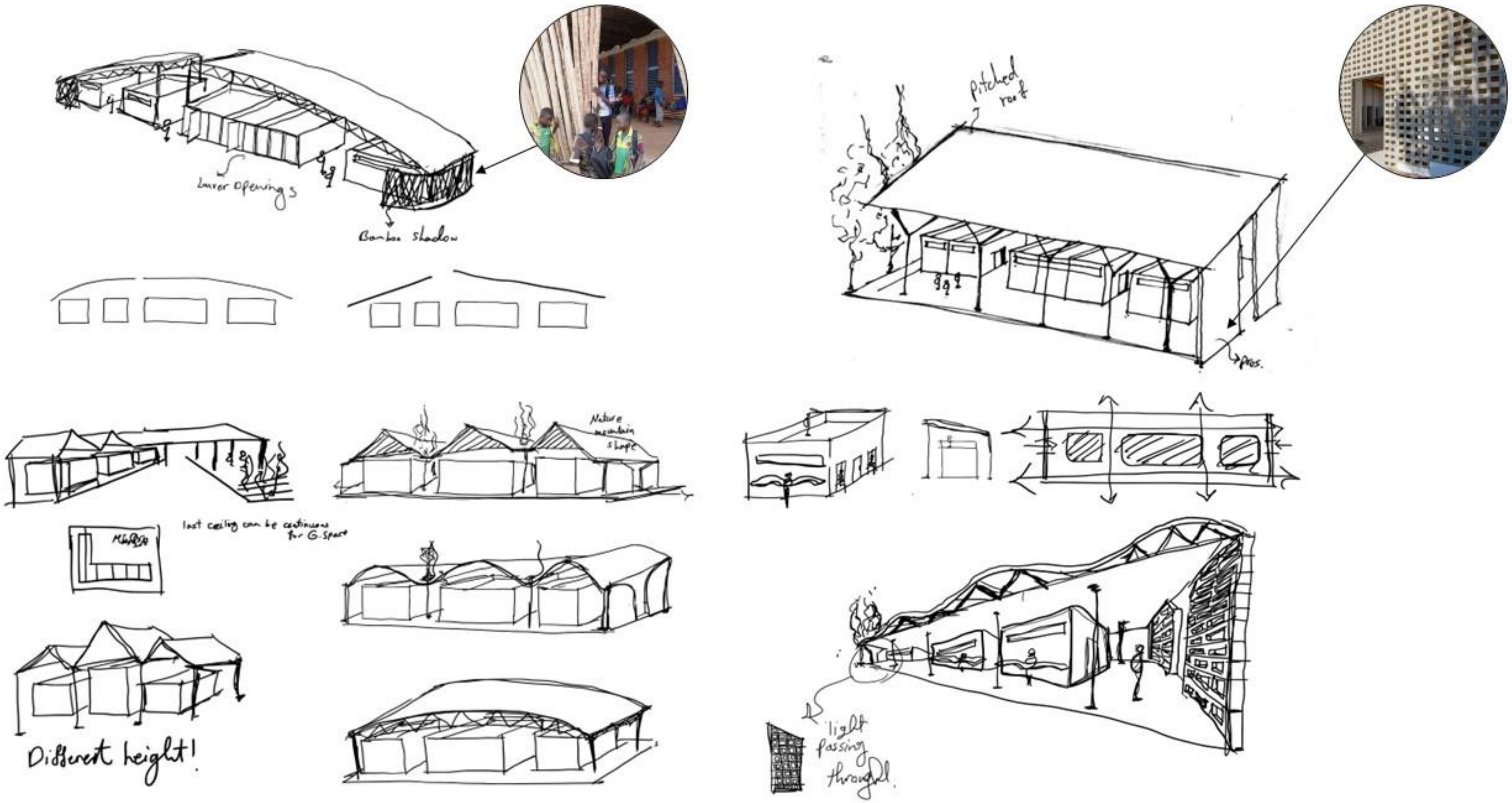
Materiality: The skin of a building can be made of various materials, including glass, concrete, brick, wood, and metal. The choice of material can affect the building's appearance, performance, and sustainability. For example, the use of sustainable materials such as timber can reduce the building's carbon footprint, while the use of glass can enhance natural light and views.

Aesthetics: The skin of a building can also provide an aesthetic appeal to the building. The design of the skin can be used to express the building's function or represent the building's cultural or historical context. For example, the use of ornate patterns in the skin can reflect the building's cultural context, while the use of clean lines and minimalist design can represent a modern aesthetic.

The skin in this design refers to the exterior layer roof of a building, which serves several functions, including protecting the building from external elements, regulating the internal temperature, and providing an aesthetic appeal. Under this skin the volumes can be dedicated to different functions according to needs in time, to have flexible approach.

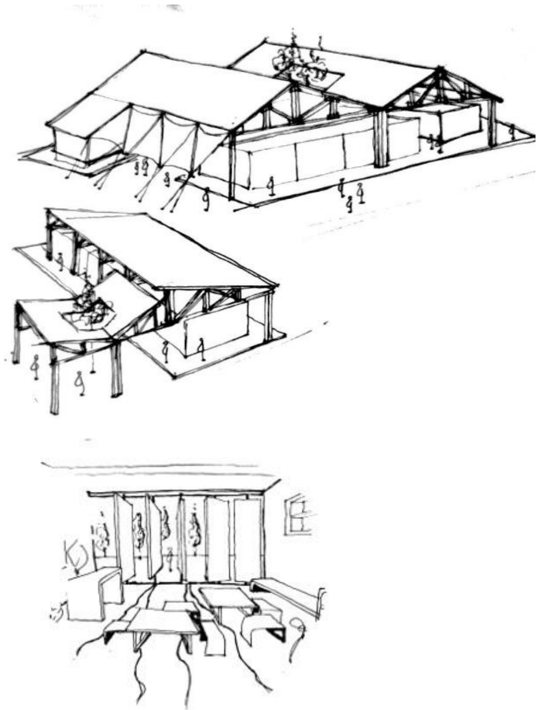

Wind
Rain
Protection
Regulates the internal temperature
privacy and security
FUNCTION
Skin
Wood
Concrete
Glass
Brick
Metal
MATERIALITY
AESTHETIC
Represent the building's cultural or historical context
Minimalist, a modern aesthetic

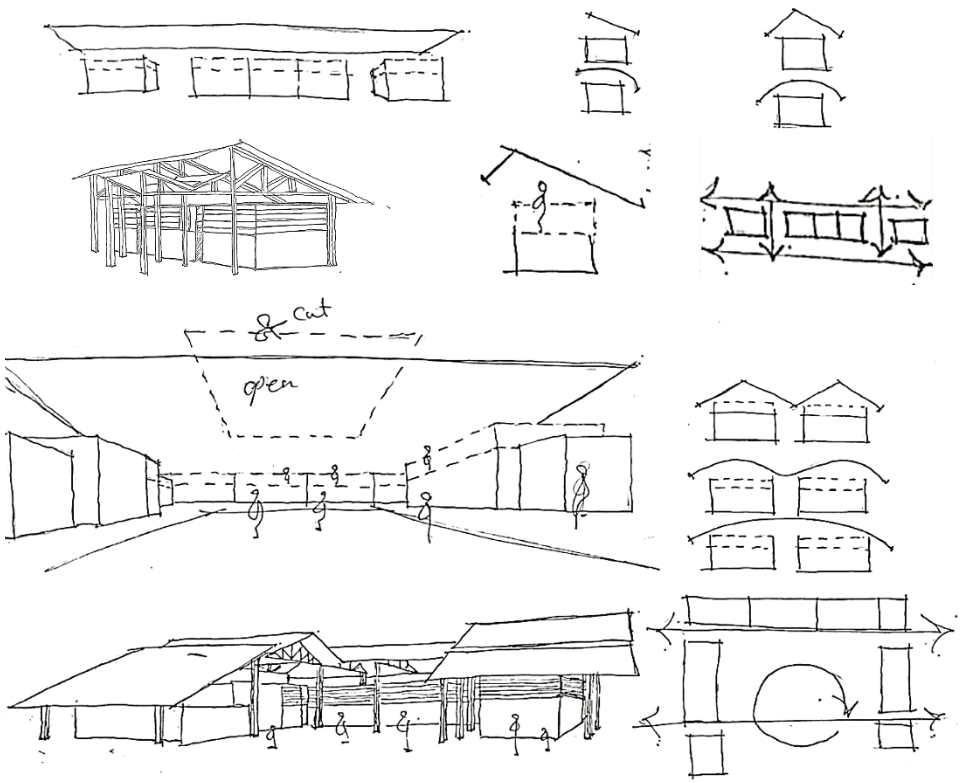



Bamboo shadow
pitched roof
Different height!
light passing through

3.1.1. BUILDING FORM IDEAS

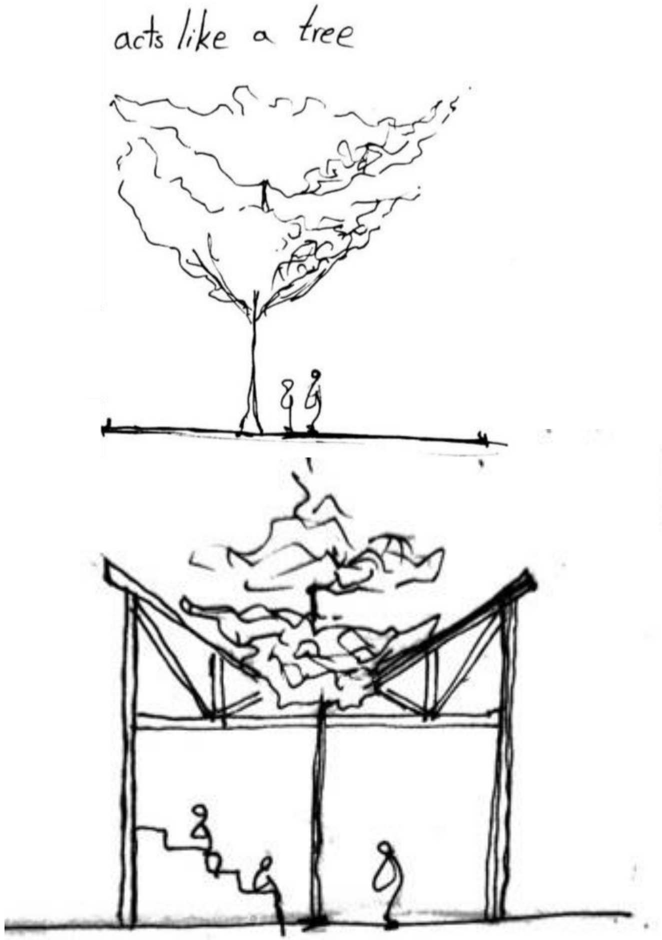
The skin is an essential aspect of the building's design as it serves several functions, including protecting the building from external elements, regulating the internal temperature, and providing an aesthetic appeal. The skin shape follows the typology of typical pitched roof in district.





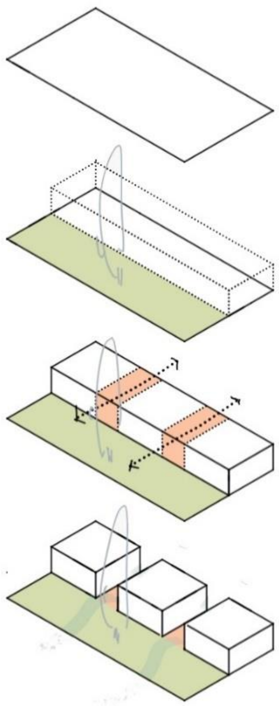
Also consider a unity point as a gathering area and agriculture spaces are part of the idea. African civilizations have traditionally valued community and meeting spaces. Traditionally, African societies were communal in nature, and people lived in extended families or small villages where everyone knew each other and worked together for the common good. Gathering places are also important for preserving cultural traditions and passing them on to future generations.

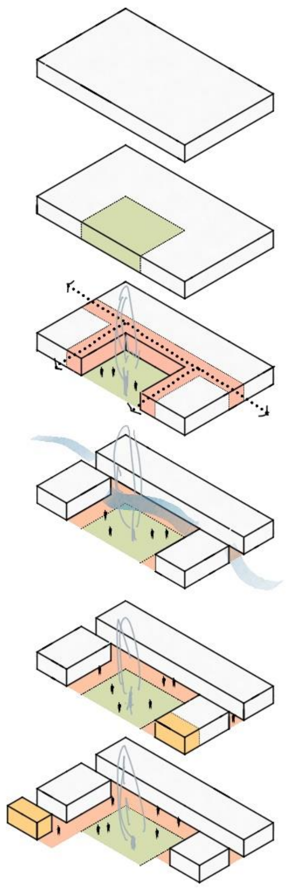
Addition to that in Tanzania, agriculture education is a part of the national school curriculum from primary to secondary levels. The main goal of agriculture education in Tanzanian schools is to equip students with practical and theoretical knowledge on modern agricultural practices, sustainable farming, and the importance of agriculture in the national economy.

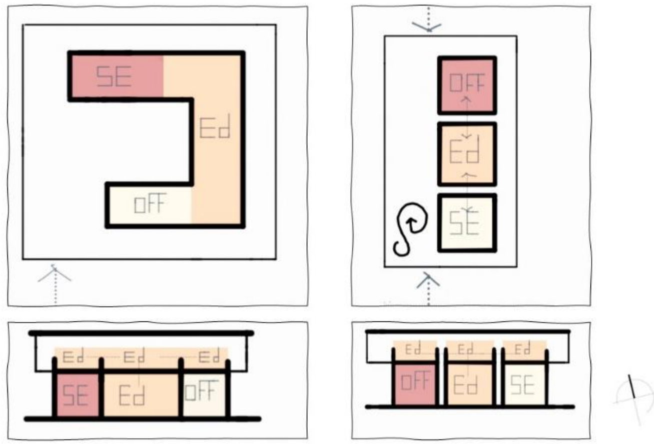


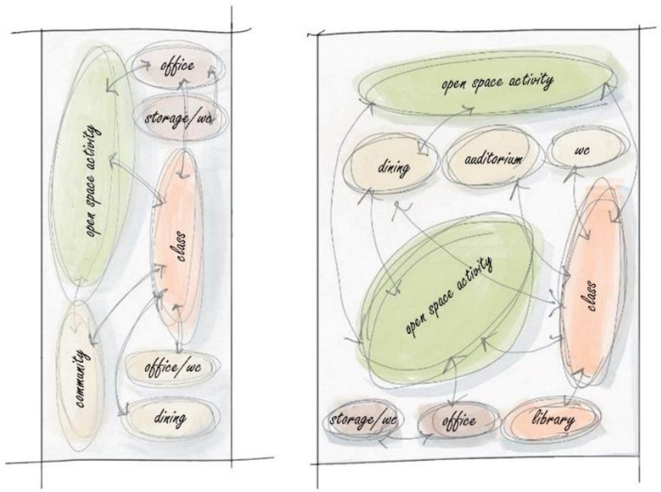
3.2.DESIGN PROCESS

Evaluate the ideas generated in the previous step by bringing nature to the building and adding corridors for proper ventilation. The design process has been shown in the following. Using the U-shaped form for primary school is for having enhanced communication and efficient use of space, enhanced aesthetics, improved safety, easy accessibility, and interaction.



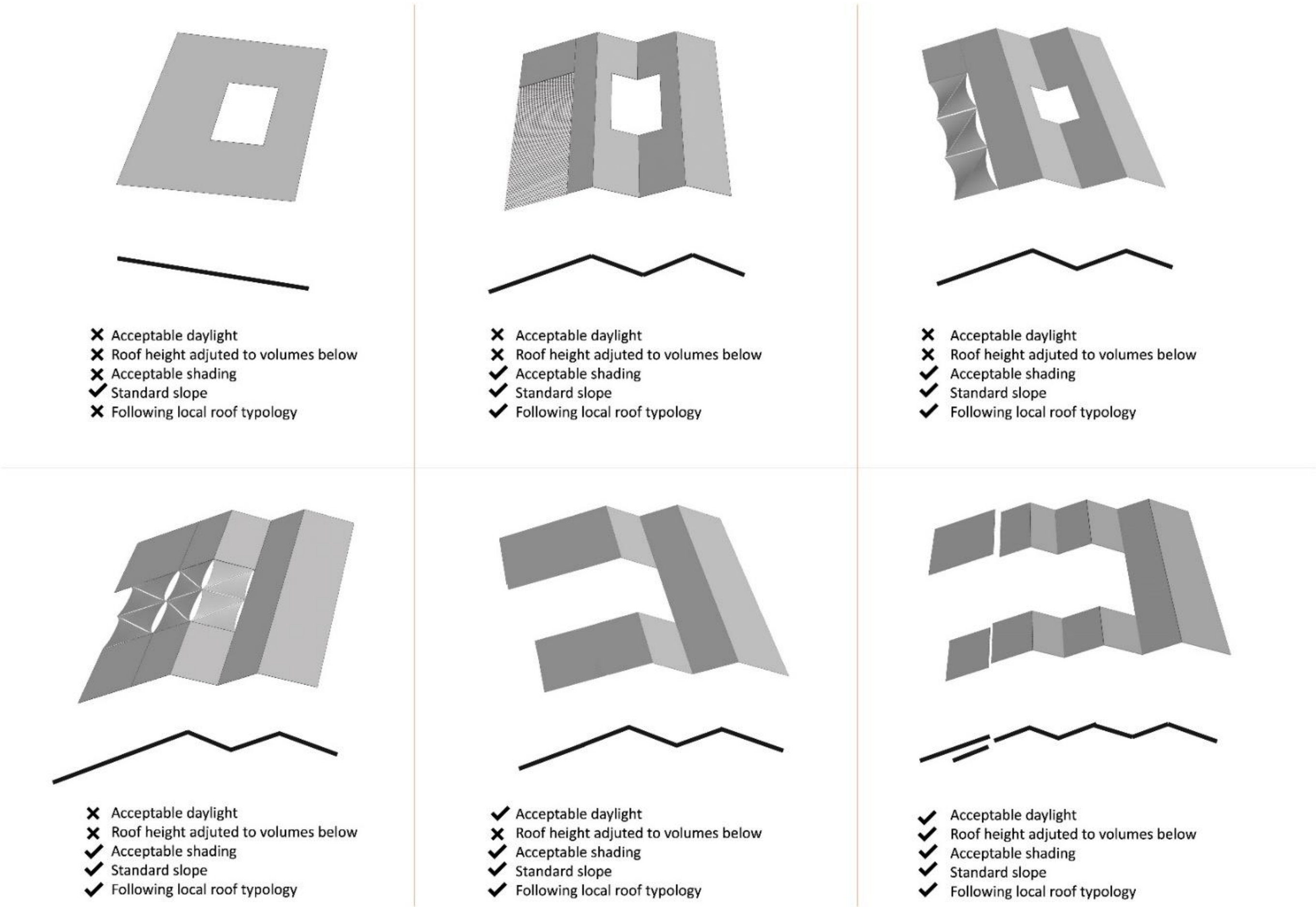






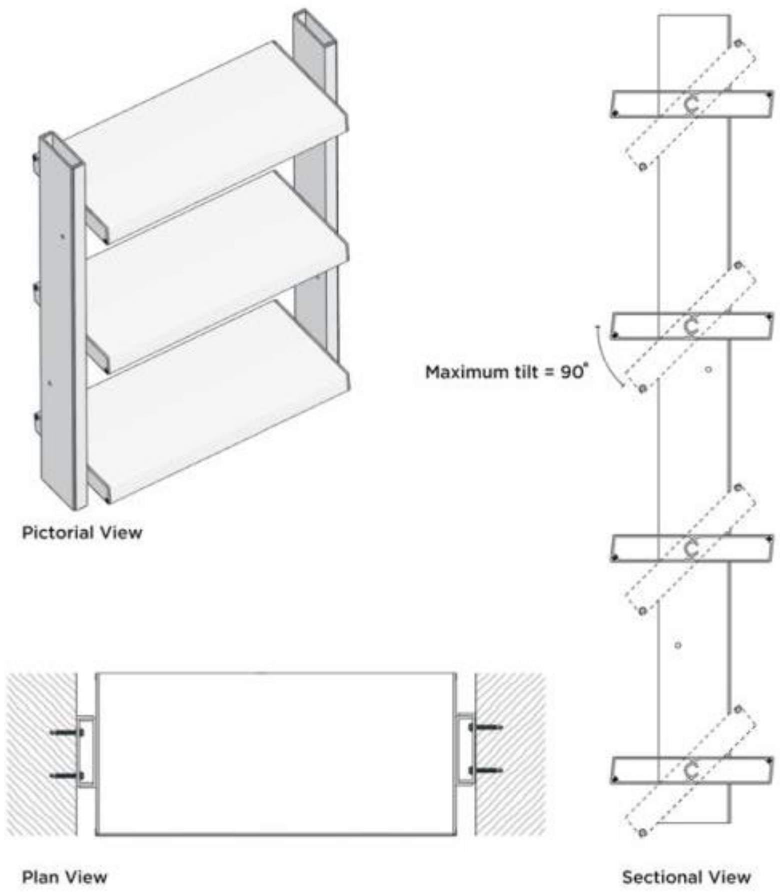
3.2.1.THE SKIN DESIGN PROCESS

We evaluate various roofing options based on five key criteria to determine the optimal choice. These criteria encompass factors such as daylight exposure, shading effectiveness, maintaining a consistent slope, ensuring the roof's surface complements the underlying structure, and adhering to the local architectural roof style.



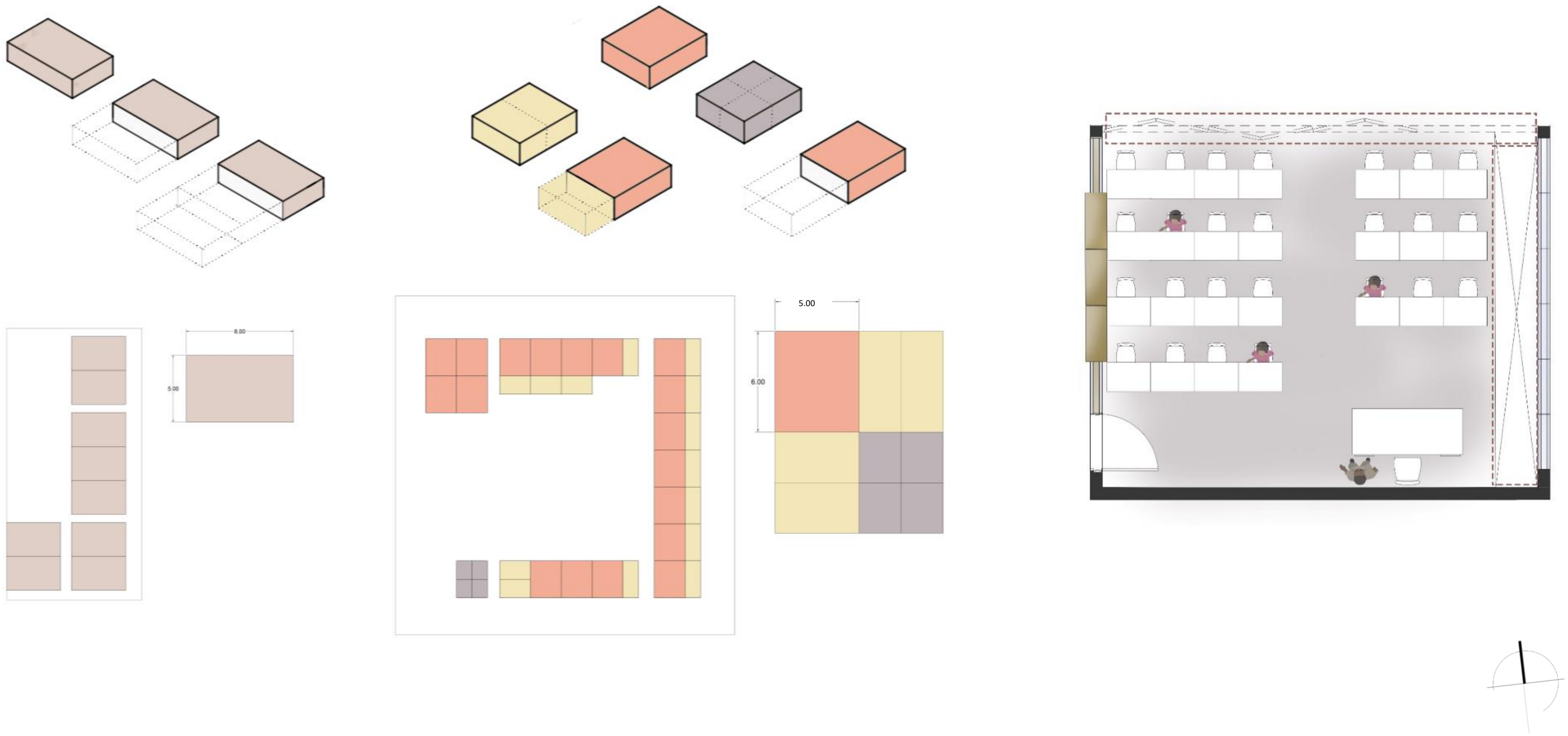
3.2.2. LOUVER DESIGN

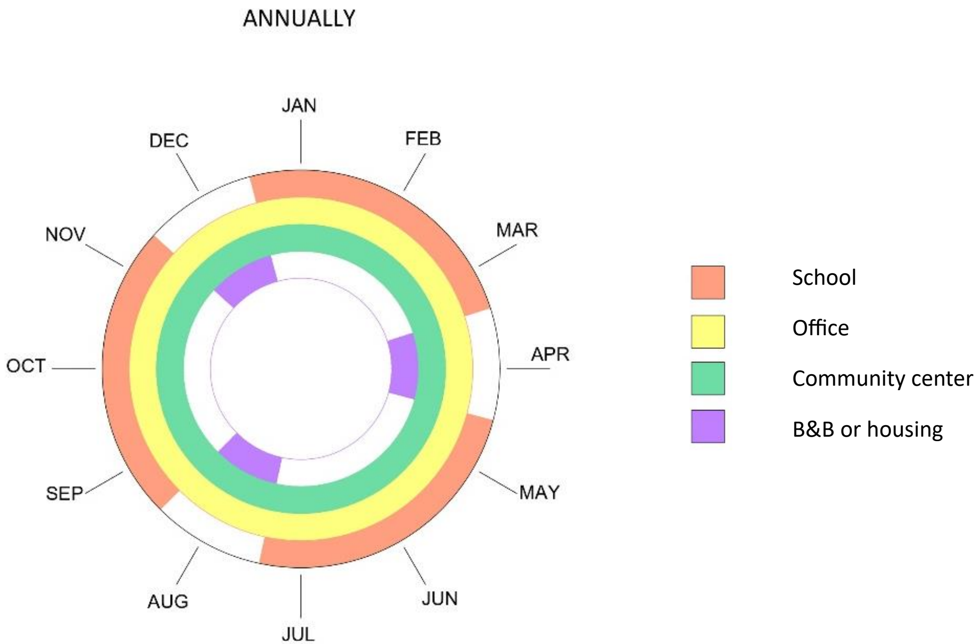
Adjustable louvers(90x30cm) play a crucial role in building design and functionality, providing a versatile solution for managing airflow, light, privacy, and aesthetics in various architectural and engineering applications.

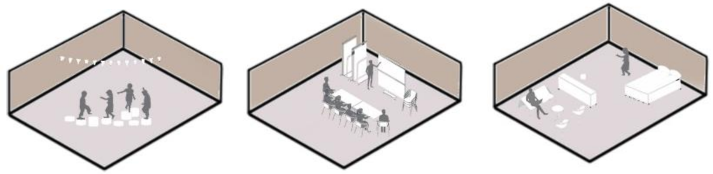


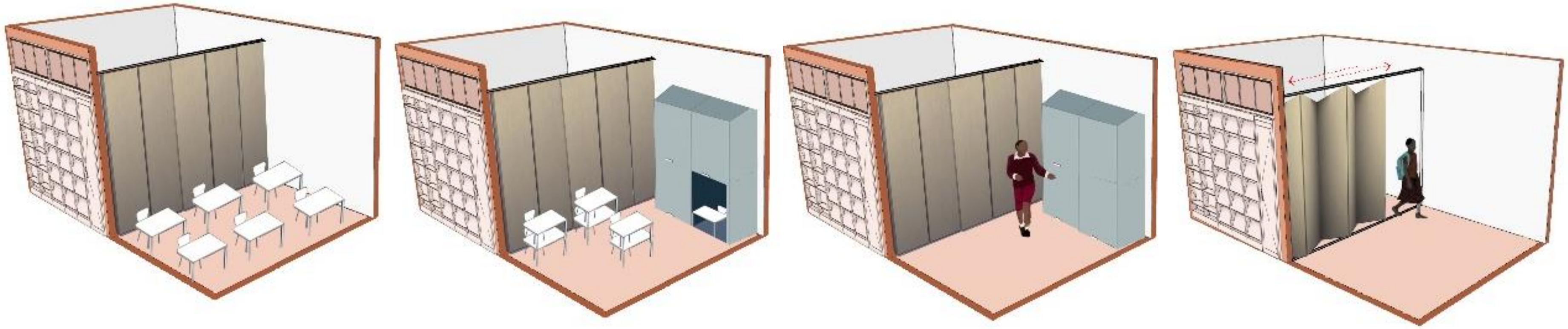
3.3. FORM DEVELOPMENT AS MODULE SYSTEM

Creating forms as a module system may be a very efficient way to develop reusable and maintained application components. You may divide the entire form into smaller, independent pieces or modules using a module system. Each module handles a certain aspect of the form's functionality, making it easier to manage and update in the future. The modules of 5x8 and 5x6 are used in kindergarten and primary school respectively.




ANNUALLY
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
School
Office
Community center
B&B or housing

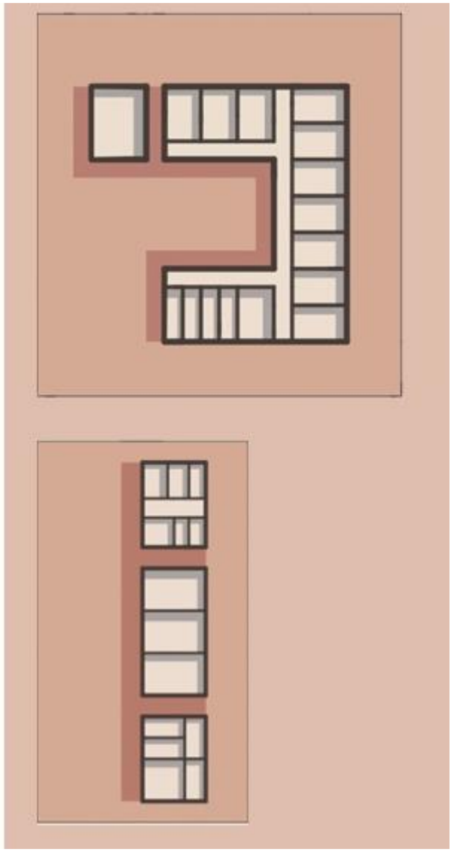




3.4. TYPE OF USES AND AREA

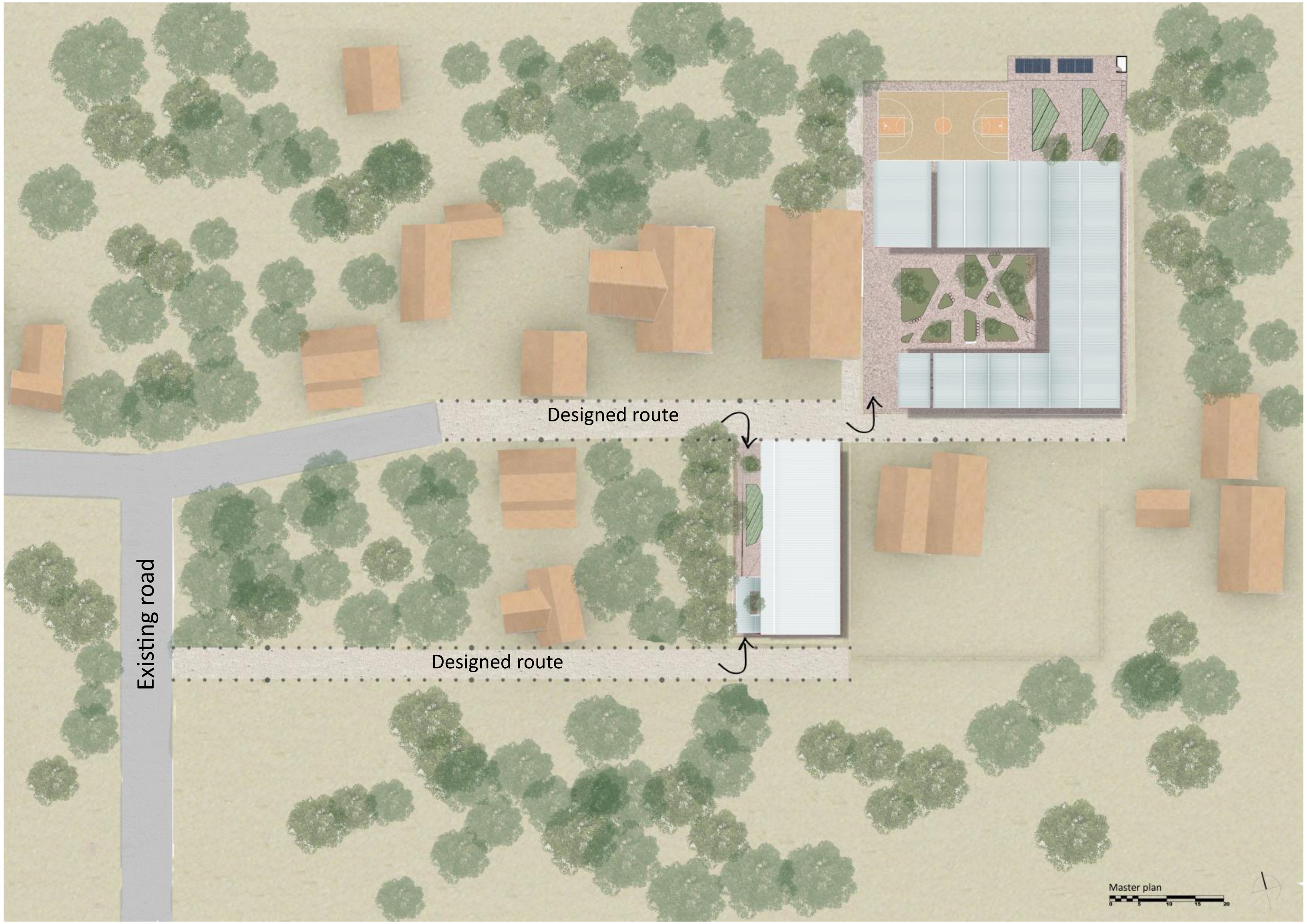
Different spaces have been considered due to the need of the students. The areas and dimensions are referred to the rules and Neufert. The modular concept has been used for designing the plans.

PRIMARY SCHOOL								
EDUCATIONAL	NUMBER	AREA (sqm)	**OFFICE**	NUMBER	AREA (sqm)	**SERVICES**	NUMBER	AREA (sqm)
Classroom	7	30each	Manager room			Bathroom	14	45
Workshop & lab	2	30+65	Meeting room	1	20	Dining and Kitchen	1	65
Library	1	30+120	Teacher room	1	25			
Semi class	7	30	Medical room	1	15			
Seminar	1	45	Psychic room	1	15			
			Archive	1	4			
			Storage	1	4			
KINDERGARTEN								
EDUCATIONAL	NUMBER	AREA (sqm)	**OFFICE**	NUMBER	AREA (sqm)	**SERVICES**	NUMBER	AREA (sqm)
Classroom	5	35 each	Manager room			Bathroom	10	30
Workshop & lab	1	35	Meeting room	1	15	Dining and Kitchen	1	30
Semi workshop	2	75 each	Teacher room	1	20			
			Medical room	1	10			
			Psychic room	1	10			
			Archive	1	5			
			Storage	1	5			

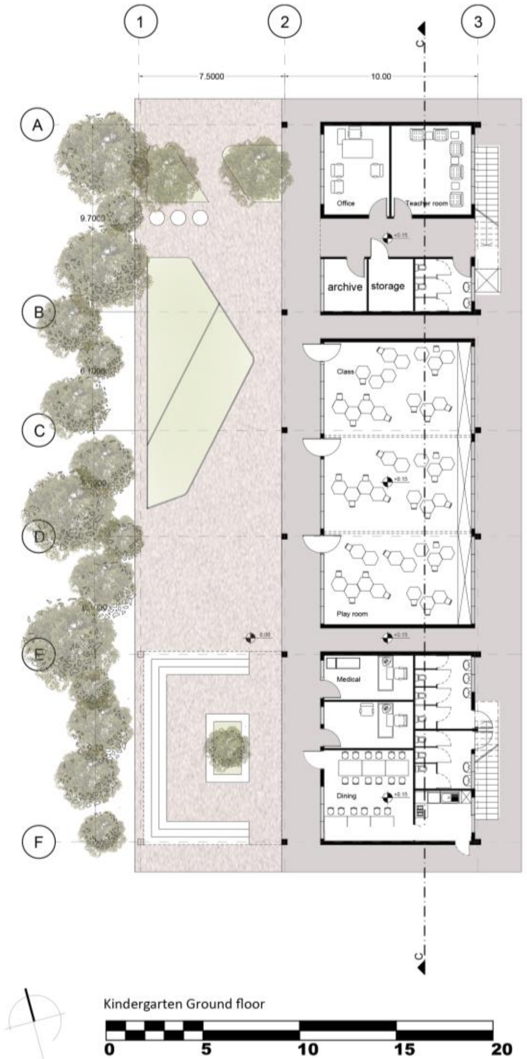


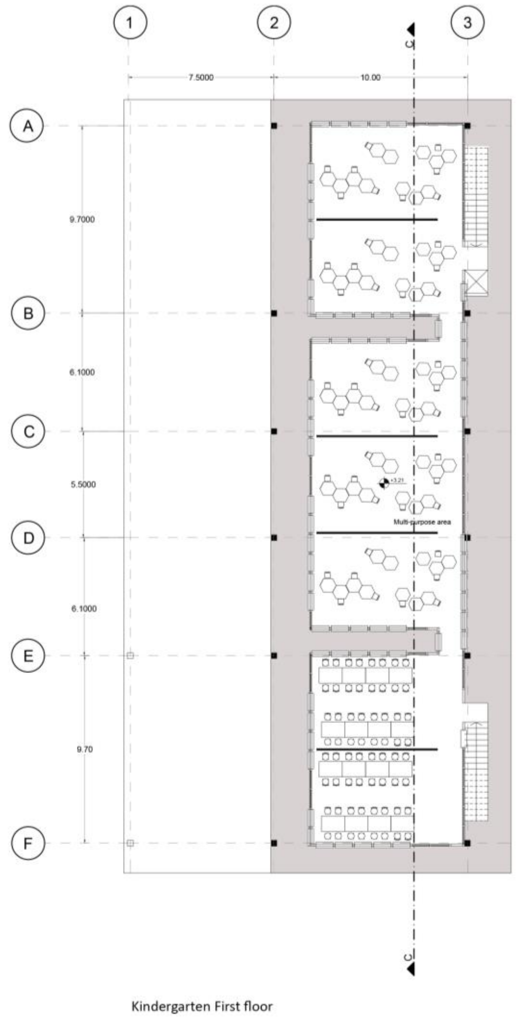
	Gross area (sqm)	Used area	Number of Users
Primary	2750	835	180-200
Kindergarten	800	280	90

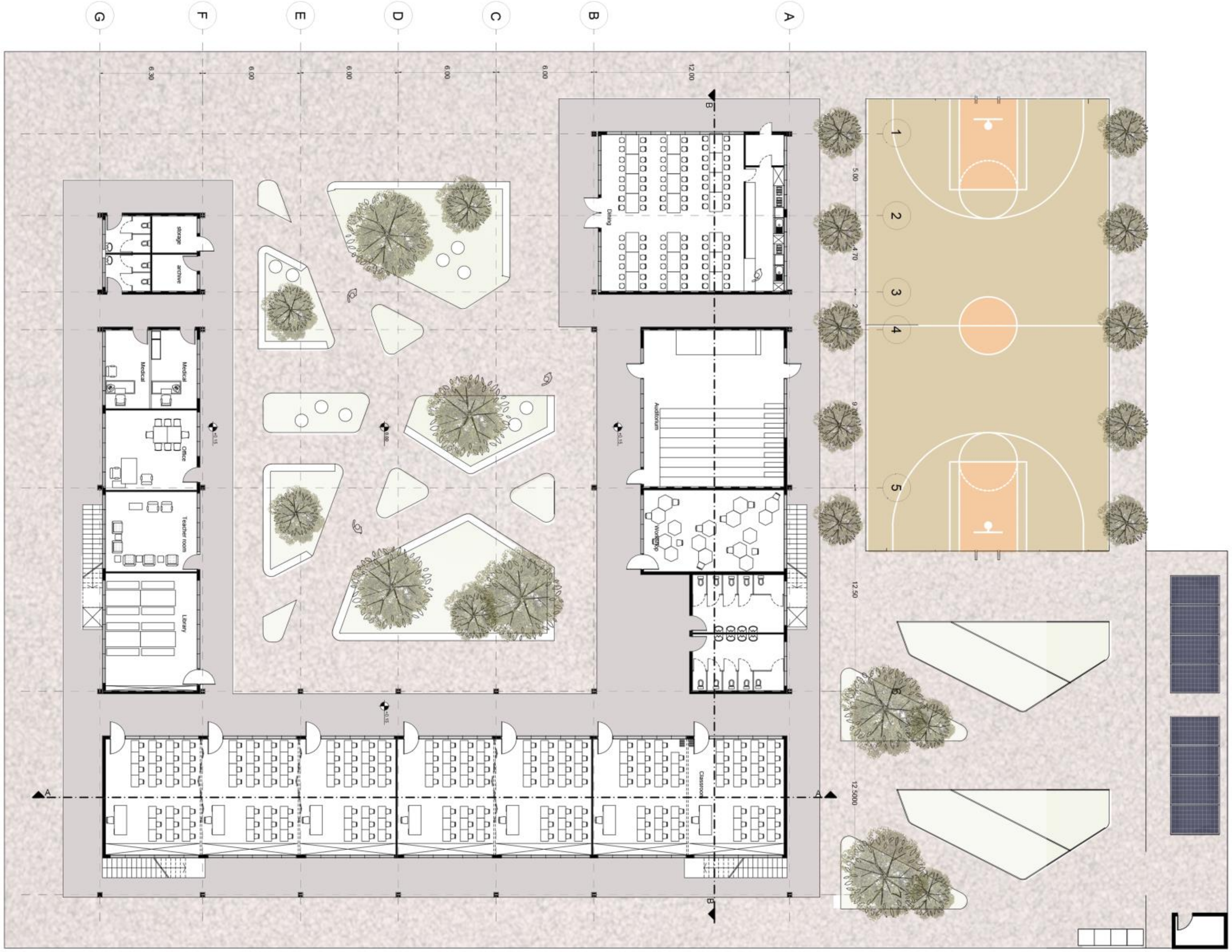
3.5. MASTERPLAN



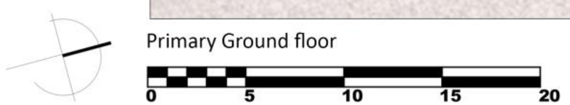
3.6.PLANS

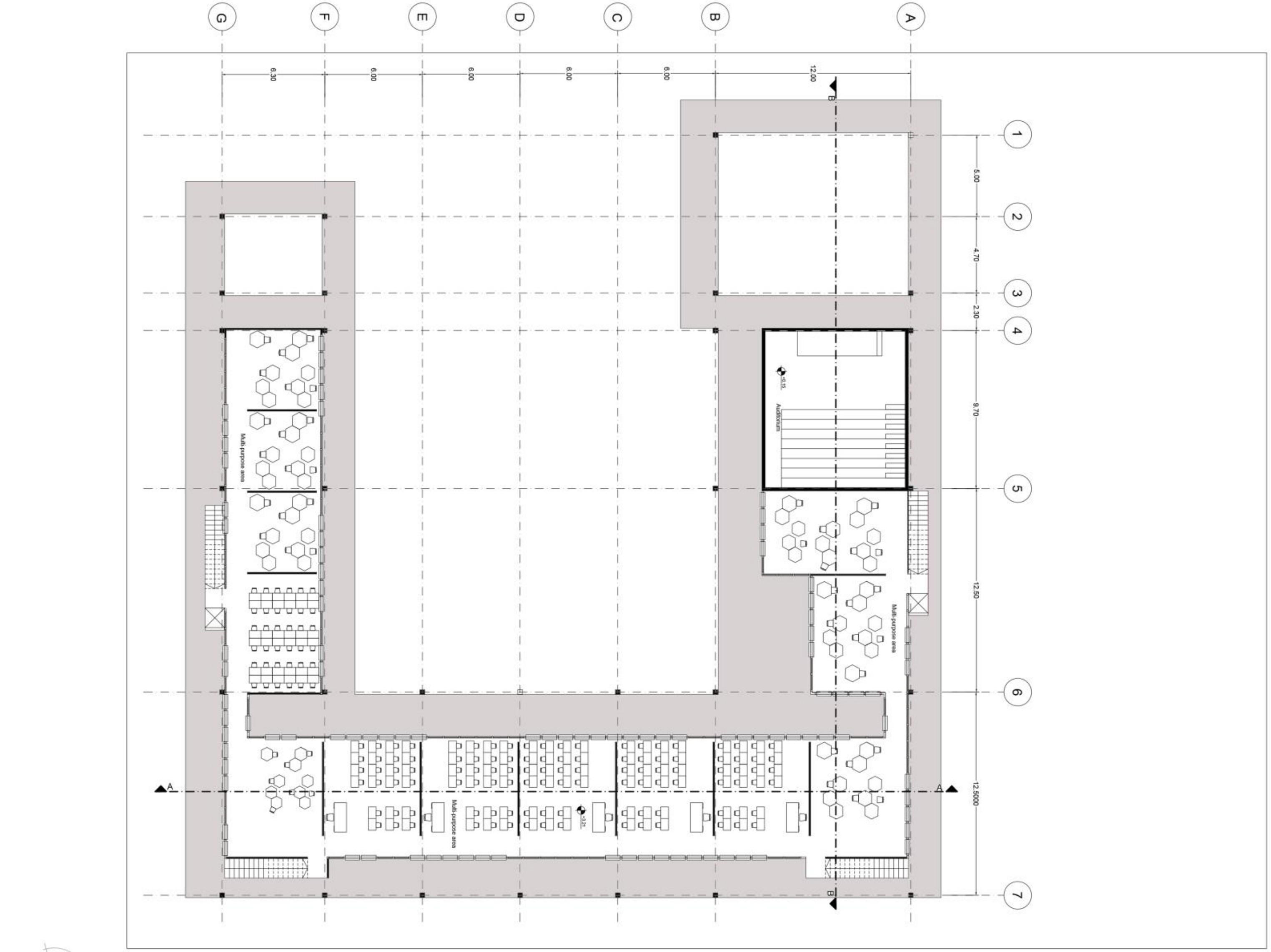

Office
Teacher room
archive
storage
Class
Play room
Medical
Dining
Kindergarten Ground floor
0
5
10
15
20


Multi-purpose area
Kindergarten First floor



Primary Ground floor





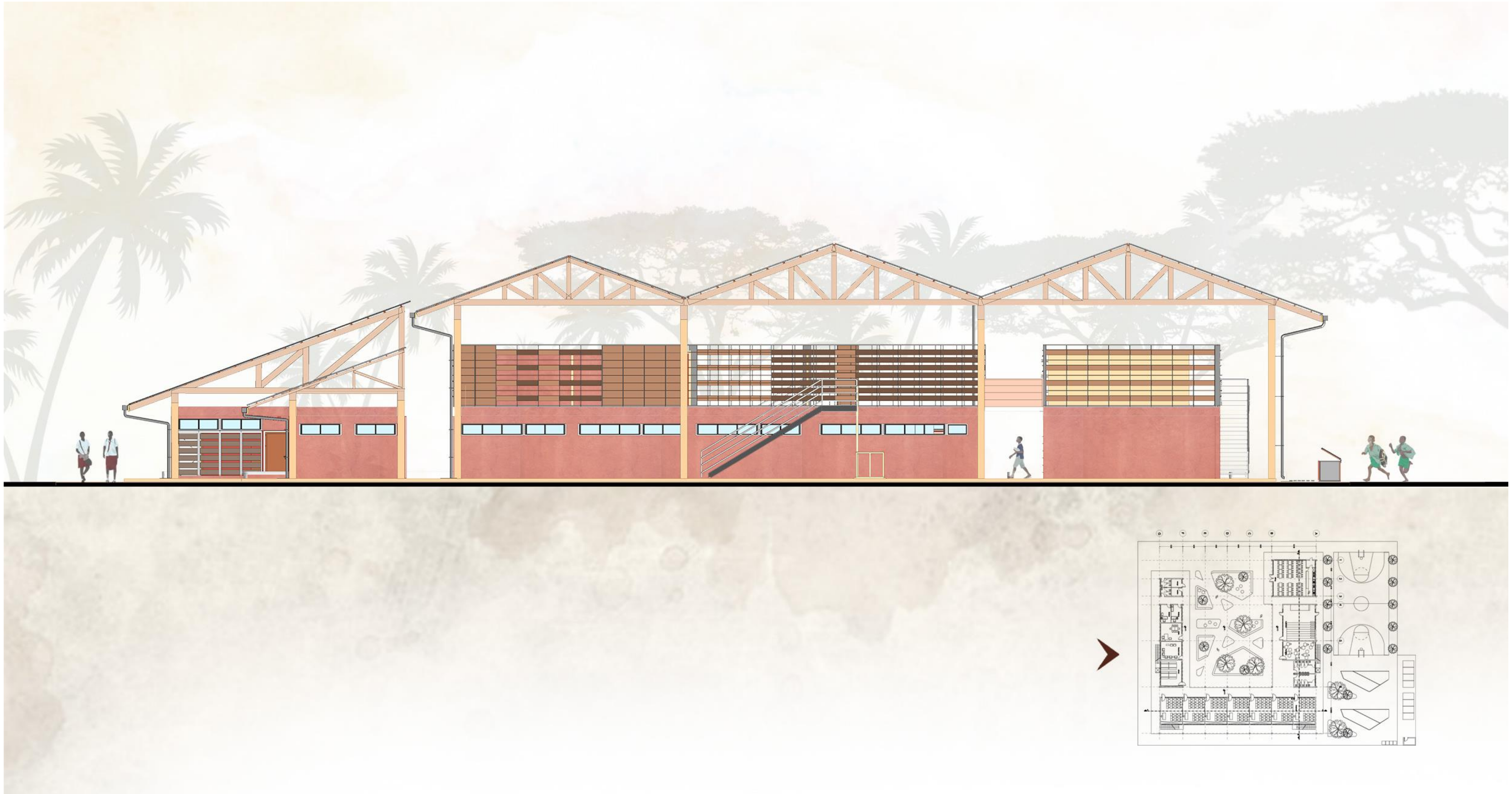
Primary First floor

0 5 10 15 20

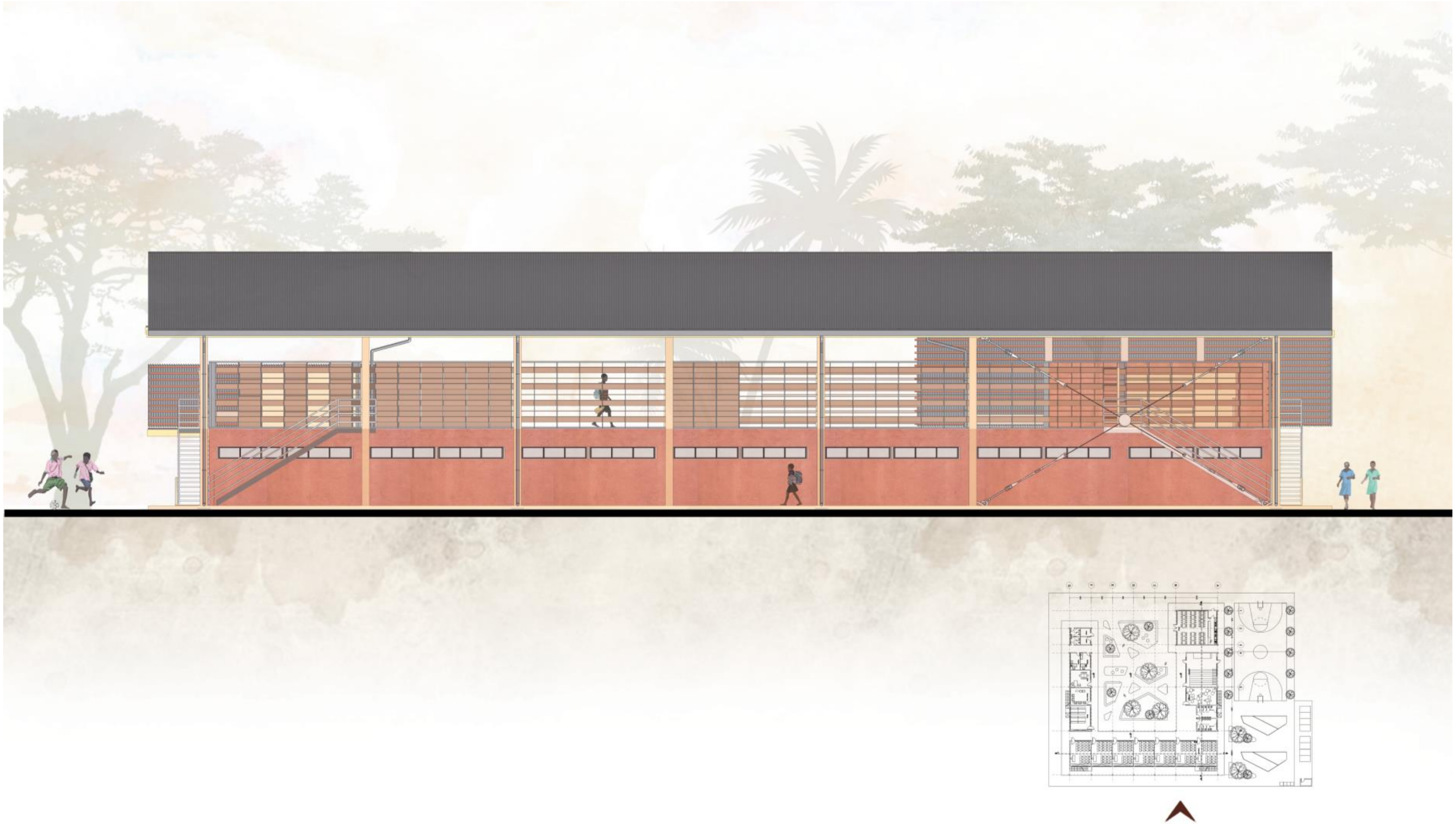
3.7. ELEVATIONS

Primary School, North Elevation

Primary School, South Elevation

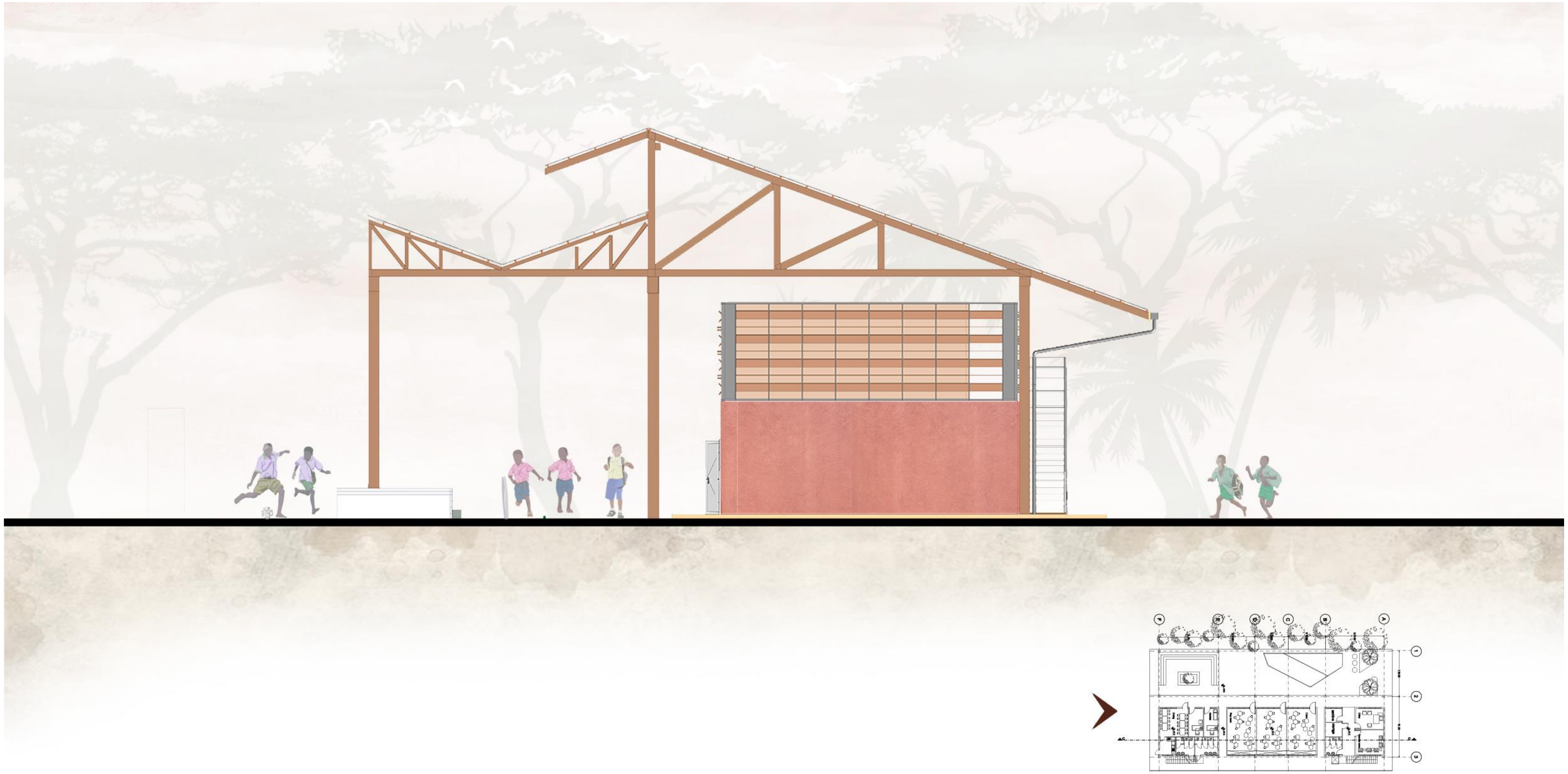


Primary School, East Elevation



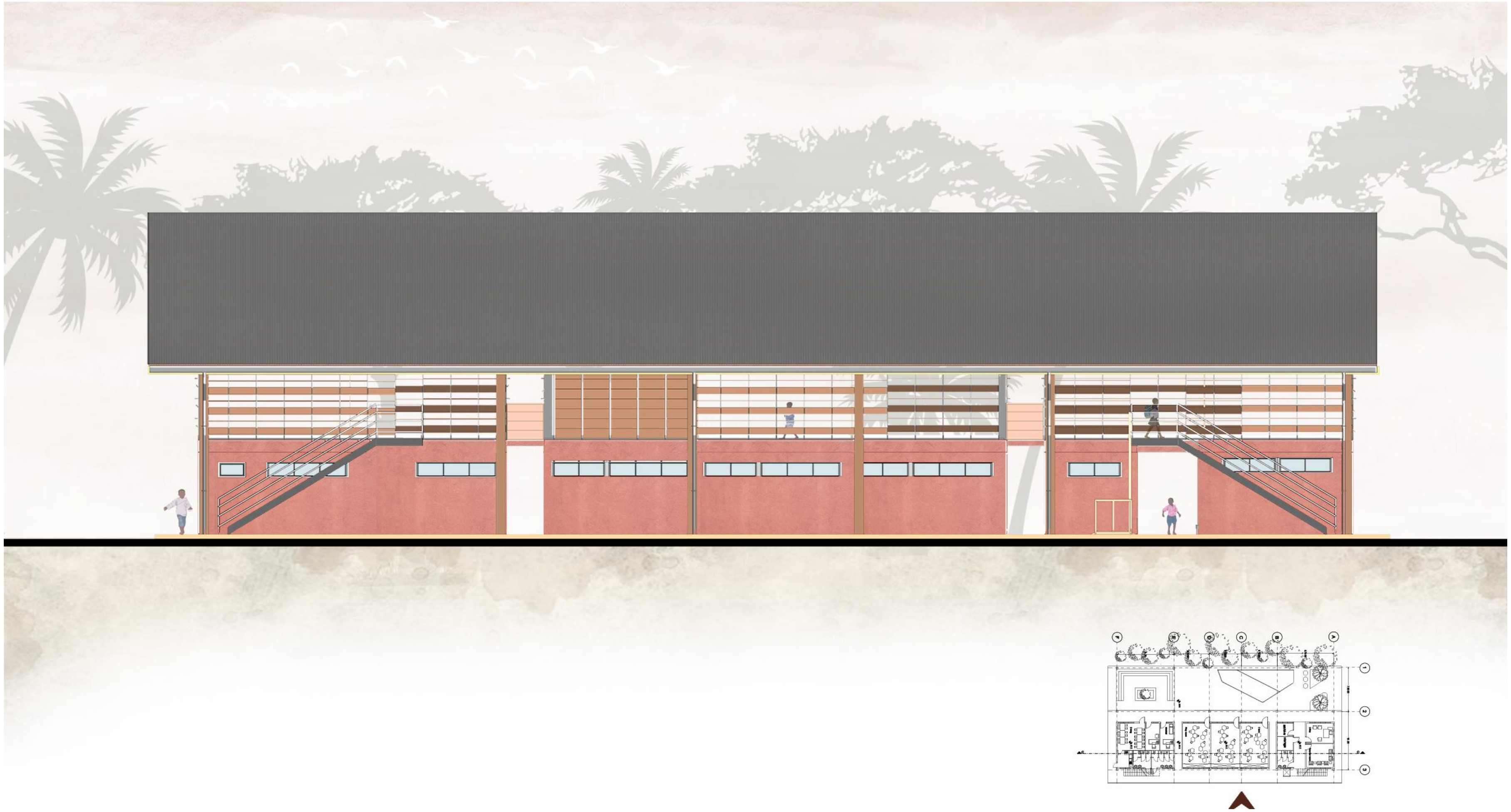
Primary School, West Elevation

Kindergarten, South Elevation



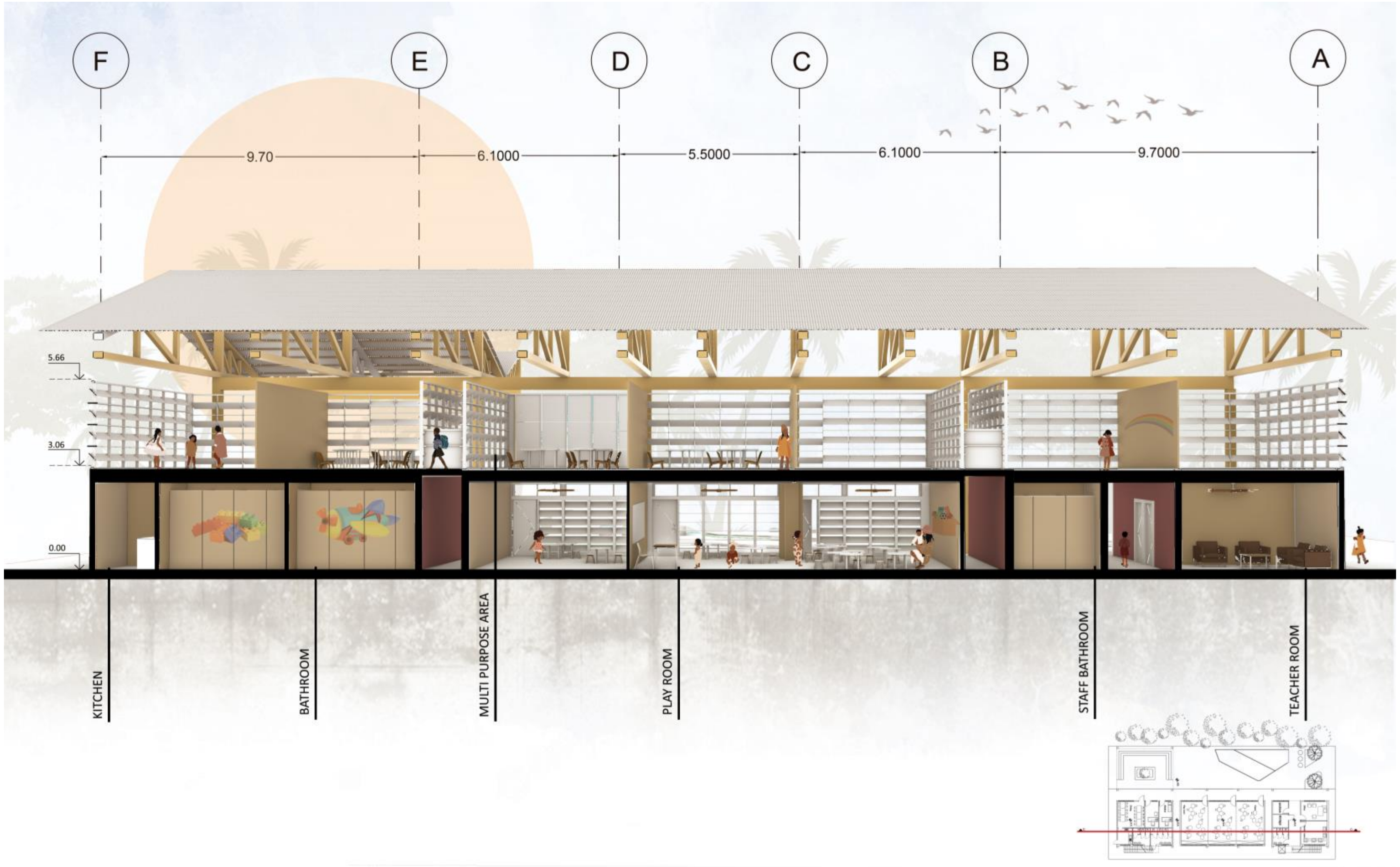
Kindergarten, North Elevation

Kindergarten, East Elevation

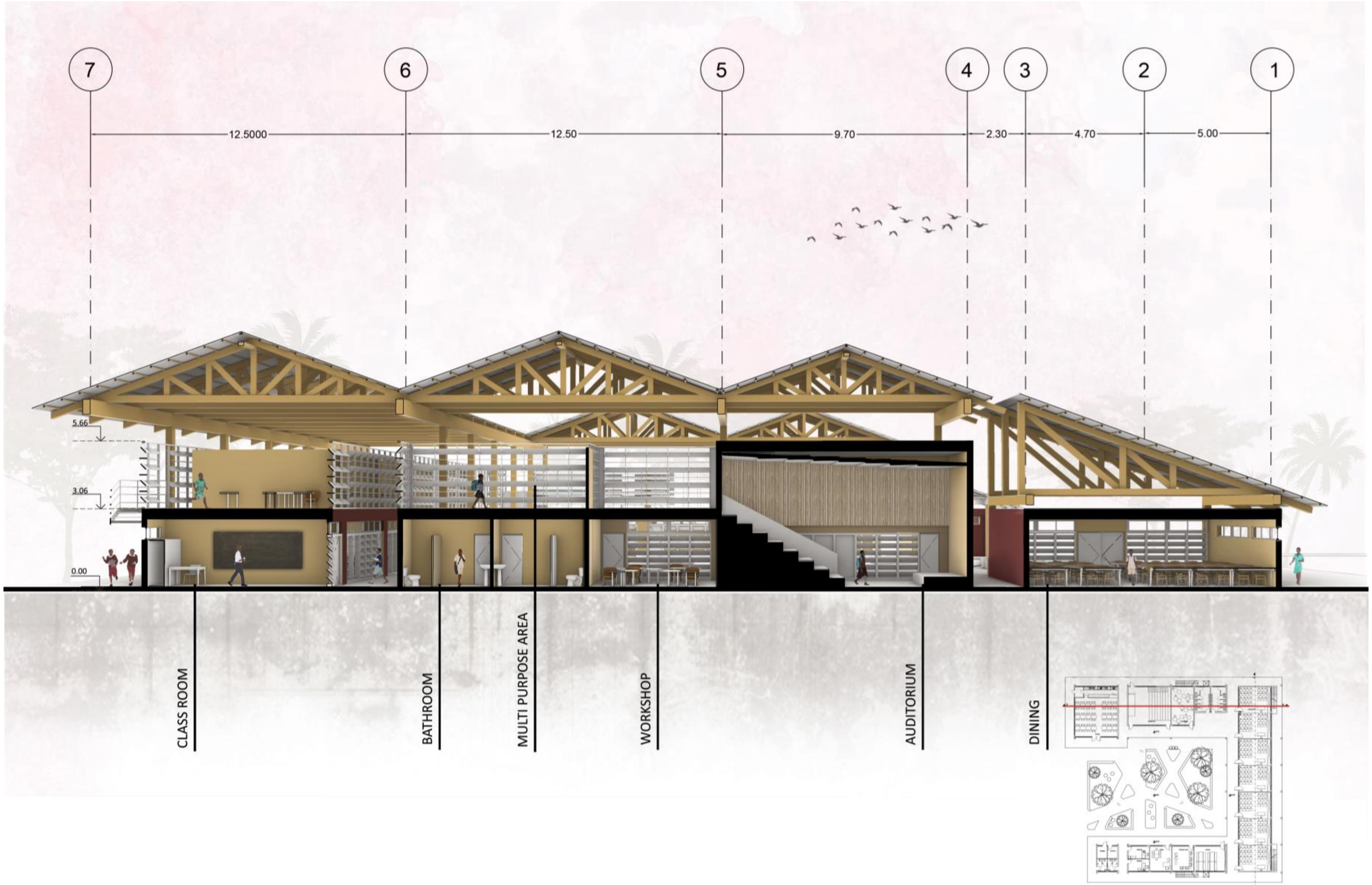


Kindergarten, West Elevation

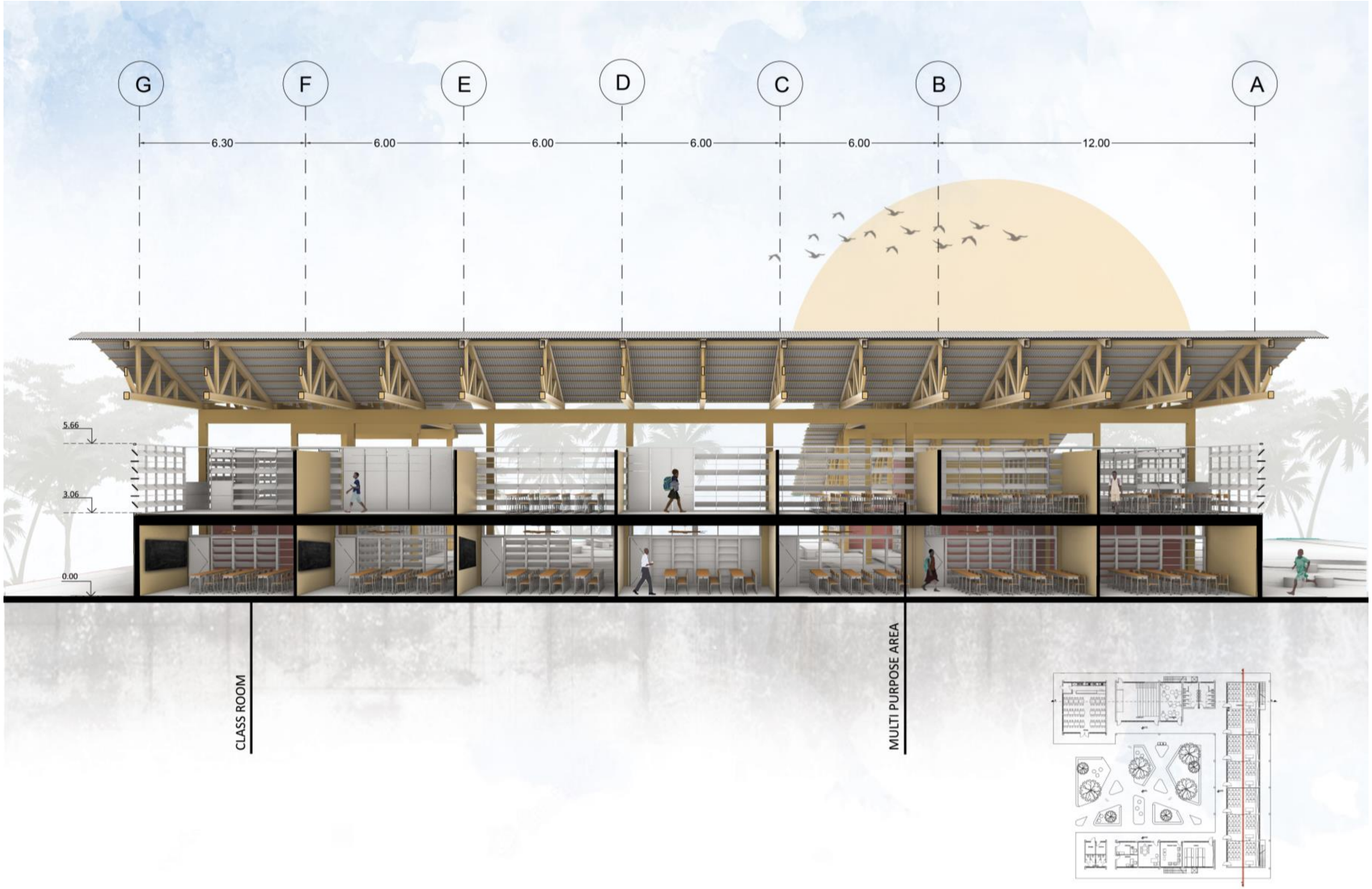
3.8.SECTIONS



Kindergarten, East section



Primary school, North section



Primary school, East section

3.9. EXTERIOR

Bird view

Primary School

Primary School

Primary School

Kindergarten

Kindergarten

3.10. INTERIOR

Primary Classroom


PERIODIC TABLE OF ELEMENTS

Library

Kindergarten play room

Auditorium

Multipurpose area

CHAPTER4: TECHNICAL STUDY

4.1. STRUCTURE

The typical buildings structure in Moshi are low-rise buildings with pitched roofs and mud-brick wall with wooden post and beam. We decided to have wooden prefabricated units with wooden truss pitched roof. The roof will be double skinned metal roofs which are highly reflective and ventilated, making them an ideal choice for high-performance roofing. They are two metal sheets layered on top of each other with the provision of a central gap for insulation and vapor gap. The heat is absorbed and then emitted back to the atmosphere consistently by natural convection. This hence makes an excellent passive cooling option for roofing. In current calculations, Eurocode 1 and Eurocode 5 are used as the foundational design standards. Eurocode 1 provides comprehensive guidance on the actions and loadings that structures may experience, ensuring accurate consideration of various forces such as wind, snow, and live loads. Simultaneously, Eurocode 5 offers essential specifications for the design of timber structures, encompassing factors like material properties, design methodologies, and structural integrity. By integrating these two Eurocodes, the calculations aim to ensure the safety, durability, and overall efficiency of the structural design while adhering to internationally recognized standards.

Design Codes

l EN1990: 2002, Eurocode 0 Part 1-1, Basis of structural design.

l EN1991-1-1: 2002 Eurocode 1 Part 1-1, Actions on structures.

l EN1991-1-4: 2005 Eurocode 1 Part 1-4, Wind actions.

l EN1995-1-1:2009, Eurocode 5 Part 1-1, Design of timber structures.

Material Properties (EC5 EN1995-1-1:2009)

Timber class C24

Service class: Class 1

Moisture content: 12% EC5 2.3.1.3

Material Factor γM 1.3 EC5 Table 2.3

Characteristic Material Properties for timber

fmk	24 MPa	ft0k	14.5 MPa	ft90k	0.4 MPa
fc0k	21 MPa	fc90k	2.5 MPa	fvk	4 MPa
E0m	11000 MPa	E005	7400 MPa	E90m	370 MPa
Gm	690 MPa	ρK	350 Kg/m2	ρm	420 Kg/m2

Span of Truss	12.5m
Height of truss	2.5m
Roof Pitch	22
Truss Spacing	3m
Purlin Spacing	0.75m
Purlin Cross section	50x50mm

4.1.1. LOAD ANALYSIS

Distributed loads on Roof		
Permanent Load of Roof covering (Ge)	0.18 kN/m2	Corrugated sheets Ge+Gt 0.28
Purlins, Finishes and Insulations (Gt)	0.10 kN/m2	
Snow load (Sk)	0.00 kN/m2	
Wind Pressure on vertical surfaces (Qw)	1.72 kN/m2	
Imposed loads (Qi)	0.40 kN/m2	

Wind Loading (EC1 EN1991-1-4: 2005 §5)

vbo	3.7 m/s		H= 50Estimated Value
Terrain cartegory	III		
z	6.9 m	(EN 1991-1-4:2005 7.2.5)	
zo	0.3 m		Lu= 600
zmin	5 m	(EN 1991-1-4:2005 Table 4.1)	
zmax	200 m		
zoII	0.05 m	(EN 1991-1-4:2005 Table 4.1)	
Kr	0.22 m		
Cr	0.68 m		
H/Lu(Φ)	0.08		
Le	600	(0,05 < Φ< 0,3)	
Known that:			
z=	50 m		
X=	400 m	Estimated values	
X/Le	0.67		
z/Le	0.10		
A	0.84		
B	(2.56)		
C	0.36		
s	0.83	(EN 1991-1-4:2005 A.7)	
Co(z)	1.14	(EN 1991-1-4:2005 A.1-3)	
Kt	1.00	(EN 1991-1-4:2005 4.7)	
Vb	3.7		

σv	0.80	Lv(Zmin)	
Lv(z)	0.28	(EN 1991-1-4:2005 4.7)	
Vm(z)	2.85	(EN 1991-1-4:2005 Table)	
qp(z)	0.0150 kN/m2	(EN 1991-1-4:2005 4.8)	Density of air 1.25 Kg/m3
qb	0.0086 kN/m2	(EN 1991-1-4:2005 4.10)	
Ce(z)	1.7508	(EN 1991-1-4:2005 4.9)	
q(z)	0.01498 kN/m2		

Wind Load Negligible due to low value of Vb

The external pressure coefficient c pe for each of zones A, B, C, D, E is defined in EN1991-1-4 Table 7.1 as a function of the ratio h /d . For the examined case: h /d = 6.700 m / 12.600 m = 0.532. Moreover, for the examined case the pressure coefficient c pe,10 is examined that corresponds to the wind effects on loaded areas in the order of 10m2 that are appropriate for global effects of the structure.

The external pressure coefficients are divided into overall coefficients c pe,10 and local coefficients c pe,1 as described in EN1991-1-4 §7.1.1(1) and §7.2.1(1) . Local coefficients c pe,1 correspond to wind pressure for loaded areas ≤ 1m2 and they may be used for the design of small elements and fixings with an area per element of 1m2 or less such as cladding elements and roofing elements. Overall

coefficients c pe,10 correspond to wind pressure for loaded areas ≥ 10m2 and they may be used for the design of the overall load bearing.

According to EN1991-1-4 §7.2.1(1) for intermediate loaded areas A between 1m2 and 10m2 the external pressure coefficient c pe may be calculated between the values c pe,1 and c pe,10 with logarithmic interpolation as follows:

c pe = c pe,1 - (c pe,1 - c pe,10)·log10A

In the examined calculation the provided external pressure corresponds to coefficient c pe,10 i.e. the results are applicable for global verifications.

Pressure zones and external pressure coefficients:

The wind load on the structure is expressed in terms of external pressure coefficients for five zones A, B, C, D, E as defined in EN1991-1-4 Figures 7.4 and 7.5 that are reproduced above. The extent of the zones depends on the length e that is defined as:

e = min(b , 2h) = min(10.000 m, 2 · 6.700 m) = 10.000 m

Wind Pressure on Roof Surface

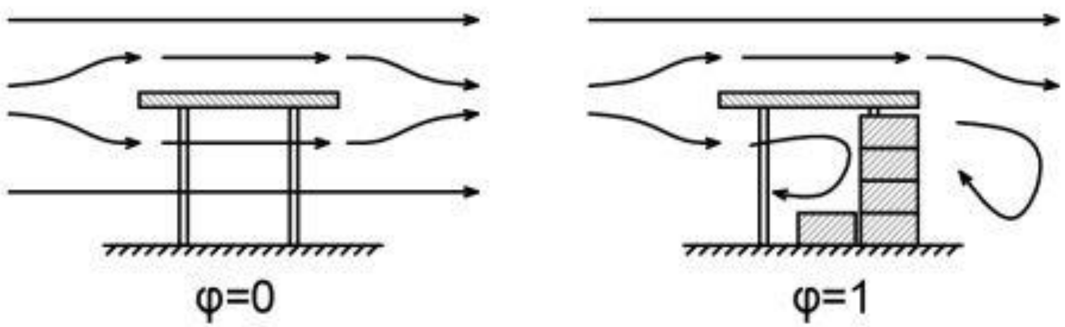
Cp(+) 0.48 (EN 1991-1-4:2005 Table 7.4)

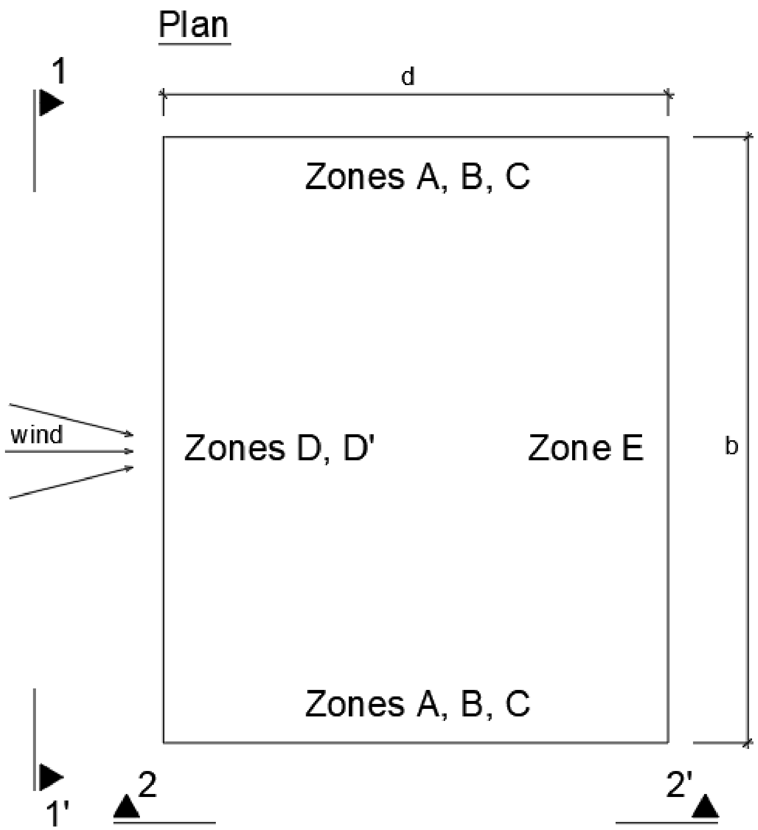
Cp(-) -0.52

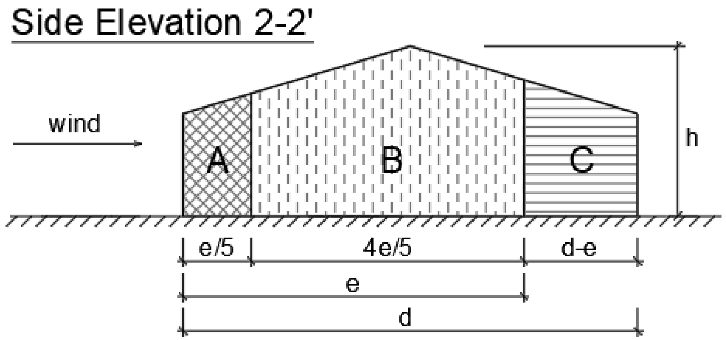
θ 22.00 degrees Design Data

Wind Pressure We (Left) 0.007190389 kN/m

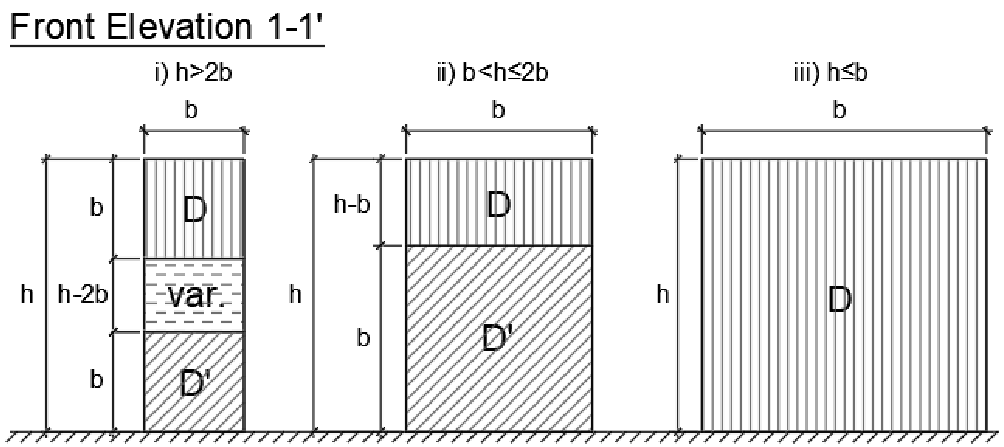
Wind Pressure We (right) (0.00778959) kN/m




Plan
1
d
Zones A, B, C
wind
Zones D, D'
Zone E
b
Zones A, B, C
1'
2
2'


Side Elevation 2-2'
wind
A
B
C
h
e/5
4e/5
d-e
e
d

e=min(b, 2h)

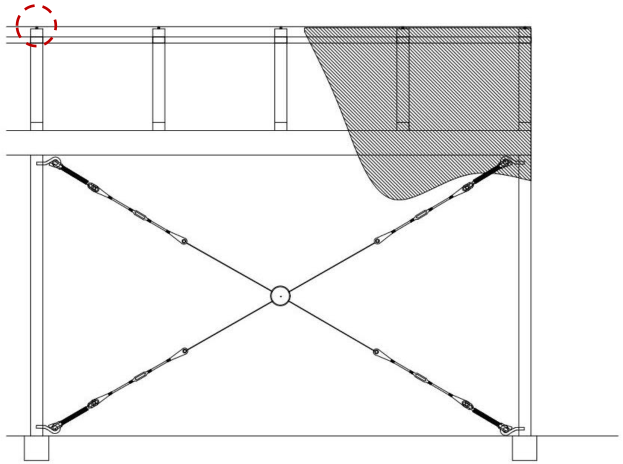

Front Elevation 1-1'
i) h>2b
ii) b<h≤2b
iii) h≤b
b
b
b
D
var.
D'
h
h-2b
b
b
D
D'
h
h-b
b
D
h

4.1.2. PURLIN

A wood purlin is a horizontal supporting element utilized for the support of roof rafters or the roof covering. Purlins provide support and stability to the roof structure, helping to distribute the weight of the roof load evenly and prevent deflection. The purlins will be designed as simply supported beams with a lengths span of 6m equal to the distance between the trusses, The purlins are loaded with a surface load of width 0.75m equal to the purlin spacing inclined at an angle of 22.

Purlin dimensions:

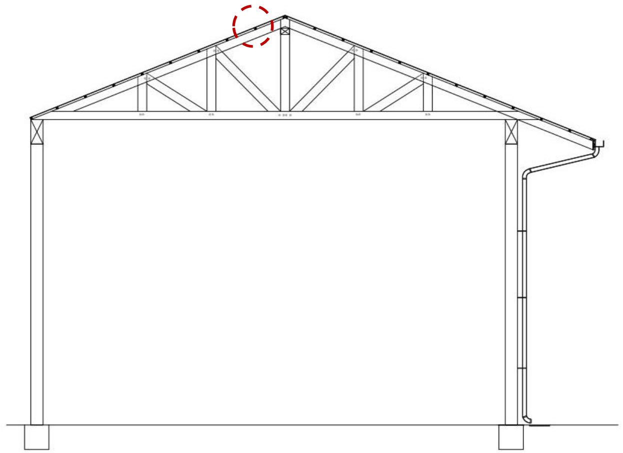
Class	C24
Moisture content:	12%
Base (B)	50 mm
Height (H)	100 mm
Truss spacing	3 m
Purlin Spacing	0.75 m
Roof Pitch	22



UNIFORM LOADING OF PURLINS :

Permanent Load of Roof covering (Ge)	0.18 kN/m2
Finishing and self weight	0.10 kN/m
Snow load(Sk)	0.00 kN/m
Wind load (Qw)	0.01 kN/m
Imposed loads (Qk)	0.40 kN/m

EN 1991-1-1:2002 Table 6.10



Load type	Load	Gkz	Gky
Permanent Load of Roof covering (Ge) +Finishing and self weight	0.21	0.19	0.079
Snow load (Qks)	0.00	0.00	0.00
Wind load (Qkw)	0.01	0.01	0.00
Imposed loads (Qkp)	0.30	0.28	0.11

Internal Forces									
Load type	Load	Action	γg	γq	ψo	Qz (kN)	Qy (kN)	Mz(kN)	My(kN)
Permanent Load of Roof covering (Ge) +Finishing and self weight	0.21	Permanent	1.35	0	1.00	0.29	0.12	0.22	0.09
Snow load(Qks)	0.00	Permanent	1	0	0.50	0.00	0.000	0.00	0.00
Wind load (Qkw)	0.01	short term	0	1.5	0.60	0.01	0.004	0.01	0.00
Imposed loads (Qkp)	0.30	Instantaneous	0	1	0.00	0.42	0.169	0.31	0.13

note:

The values of ψo can be obtained in the design code EN 1990:2002+A 1 :2005 Table A1.1

The values of ψo can be obtained in the design code EN 1990:2002+A 1 :2005 Table A1.2

SERVICEABILITY LIMIT STATE EN1995-1-1:2009

Known that:

Modulus of elasticity mean (N/mm2) 10,800 N/mm2

"Moment of Inertia I for a rectangle with height ""h"" and width ""b"":

I = (b * h^3) / 12 4166666.667 mm4

Deflection control: The deflection check is a crucial aspect of structural analysis to ensure the integrity and safety of a design. It involves assessing how much a structural element or system bends or flexes under various loads and conditions.

$$\delta max = \frac{5}{384} * \frac{(g+q)*L^4}{E*I}$$

LOAD TYPE	Load (kN/m)	u(mm)	Action	ψo	ψ1	ψ2	kdef
Permanent Load of Roof covering (Ge)	0.19	4.563	Permanent	1.00	1.00	1.00	0.6
Snow load(Qk1)	0.00	0.00	Permanent	0.50	0.20	0.00	0.6
Wind load (Qk2)	0.01	0.17	short term	0.60	0.20	0.00	0.6

Loading Combination	w.inst	w.fin(mm)
Gk	4.563	7.302
Gk+Qk1	4.56	7.302
Gk+Qk2	4.733	7.403
Gk+Qk1+ψoQk2	4.665	7.363
Gk+Qk2+ψoQk1	4.733	7.403

Final Deflection Check EN 1995-1-1 :2009 table 7.2

w.inst 4.73 < 10 OKAY

w.fin(mm) 7.40 < 20 OKAY

w.net.fin (mm) 7.40 < 12 OKAY

Check of purlins, ultimate Limit state of design (EC5 EN1995-1-1:2009, §6)

Loading Combination	Duration Class	Qz	Qy	Mz	My
γg*Gk	Permanent	0.39	0.16	0.30	0.12
γg*Gk+γq*Qk1	Short-term	0.39	0.16	0.30	0.12
γg*Gk+γq*Qk2	Short-term	0.41	0.17	0.31	0.12
γg*Gk+γq*Qk3	Instantaneous	0.81	0.33	0.61	0.25
γg*Gk+γq*Qk1+γq*ψoQk2	Short-term	0.40	0.16	0.30	0.12
γg*Gk+γq*Qk2+γq*ψoQk1	Short-term	0.41	0.17	0.31	0.12

According to the Load combinations, the maximum is attained with the combination γg*Gk+γq*Qk3

Shear Check		
Fv	0.81 kN	
Rectangular cross section.		
Kcr =	0.67	EN 13986 and EN 14374.
h	100 mm	
bef(mm)	33.5 mm	EN 1995-1-1 :2009 6.13(a)
Area A(mm2)	3350 mm2	
Modification Factor kmod	1.10	EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3	EN 1995-1-1 :2009 table 2.3
fvk (solid wood C24)	4 N/mm2	
fvd	3.38 N/mm2	EN 1995-1-1 :2009 2.14
Ꞇvod	0.36	
Shear Check	**Check Satisfied**	

Fv	0.33	
Rectangular cross section.		
Kcr =	0.67	EN 13986 and EN 14374.
h	100 mm	
bef(mm)	33.5	EN 1995-1-1 :2009 6.13(a)
Area A(mm2)	3350 mm2	
Modification Factor kmod	1.10	EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3	EN 1995-1-1 :2009 table 2.3
fvk (solid wood C24)	4 N/mm2	
fvd	3.38	EN 1995-1-1 :2009 2.14
Ꞇvod	0.15	
Shear Check	**Check Satisfied**	

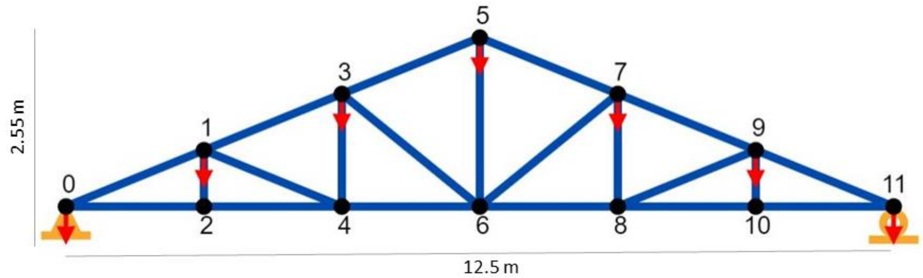
Bending Check		
Myd	0.25	EN 1995-1-1 :2009 §6.1.6
Mzd	0.61	
Rectangular cross section.	5000 mm2	
Wy	8.33E+04 mm3	
Wz	8.33E+04 mm3	
Modification Factor kmod	1.1	EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3	EN 1995-1-1 :2009 table 2.3
fmyk	24 N/mm2	

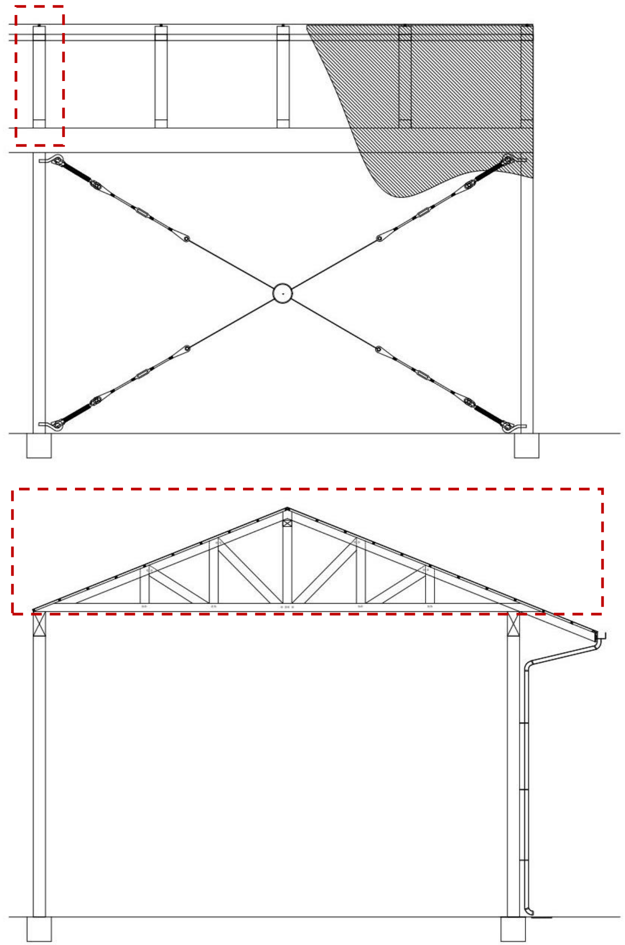
fmzk	24 N/mm2	
fmyd	20.31 N/mm2	
fmzd	20.31 N/mm2	
Rectangular cross section. Km	0.7	EN 1995-1-1 :2009 §6.1.6(2)
omyd	2.95 N/mm2	
omzd	7.30 N/mm2	
omyd/fmyd+km*omzd/fmzd	0.30	
km.omyd/fmyd+omzd/fmzd	0.46	
Bending Check	**Check Satisfied**	

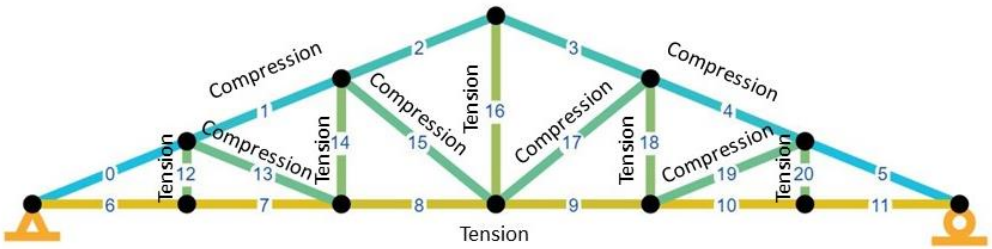
4.1.3. TRUSS

Calculating wood trusses involves determining the dimensions, member sizes, and load-carrying capacities of the individual components that make up the truss system. These components typically include top and bottom chords, webs, and any bracing or reinforcement.

Length L	12.5	m
Height (H)	2.5	m
Truss spacing	3	m
Roof Pitch (θ)	22	degrees
Tan (θ)	0.40	
Sin (θ)	0.37	
Cos (θ)	0.93	
Numbers of nodes	12	
Numbers of Elements	21	
Supports	2	







LOADS PER TRUSS	
Timber density	350 kg/m3
Truss self weight	1.42 kN
Truss pacing	3
Weight of truss connections	-

Permanent line loads(kN/m)	
Permanent Load of Roof covering +Finishing and self weight(Gk1)	13.43 kN
Wind Load (Gk2)	0.09 kN

Loads as provided	
Total Load on Top code	13.43 kN
Total wind load	0.09 kN
Imposed loads (Qkp)	5.11
Rl=Rr	84.61 kN

Loads at panel point	
Dead load	2.24 kN
Wind load	0.02 kN
Imposed loads (Qkp)	0.85 kN

Checking for Compression of Members : Consider the member at maximum Compression for sizing.		
Condition 1		
σc,0,d<fc,0,d		
f,c,0,d	21.00 N/mm2	

σc,0,d	7.49 N/mm2		
Check	**Check Satisfied**		
Condition 2			
σc,90,d<kc,90*fc,90,d			EN 1995·1 ~1 :2009 §6.1.5
f,c,90,d	2.12	N/mm2	
σc,90,d	1.82		EN 1995·1 ~1 :2009 6.4
kc ,90	1.25		
kc ,90*f,c,90,d	2.64		
Fc,90,d	1236600		
L contact	2260	mm	
Aef	678000	mm2	
Check	**Check Satisfied**		
Checking for Tension of Members : Consider the member at maximum Tension for sizing.			
Condition			
σt,0,d<ft,0,d			
f,t,0,k	14.5	N/mm2	
f,t,0,d	12.27	N/mm2	
σt,0,d	6.98	N/mm2	
Modification Factor kmod	1.1		EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3		EN 1995-1-1 :2009 table 2.3
fcok	21	N/mm2	
Check	**Check Satisfied**		

4.1.4. BEAM

Considering a section of a beam simply supported on columns at the spacing of 6m apart.

Construction Type :

Timber beam class C24

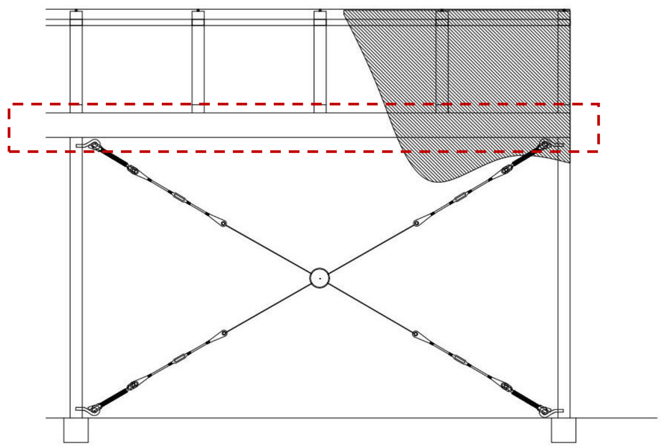
Beam length 6 m

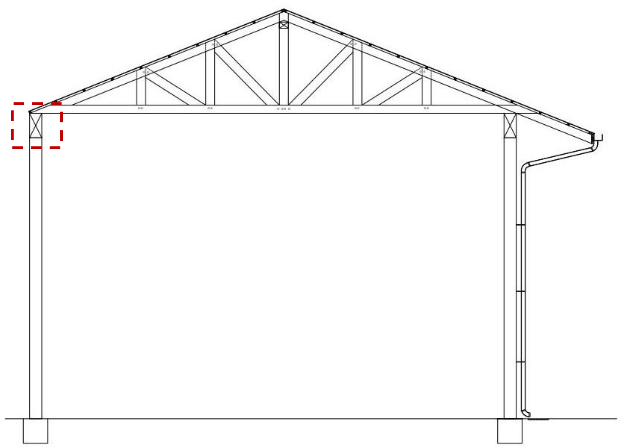
Beam base 300 mm

Beam height 650 mm

Lateral restrictions of Beam 2 m

Density of C24 4.2 kN/m3





Line loads (kN/m)	
Permanent Load	1.319 kN/m
Dead load	84.61 kN
Live load	0 kN/m

Rectangular cross section	195000 mm2
I = (b * h^3) / 12	6.87E+09 mm4
W	2.11E+07 mm3
Beam self weight	0.819 kN/m
Mmax	3.686
Qmax	2.457

considering Point load at the center then Maximum Moment would change as follows:

Mmax=P×L/4 126.91 kN

Support reactions 42.30 kN

Known that:

Modulus of elasticity mean (N/mm2) 10,800 N/mm2

"Moment of Inertia I for a rectangle with height ""h"" and width ""b"":

I = (b * h^3) / 12 6865625000 mm4

Deflection: $$\delta\text{max} = \frac{5}{384} * \frac{(g+q)*L^4}{E*I}$$

LOAD TYPE	Load (kN/m)	u(mm)	Action	ψo	ψ1	ψ2	kdef
Permanent Load +Dead load	85.93	19.555	Permanent	1.00	1.00	1.00	0.6
Live load	0.00	0.000	Instantaneous	0.70	0.50	0.30	0.6

Loading Combination	w.inst	w.fin(mm)
Gk	19.56	31.288
Gk+Qk1	19.56	31.288

Maximum deflection values.

w.inst w.fin(mm) Wc

19.56 31.29 not applied.

Final Deflection Check EN 1995-1-1 :2009 table 7.2

w.inst	19.56	<	20	OKAY
w.fin(mm)	31.29	<	40	OKAY
w.net.fin (mm)	23.47	<	24	OKAY

ULTIMATE LIMIT STATE EN1995-1-1:2009

Loading Combination	Action	γg	γg	ψo
92.521	Permanent	1.3	0.00	1.00
0	Medium term	0	1.50	0.70

Loading Combination	Ved	Med	Duration Class	kmod	V/Kmod	M/Kmod
γg*Gk	360.830	541.245	Permanent	0.6	601.38	902.08
γg*Gk+γq*Qk1	360.830	541.245	Medium term	0.9	400.92	601.38
Max	360.83	541.25			601.38	902.08

Shear Check		
Fv	216.50 kN	
Rectangular cross section.		
Kcr =	0.67	EN 13986 and EN 14374.
h	650 mm	
bef(mm)	201 mm	EN 1995-1-1 :2009 6.13(a)
Area A(mm2)	130650 mm2	
Modification Factor kmod	0.90	EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3	EN 1995-1-1 :2009 table 2.3
fvk (solid wood C24)	4 N/mm2	
fvd	2.77 N/mm2	EN 1995-1-1 :2009 2.14
Ꞇvod	2.49	
Shear Check	**Check Satisfied**	

Bending Check		
Myd	487.12	EN 1995-1-1 :2009 §6.1.6
Mzd	324.75	
Rectangular cross section.	195000 mm2	
Wy	2.11E+07 mm3	
Wz	2.11E+07 mm3	
Modification Factor kmod	0.90	EN 1995-1-1 :2009 table 3.1
Material Factor γM	1.3	EN 1995-1-1 :2009 table 2.3

fmyk	24 N/mm2	
fmzk	24 N/mm2	
fmyd	16.62 N/mm2	
fmzd	16.62 N/mm2	
Rectangular cross section. Km	0.7	EN 1995-1-1 :2009 §6.1.6(2)
omyd	23.06 N/mm2	
omzd	15.37 N/mm2	
omyd/fmyd+km*omzd/fmzd	0.79	
km.omyd/fmyd+omzd/fmzd	0.78	
Bending Check	**Check Satisfied**	

4.1.5. COLUMN

ULTIMATE LIMIT STATE, stability EN1995-1-1:2009 §6.3.2

a 300 mm

b 300 mm

Height of column 6900 mm

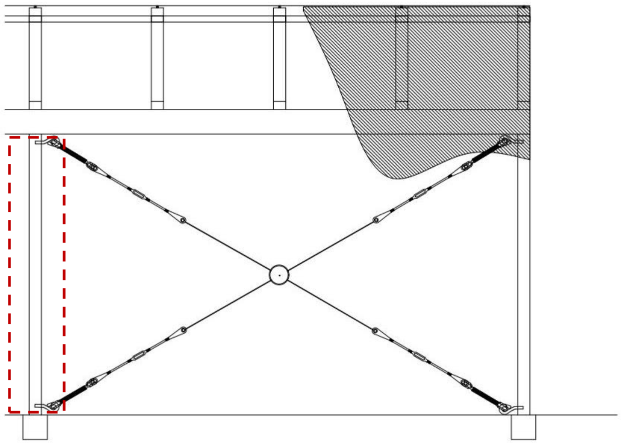
Rectangular cross section 90000 mm2

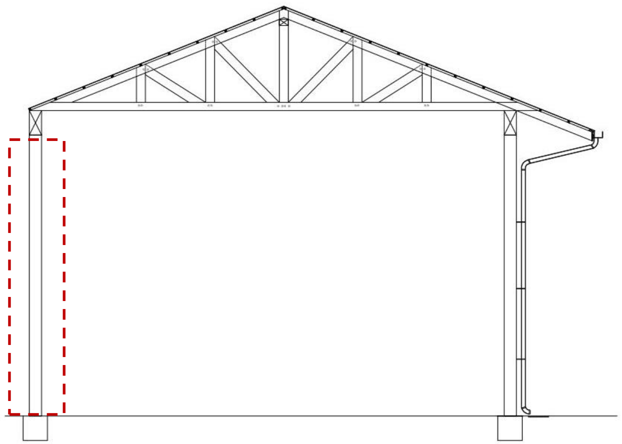
I = (b * h^3) / 12 6.75E+08

Wy 4.50E+06 mm3

Wz 4.50E+06 mm3

Modification Factor kmod	0.6	EC5 Table 3.1
Characteristic Material Properties for timber		
fc0k	21 MPa	
fmyk	24 MPa	
fmzk	24 MPa	
f,c,0,d	9.69 MPa	
fmyd	11.08 N/mm2	
fmzd	11.08 N/mm2	
E005	7400 MPa	
F,c,0,d	84.61 kN	





Column stability EN1995-1-1:2009 §6.3.2

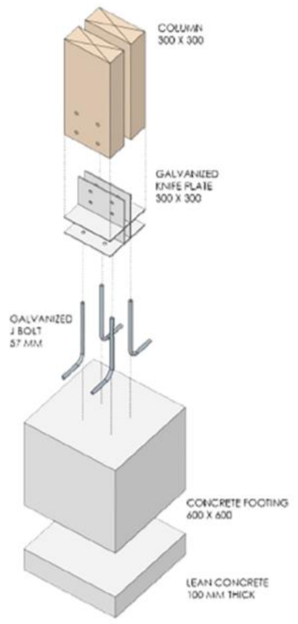
For rectangular cross sections km 0.7 EN1995-1-1:2009 §6.1.2 (2)

σc,0,d 0.94

Buckling Length	
Sky=Skz	6200 mm
Lef	5580 mm

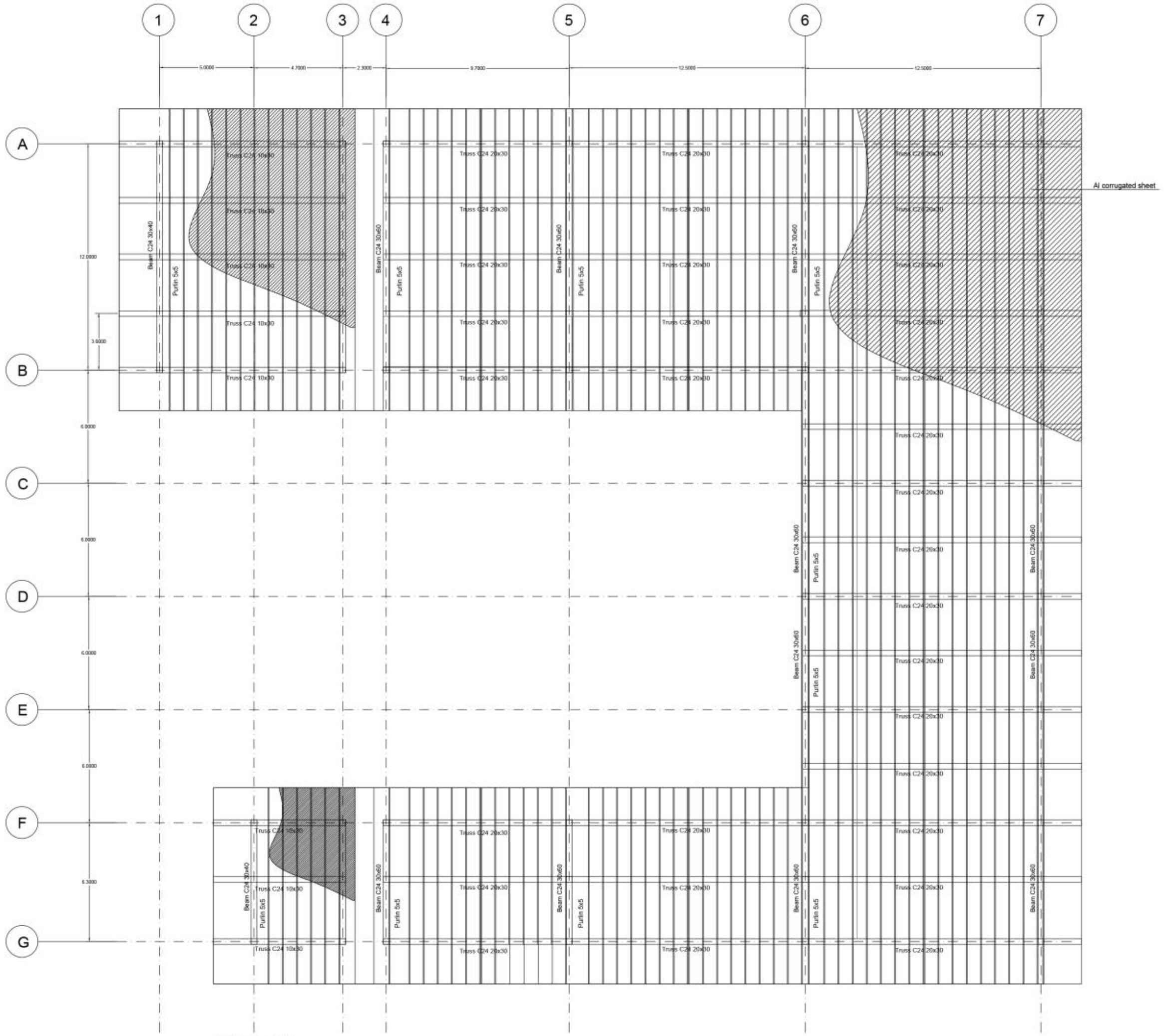
EN 1991-1-1:2002 Table 6.1

Slenderness	
Iz = (h * b^3) / 12	675000000 mm4
Iy = (b * h^3) / 12	675000000 mm4
iz= Iy/A	86.60 mm
iy= Iz/A	86.60 mm
λz	79.67
λy	79.67

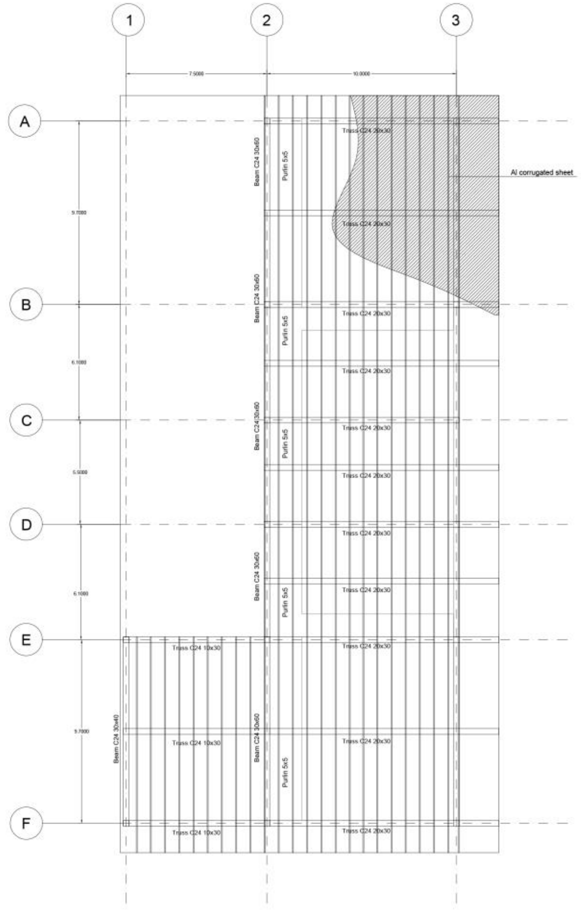


Critical stresses		
σc,crity	11.51	
σc,critz	11.51	
λrel, y	1.35	EN 1991-1-1:2002 Eq.6.21
λrel, z	1.35	EN 1991-1-1:2002 Eq.6.22
βc	0.20	EN 1991-1-1:2002 Eq.6.29
ky= 0.5 (1 + βc (λrel, y - 0,3) + λrel, y^2)	1.52	EN 1991-1-1:2002 Eq.6.27

kz= 0.5 (1 + βc (λrel, z - 0,3) + λrel, z^2)	1.52	EN 1991-1-1:2002 Eq.6.28
kcy= 1/(ky+(ky^2-λrel, y^2)^0.5)	0.45	
kcz= 1/(kz+(kz^2-λrel, z^2)^0.5)	0.45	
σc,0,d/kcy*fcod	0.21	
σc,0,d/kcz*fcod	0.21	
Check	**CHECK SATISFIED**	



Pimary

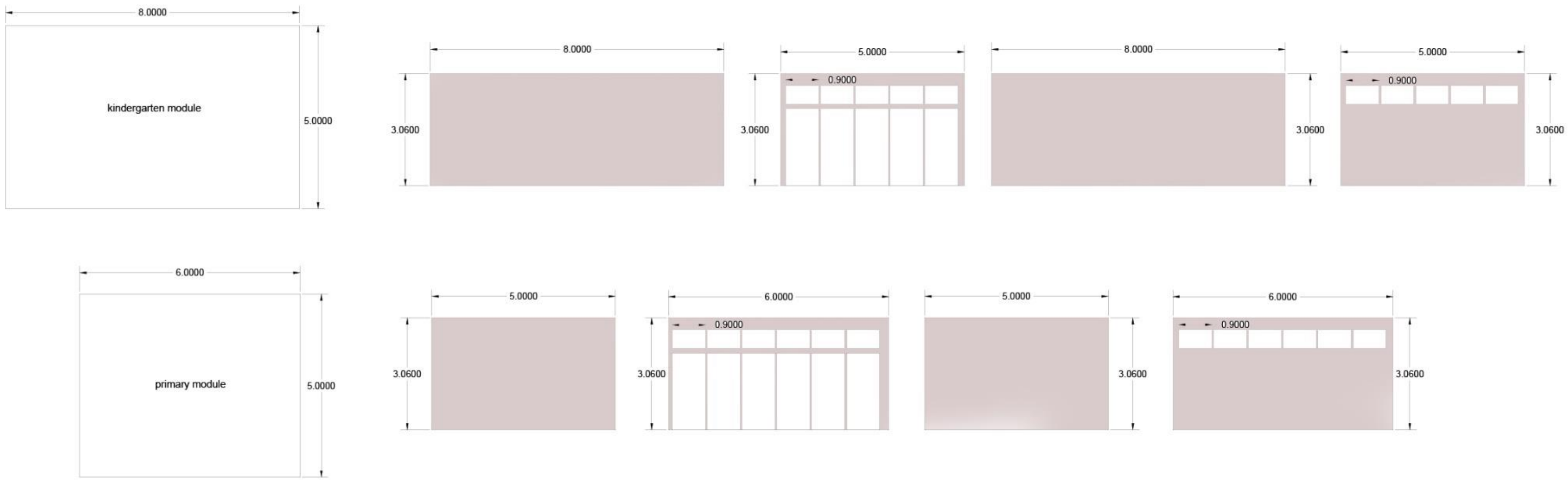


Kindergarten

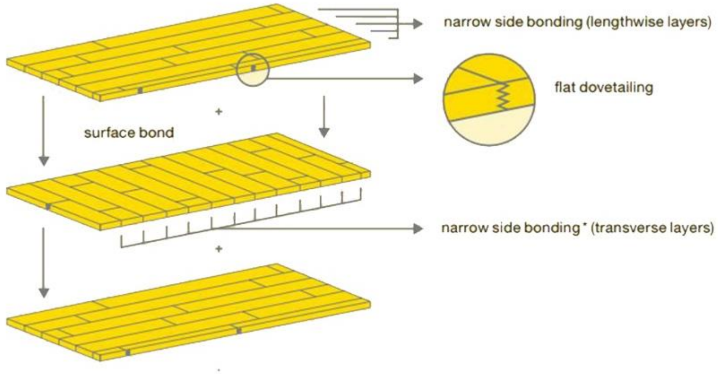
4.2. PREFABRICATED UNITS

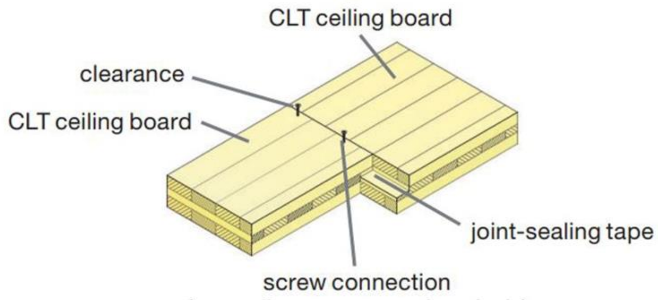
In the process, some construction methods have proven to be worthwhile and have become established. Building with wood means building for the future. While other resources are becoming rarer and more expensive, sustainable buildings with wood are becoming more and more popular. Intelligent solutions help to make buildings with wood not only environmentally friendly and financially interesting. The possibility of insulating the walls and ceilings also results in increased living comfort compared to conventional building methods in southern Africa. Presently there are over 20 engineered wood factories in Tanzania producing various EWP products including veneer sheets, plywood and marine boards, manufacturing block boards, finger-jointed boards, and fiber boards. Medium Density Fiber Board (MDF) factories in currently being established.

CLT solid wood panels are made up of at least three layers of bonded single layer panels arranged at right angles to one another. The high level of prefabrication and related short assembly times are a major advantage. It should also be borne in mind that, throughout its service life, CLT is exposed to fluctuating moisture conditions due to residual moisture from the construction of the building, moisture during the heating season and humid air in the summer. These fluctuating moisture conditions can result in a timber moisture content varying between 8% and 14% which affects CLT's vapour diffusion behavior.



Application	Structural elements for walls, floors and roofs
Maximum element dimensions	Length: 16 m / Width: 3.45 m / Thickness: 0.35 m
Invoiced widths	2.25 m / 2.45 m / 2.75 m / 2.95 m / 3.25 m / 3.45 m 3.25 m and 3.45 m only available from Gruvön mill on request
Panel lay-up	3, 5, 7 or more layers depending on structural design requirements
Wood species	Spruce (pine, fir, stone pine/larch and other wood types on request)
Strength class	C24 according to EN 338, maximum 10% C16 permitted (other strength class compare with ETA 14/0349)
Moisture of wood according to EN 13183-2	6% to 15% Within one member of CLT the moisture content shall not differ by more than 5%
Adhesive	Formaldehyde-free PUR adhesive for finger jointing and surface bonding, approved for load-bearing and non-load-bearing components indoors and outdoors according to EN 15425; Formaldehyde-free EPI adhesive for narrow side bonding
Surface quality	Non-visual quality (NVI), Industrial visual quality (IVI) and Visual quality (VI); the surfaces are always sanded on both faces
Weight	5.0 kN/m³ according to DIN 1055-2002 for structural analysis 490 kg/m³ for determination of transport weight
Fire rating	In accordance with Commission Decision 2003/43/EC: • Timber components (apart from floors) ➲ Euroclass D-s2, d0 • Floors ➲ Euroclass Dfl-s1
Thermal conductivity	0.12 W/(mK)
Air tightness	CLT panels are made up of at least three layers of single-layer panels and are therefore extremely air-tight. The air-tightness of a 3-layer CLT panel was tested according to EN 12 114
Service class	Service class 1 and 2 according to EN 1995-1-1

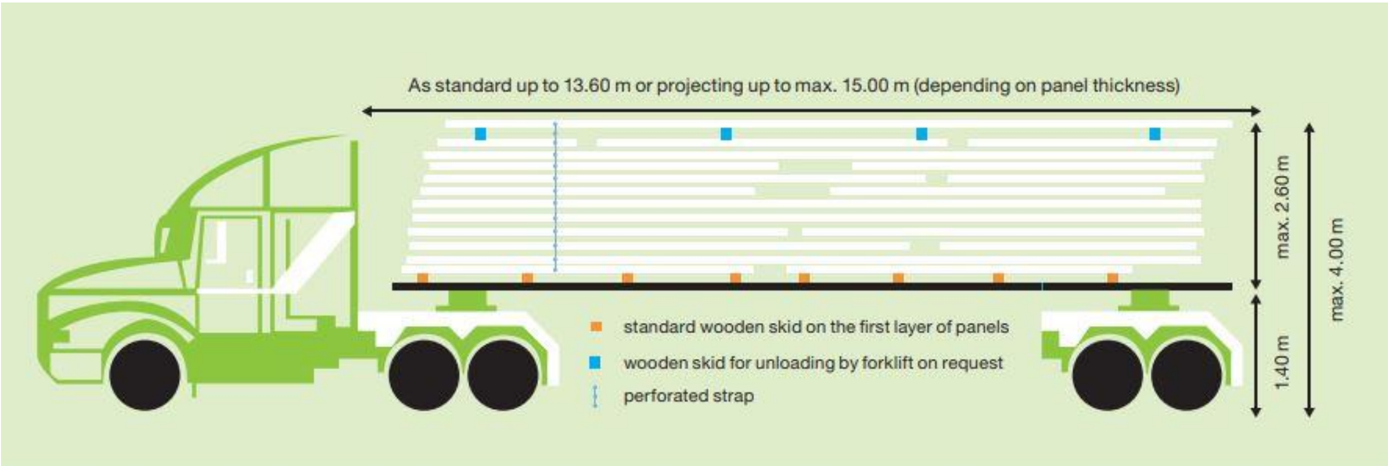


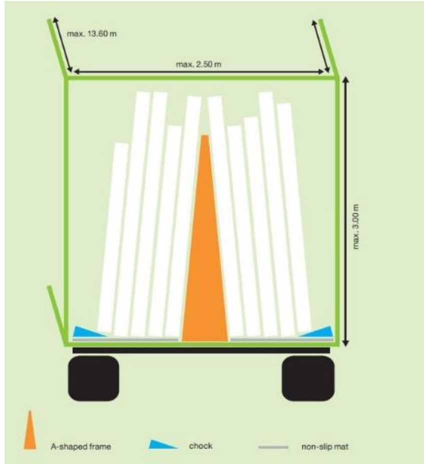


4.2.1. SHIPPING

Horizontal transport: A standard articulated trailer can be loaded up to a maximum of 25 t in the case of horizontal transport, with a maximum load length of 13.60 m and a maximum load width of 2.95 m.

Vertical transport: A mega trailer can be loaded to a maximum of 24 t in the case of vertical transport, with a max. load length of 13.50 m and a max. load height of 2.95 m.



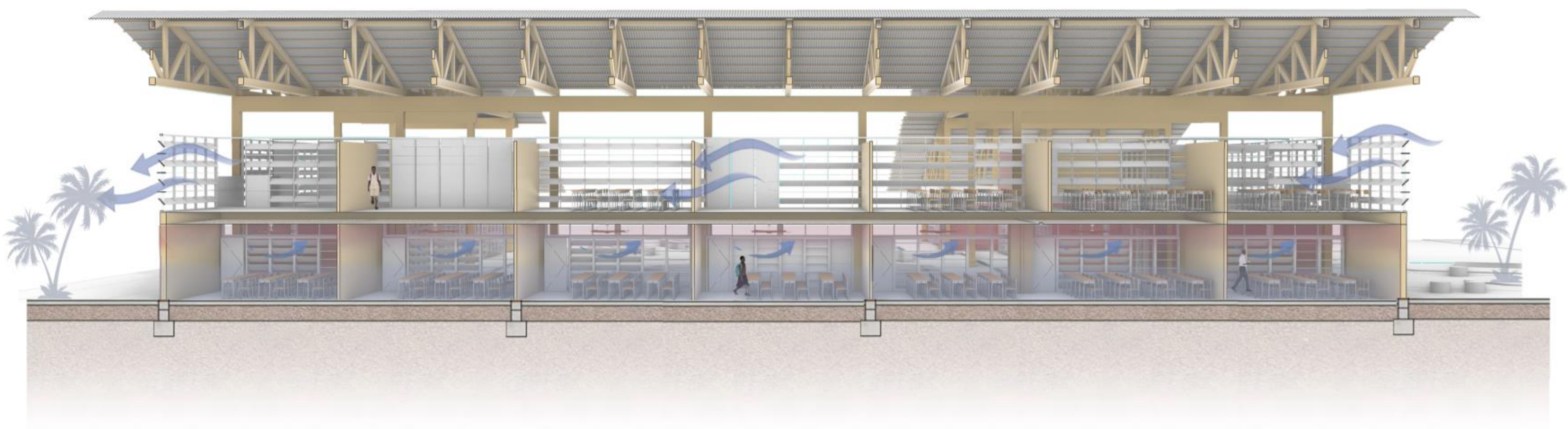


4.3. BUILDING STRATEGY DESIGN

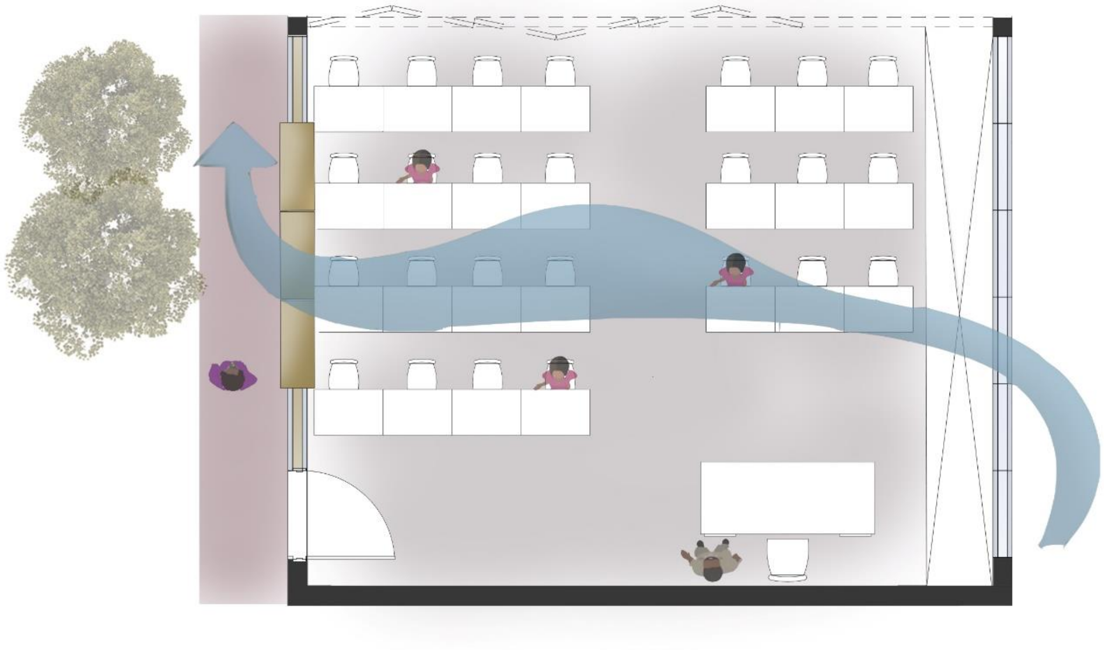
4.3.1. PASSIVE SYSTEM

Kindergarten

Primary School

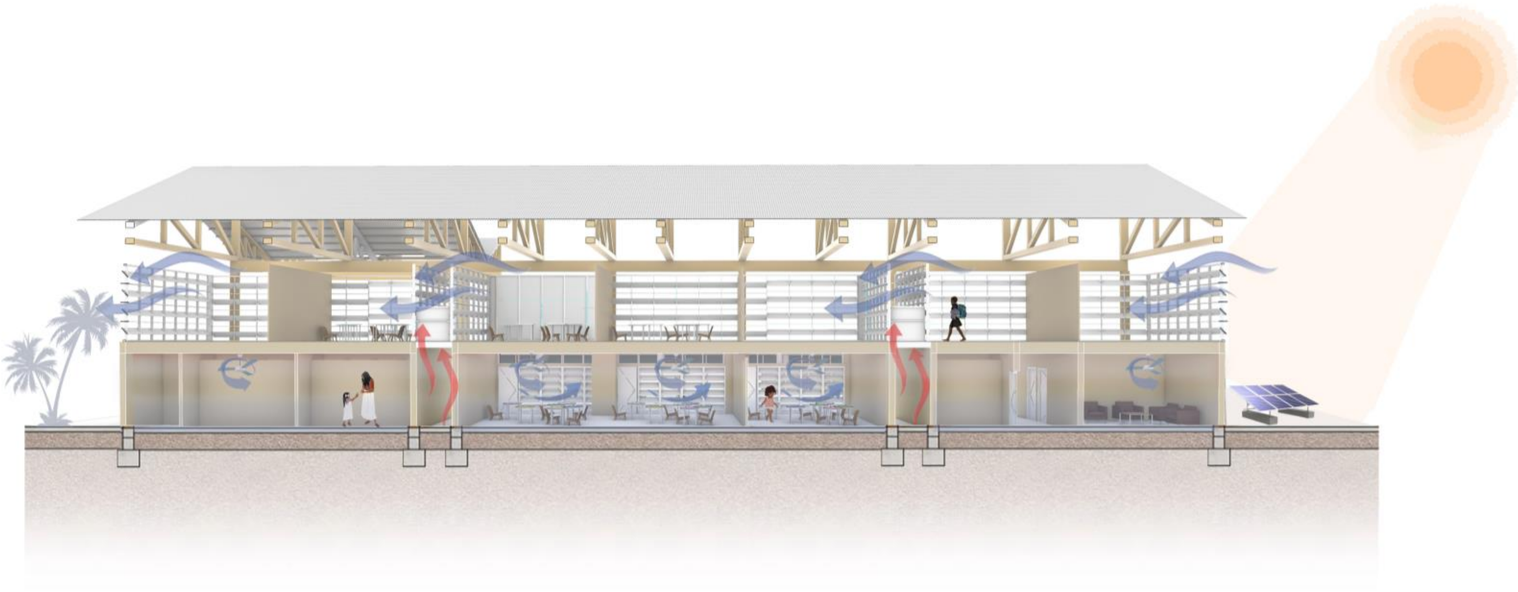


Passive ventilation strategy involves the use of natural forces such as wind, temperature differences. Cross-ventilation takes advantage of prevailing winds and temperature differences between indoor and outdoor air. It involves positioning windows or openings on opposite sides of a building to create a flow of air from one side to the other, allowing for fresh air to enter and stale air to exit. Designing buildings with adjustable louvers or operable windows allows occupants to control the amount of airflow based on their comfort needs. These elements can facilitate natural ventilation by allowing for the adjustment of air intake and exhaust.



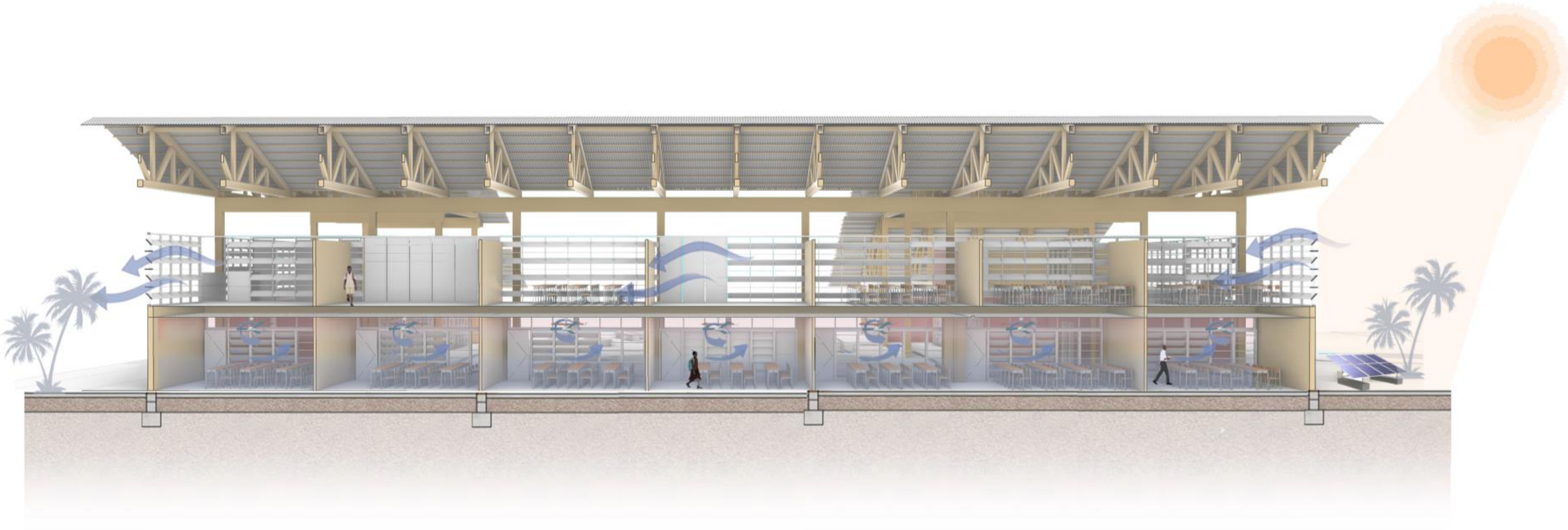
4.3.2.ACTIVE SYSTEM

Kindergarten



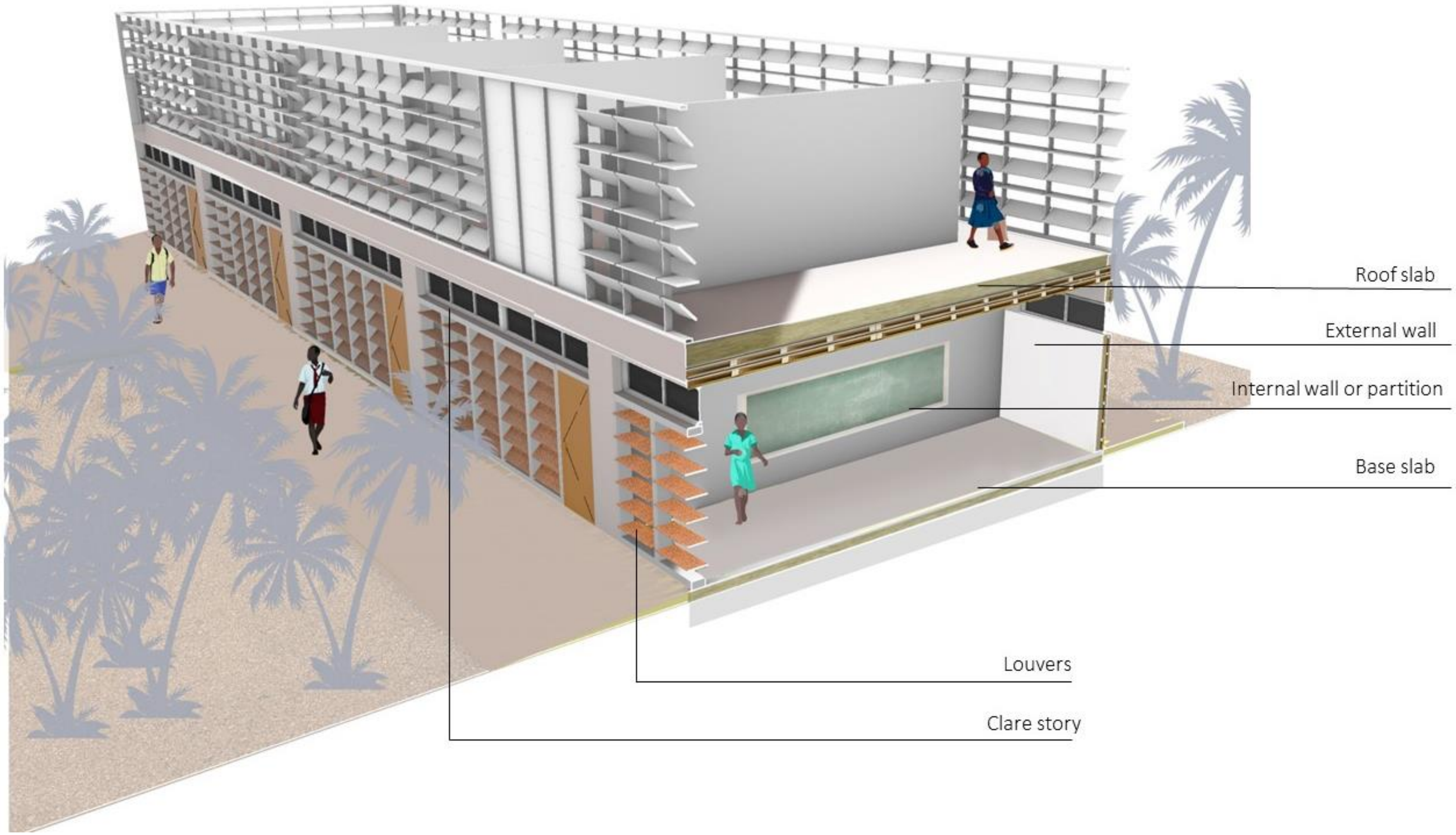
Active strategies in building design and management contribute to energy efficiency, sustainability, and occupant comfort. By using renewable energy sources like solar panels for active management of energy production and consumption and producing electricity. Using fans for increasing ventilation and cooling.

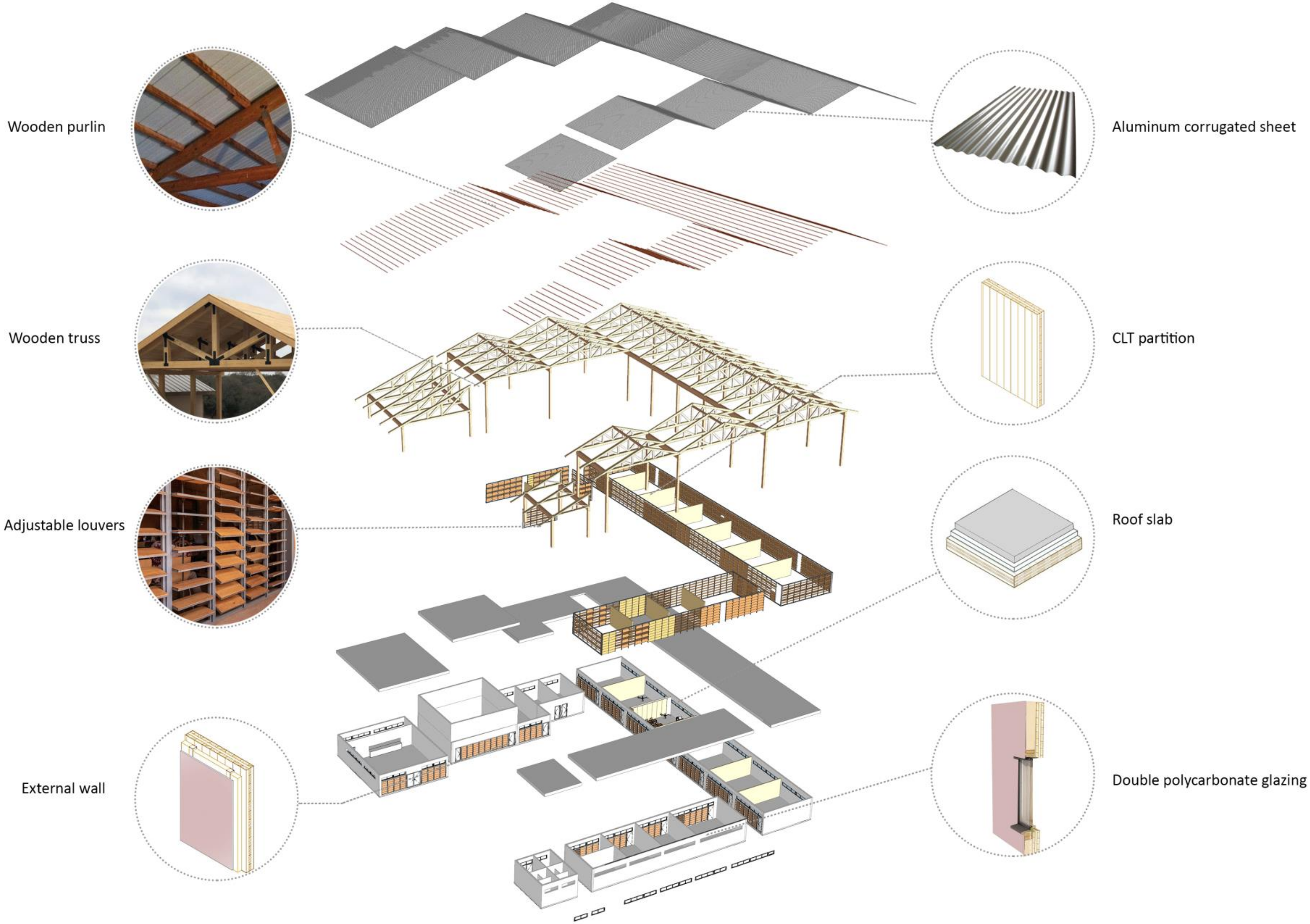
Primary School



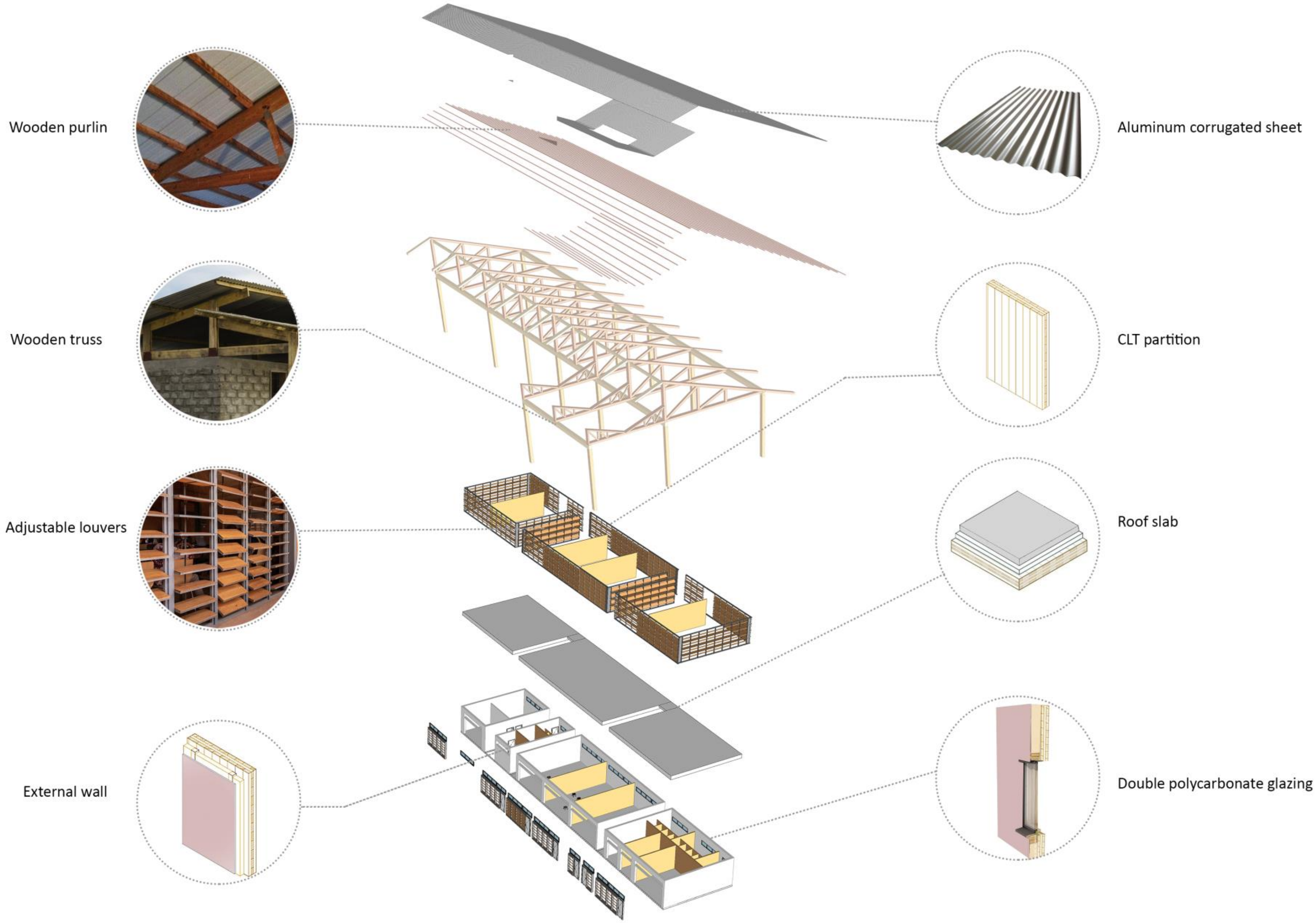
By considering PV panels in the yard of the primary school and considering the calculations it can help to save energy and produce electricity for artificial light and fans.

4.4.CONSTRUCTION COMPONENT



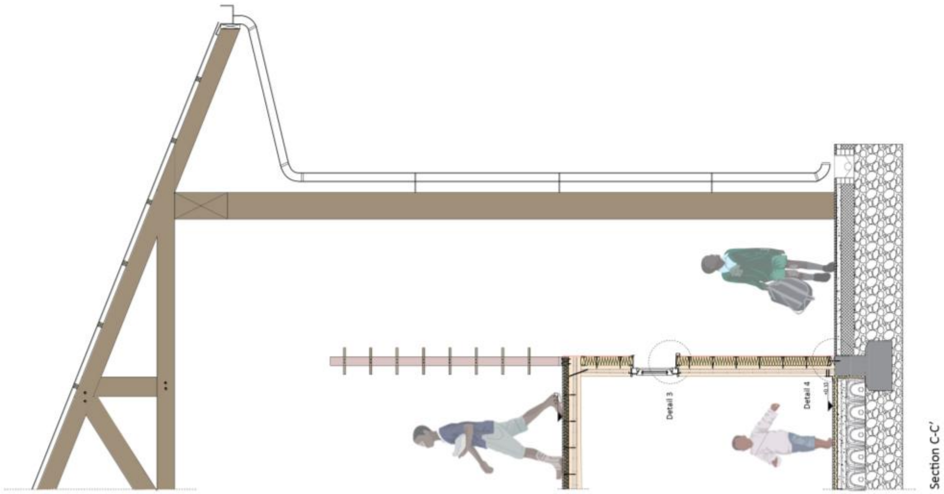


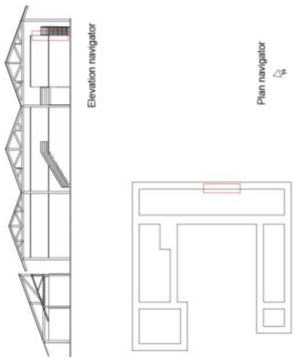
Wooden purlin
Wooden truss
Adjustable louvers
External wall
Aluminum corrugated sheet
CLT partition
Roof slab
Double polycarbonate glazing

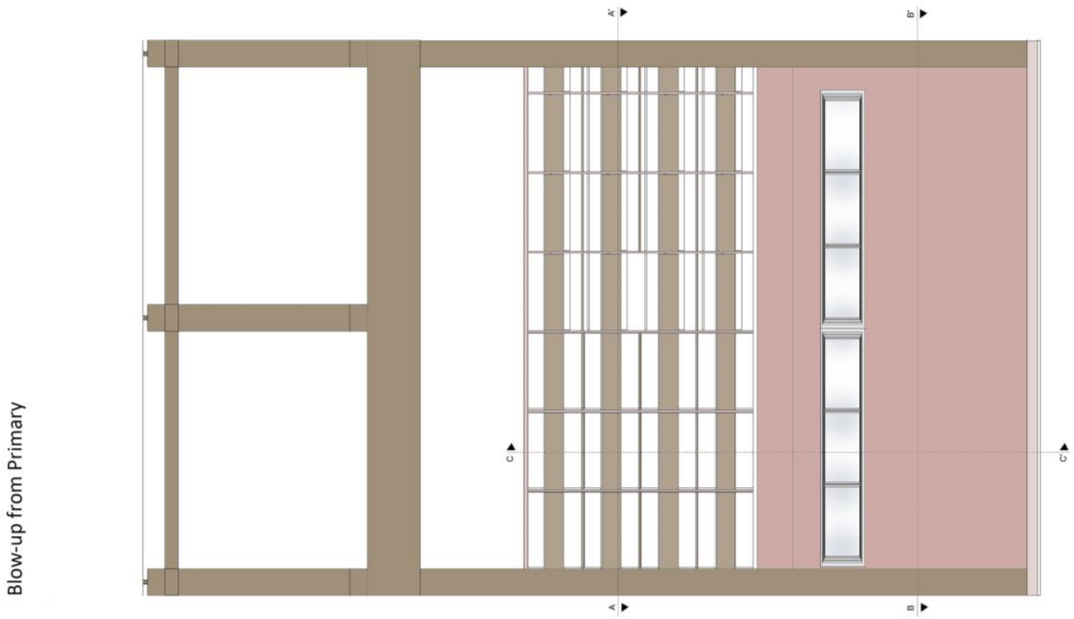


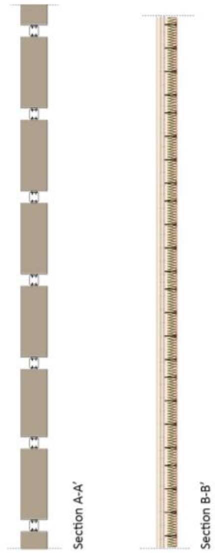
Wooden purlin
Aluminum corrugated sheet
Wooden truss
CLT partition
Adjustable louvers
Roof slab
External wall
Double polycarbonate glazing

4.4.1. BLOW UP

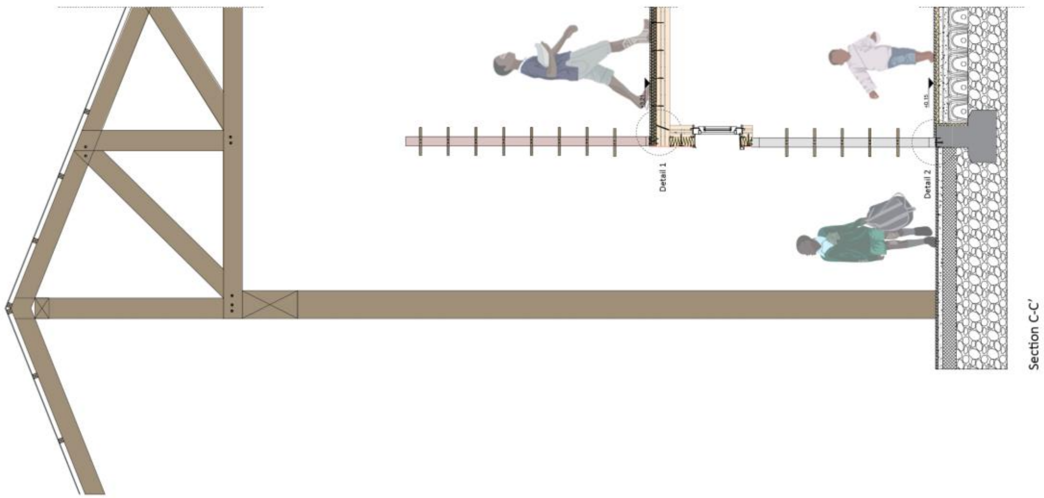

Detail 3
Detail 4
Section C-C'

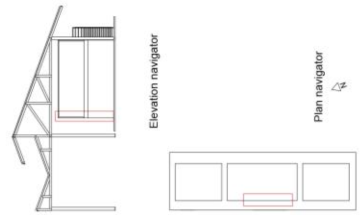

Elevation navigator
Plan navigator

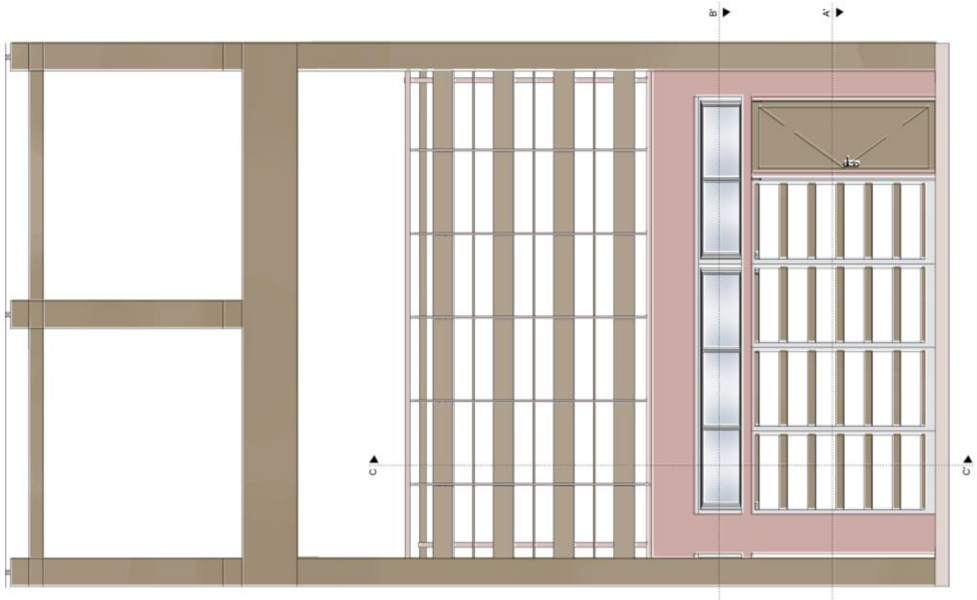

Blow-up from Primary

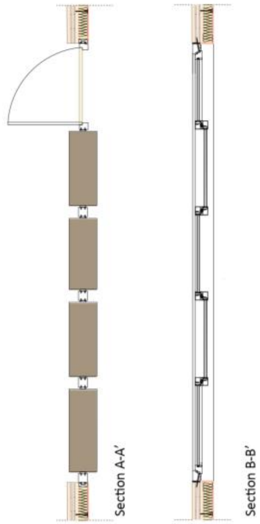

Section A-A'
Section B-B'

Blow-up from kindergarten

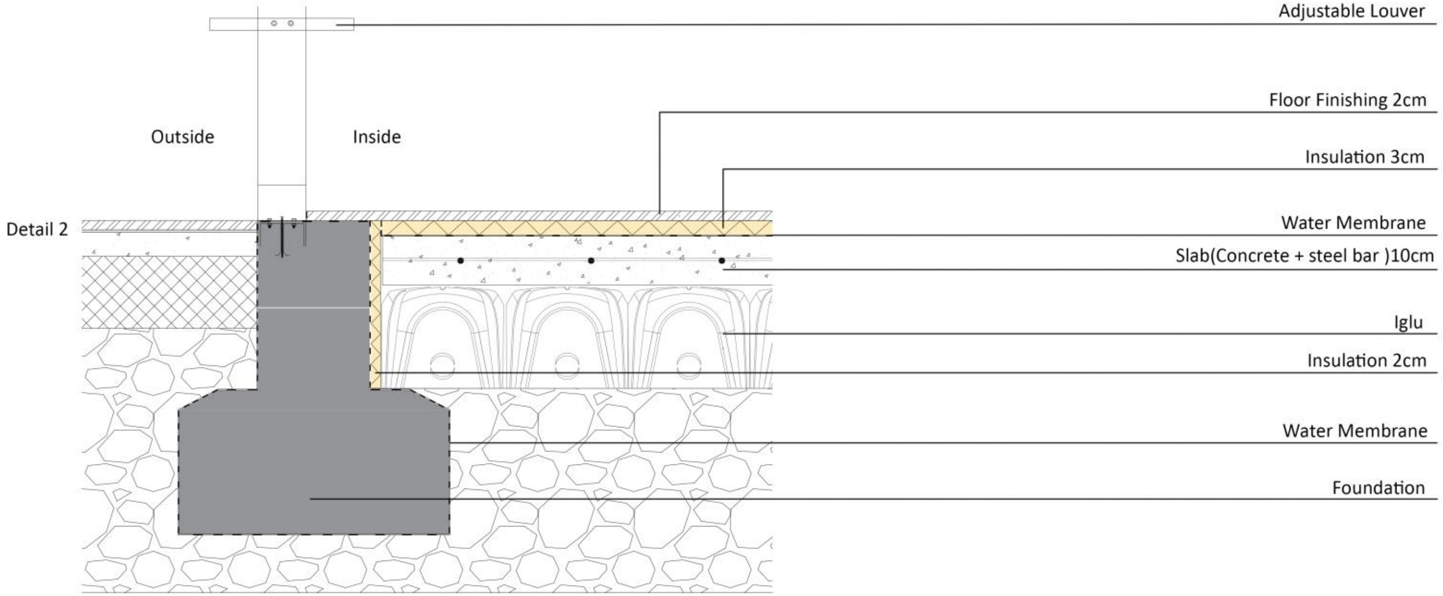


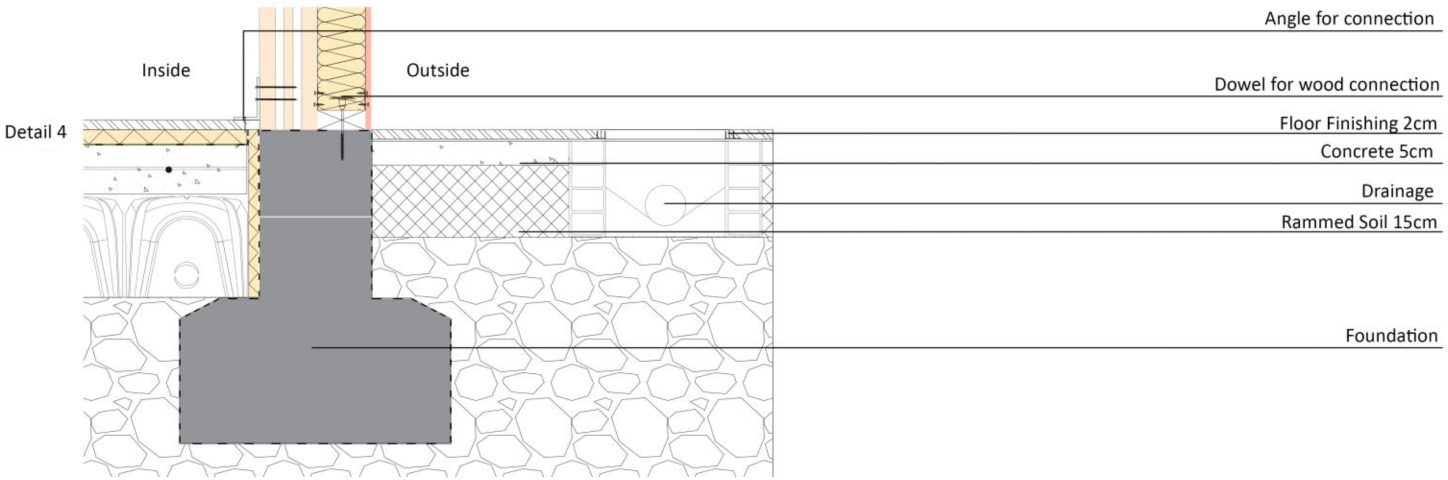


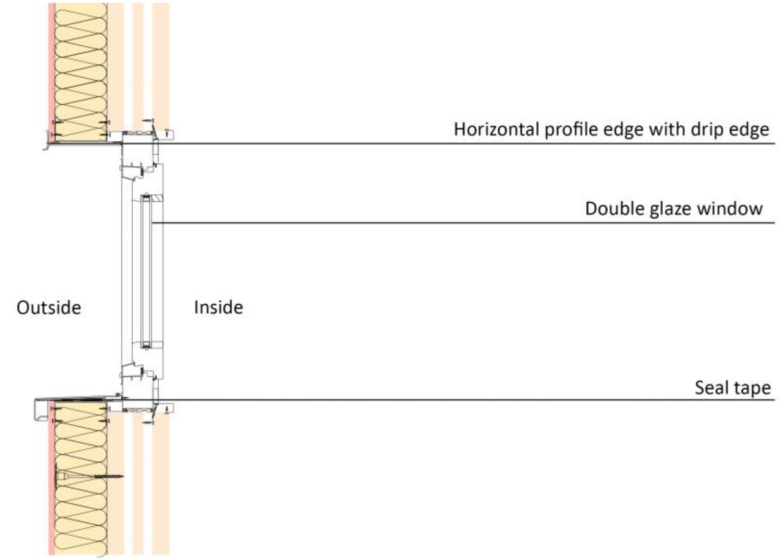




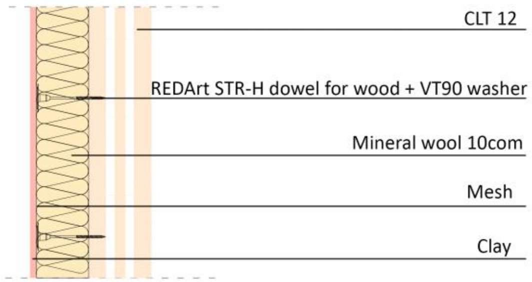
4.4.2.DETAILS


Adjustable Louver
Outside
Inside
Floor Finishing 2cm
Insulation 3cm
Detail 2
Water Membrane
Slab(Concrete + steel bar)10cm
Iglu
Insulation 2cm
Water Membrane
Foundation

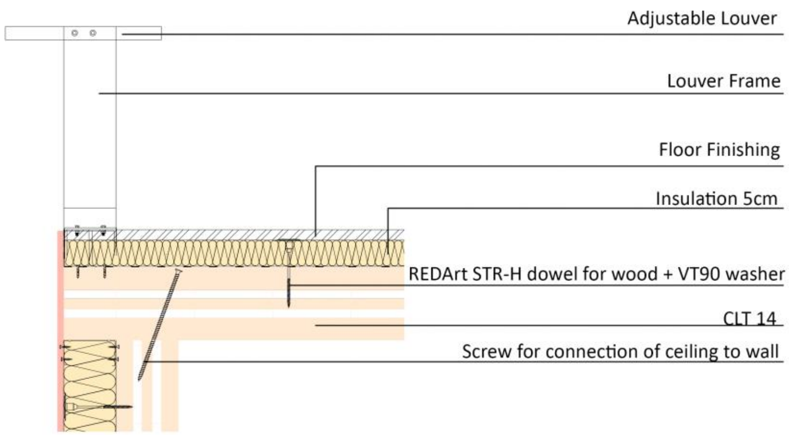

Angle for connection
Inside
Outside
Dowel for wood connection
Floor Finishing 2cm
Detail 4
Concrete 5cm
Drainage
Rammed Soil 15cm
Foundation



Detail 3



External wall



Detail 1

Internal Partition

4.5.THERMAL AND ENERGY ANALYSIS

Introduction:

The energy and daylight analysis commenced by comprehending Moshi's weather conditions. This crucial data guided the development of both passive and active strategies in the building and influenced architectural modifications. To conduct the energy analysis of the buildings, Climate Studio software was employed. The analysis process initiated with a preliminary examination within the software's simulation sector. Leveraging the 3D model from Rhino software, various settings could be assigned. Additionally, all building envelopes were integrated into the construction sector for further evaluation.

With the defined parameters, ClimateStudio performs energy analysis simulations. It calculates how the building responds to external environmental conditions over time, considering factors like heat gain and loss, thermal performance of materials, and HVAC (heating, ventilation, and air conditioning) systems. This analysis helps identify energy consumption patterns, potential areas of inefficiency, and opportunities for improvement.

The primary school is subdivided into 12 zones, each of which has been defined in ClimateStudio. The analysis comprises several stages, commencing with a basic envelope and passive design approach. As the analysis progresses, more insulated envelopes and active strategies are incorporated to enhance thermal comfort. The aim is to iteratively improve the building's energy efficiency and occupant comfort by optimizing its design and incorporating various strategies and materials. Same progress for kindergarten with 8 zones. To achieve improved indoor comfort and reduce energy consumption, we divide the analysis into three main stages. These stages are crucial for designing buildings with optimal natural ventilation and energy efficiency. By following this structured approach, we can create spaces that offer a pleasant and sustainable learning environment while minimizing the reliance on energy-intensive cooling and ventilation systems. In the initial phase, an assessment is conducted to compare the performance of three different façade technologies. Subsequently, two scenarios are examined: one with shading and one without shading, in relation to their impact on indoor comfort. In the final stage, an analysis is carried out to evaluate the effects of various Air Changes per Hour (ACH) rates on natural ventilation. Additionally, the question of whether mechanical ventilation enhances the overall indoor conditions is addressed.

4.5.1. WEATHER ANALYSIS

In Tanzania, including Moshi, the weather is generally divided into two main seasons: the dry season (winter) and the wet season (summer).

1. Dry Season (Winter):

The dry season in Moshi typically occurs from June to October. During this time, the weather is cooler and drier. The temperatures are generally more comfortable, with daytime temperatures ranging from 20°C to 25°C. At higher elevations, such as on Mount Kilimanjaro, temperatures can drop significantly, and there might even be snow on the summit.

2. Wet Season (Summer):

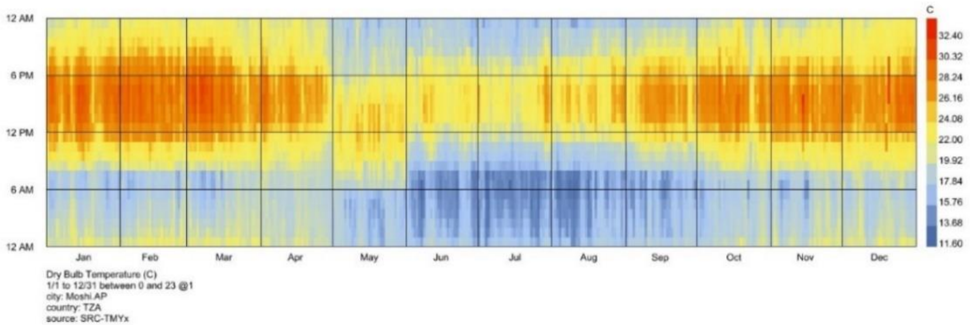
The wet season in Moshi typically takes place from November to May. This period includes both the long rains (from March to May) and the short rains (from November to December). During the wet season, rainfall is more frequent, and humidity levels are higher. Daytime temperatures can vary, ranging from 25°C to 30°C.

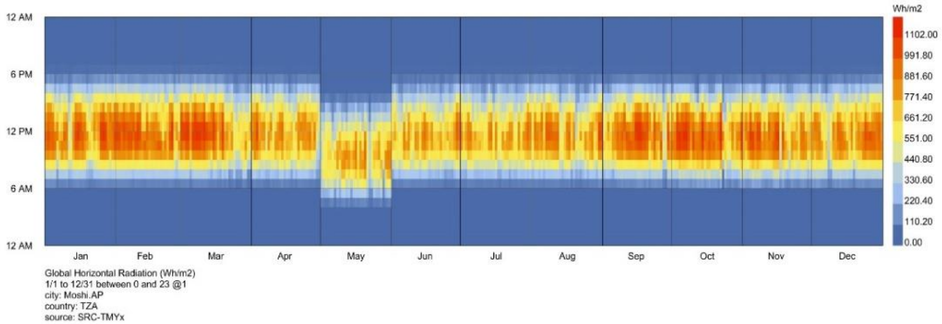
Dry bulb temperature:

The graph shows the temperature trend: During the first four months of the year, the temperature steadily rises until May, which marks the onset of summer. The temperature ranges from 11.60°C to 32.40°C, with shades of blue representing low temperatures and shades of red indicating high temperatures. From May to September, the graph mostly shows shades of blue, indicating low temperatures ranging between 11.60°C and 20°C. This period corresponds to the winter months, where mornings and nights are particularly cool. Between September and December, there is another temperature rise, with peaks reaching up to 31°C. This increase in temperature is prominent during the operating hours of school, from 12 PM to 6 PM.

Global horizontal radiation:

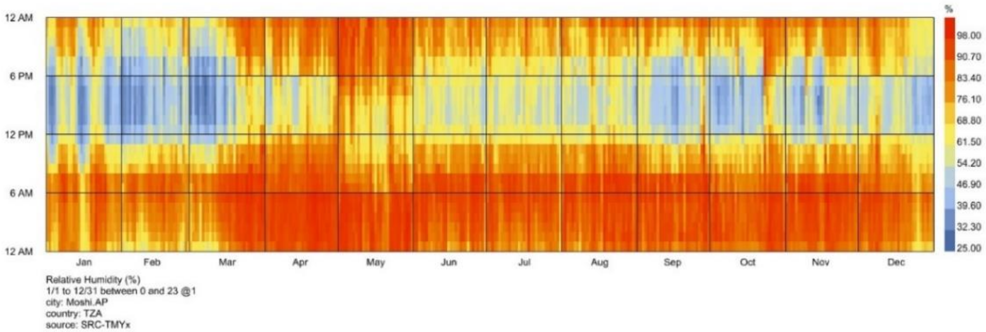
The greater the total daily irradiation, the greater the carpet is in favor of red. Global irradiation occurs predominantly in the central hours of the day. From the analysis of the graphs, an initial analysis can be developed on the need for shading systems both in summer and in winter; It will be useful to design and develop a shading system suited to the needs and requests for comfort related to the visual task and the intended use of the premises. As we can see providing constant shading during the year is needed.

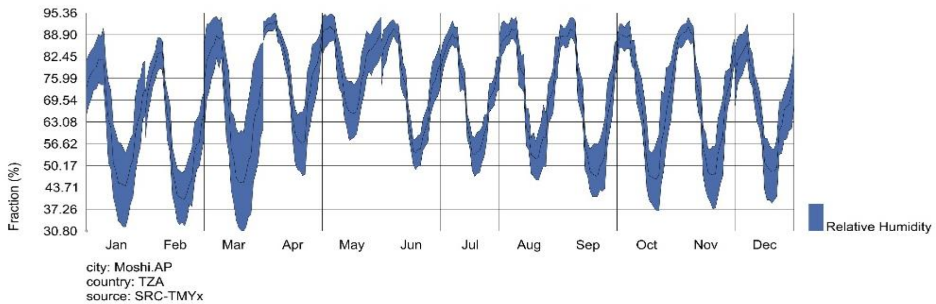




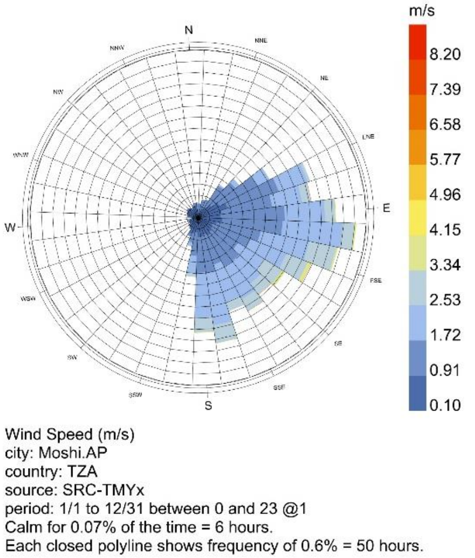
Relative Humidity:
The highest humidity is associated with red, while the days with lower humidity are demonstrated in blue. It is noted that the hours with the highest humidity are morning and evening, while the afternoon hours have a drier climate. The annual average relative humidity records the value of 85% with a minimum of 30% in March and a maximum of 95% in April.

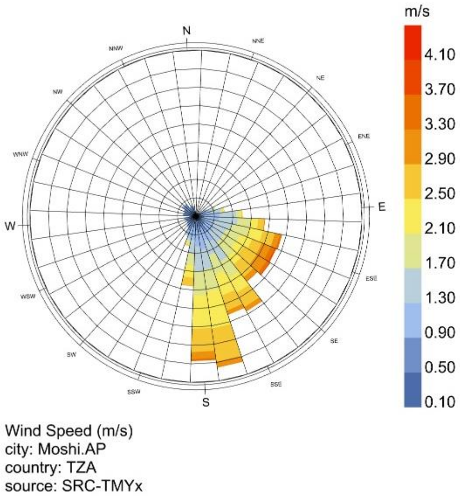
Wind rose:
Wind rose analysis is a valuable tool to create energy-efficient and sustainable structures that promote natural ventilation. By analyzing the prevailing wind patterns in Moshi, this technique helps identify the most favorable building orientation and strategic placement of openings, such as windows, doors, and vents, to harness the power of natural breezes.
Choosing the optimal building orientation is crucial for maximizing the benefits of natural ventilation. By aligning the building's longest facades with the prevailing wind directions, we can create a pathway for fresh air to flow through the interior spaces. This cross-ventilation design not only cools indoor environments but also reduces the need for energy-intensive mechanical cooling systems, leading to lower utility costs and a

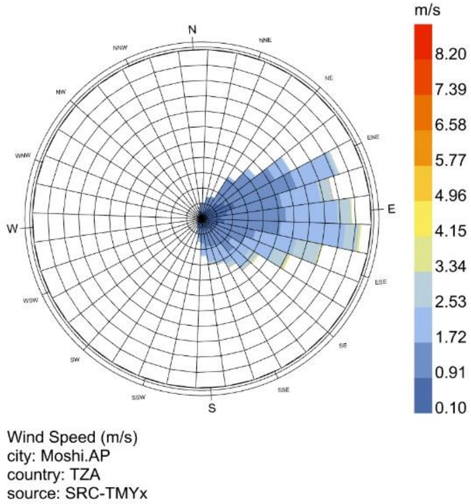




reduced carbon footprint. In these diagrams the frequency and speed of the wind are demonstrated based on a wind rose model, which are annual, dry season(winter) and wet season (summer), The wind patterns during these seasons can vary.





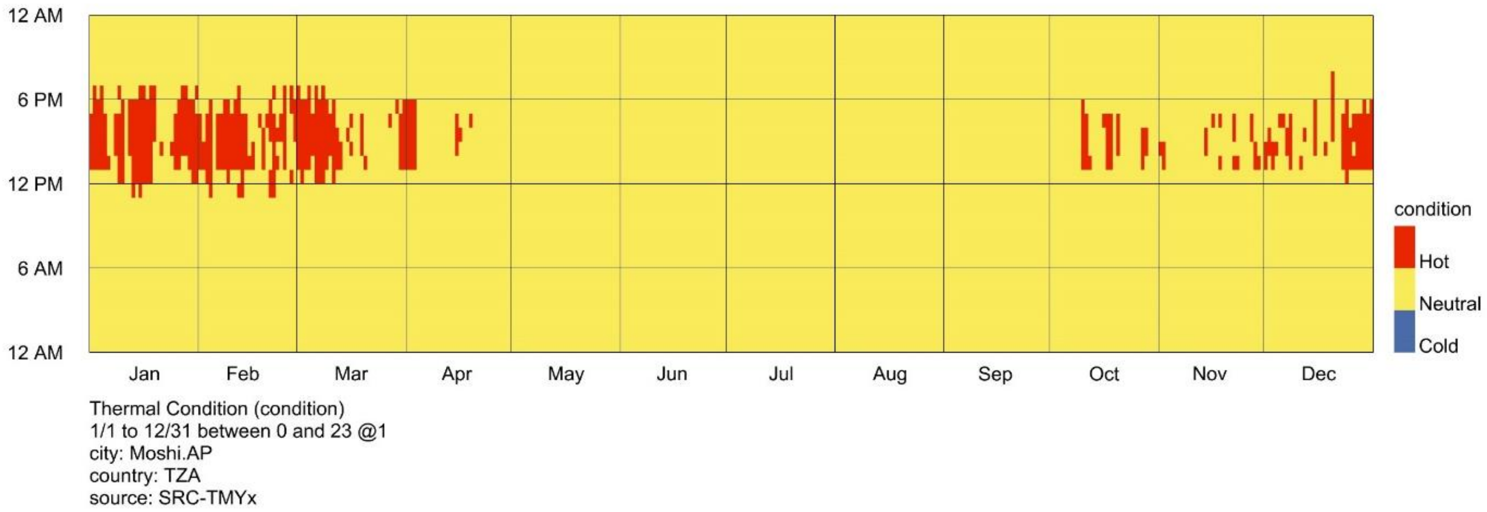


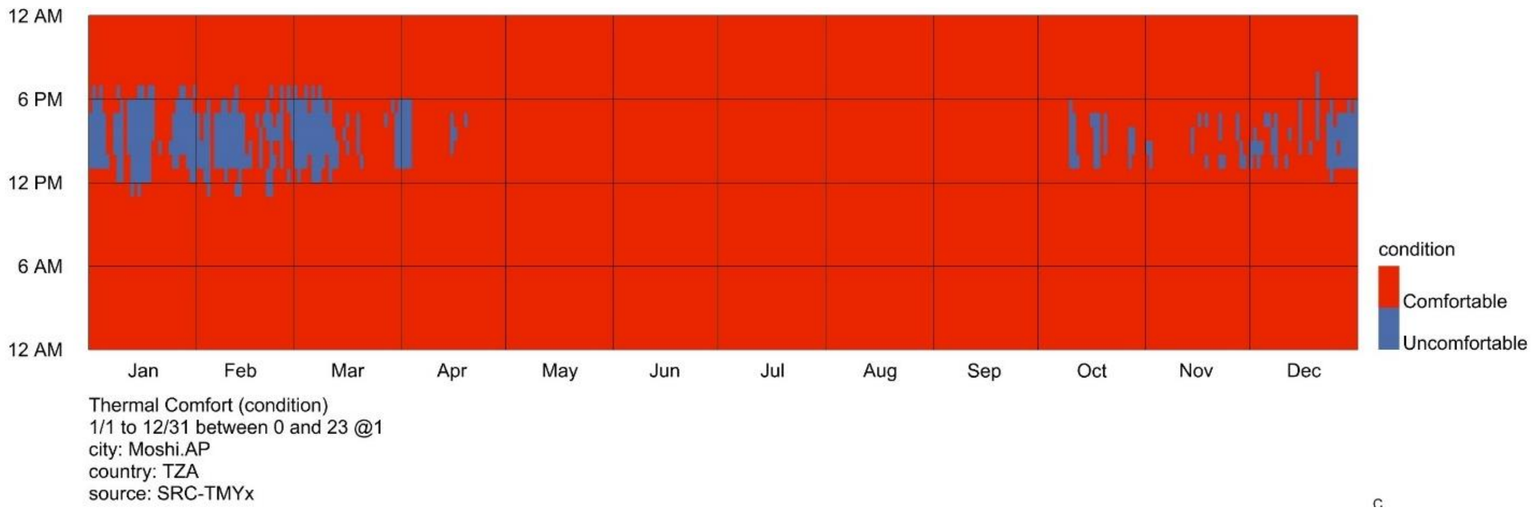
The wind rose analysis reveals that the prevailing winds predominantly originate from the south and east directions. During the dry season, the winds are primarily from the south, with a maximum speed of 3.30 m/s. In contrast, the wet season sees winds mostly coming from the east, with a maximum speed of 2.50 m/s. Overall, the highest wind speed recorded throughout the analyzed period is 3.30 m/s, indicating generally moderate wind conditions in the area.

Comfort analysis

Moshi experiences a mild and comfortable climate due to its elevation and proximity to Mount Kilimanjaro. The town's thermal comfort is influenced by its geographical location, with temperatures typically ranging from moderate to cool.

Moshi's climate provides a relatively comfortable thermal environment for residents and visitors, especially in the dry season when the weather is cooler and more pleasant. However, during the wet season, higher humidity levels might lead to a perceived increase in discomfort, particularly if buildings lack proper ventilation or cooling systems. Proper building design, taking advantage of natural ventilation and shading techniques, can further enhance thermal comfort in both seasons.





4.5.2. ENERGY SIMULATION PRIMARY SCHOOL

Climate Zone

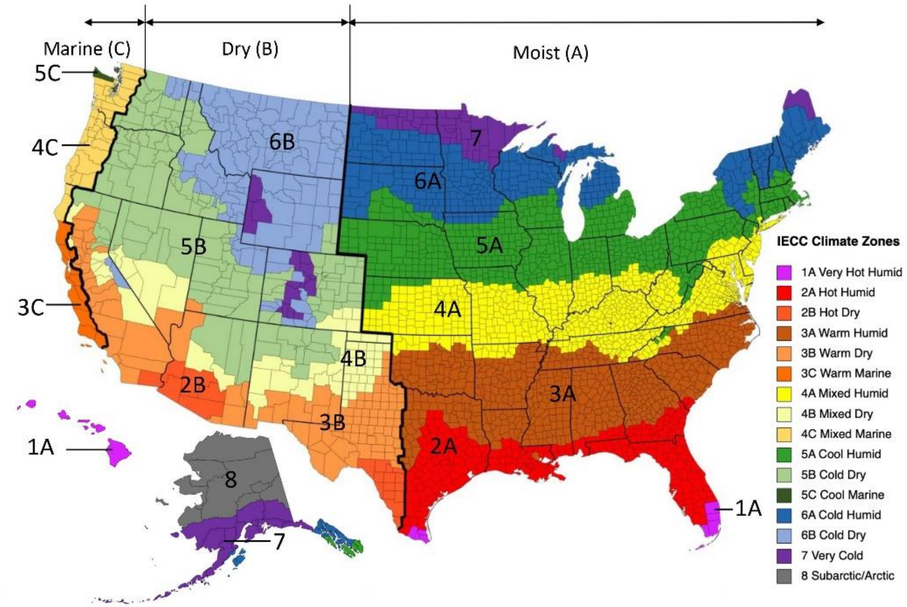
Koppen climate zone:	Temperate, No Dry Season, Warm Summer (Cfb)
ASHRAE climate zone:	Hot (2)
Average annual temperature:	21 °C
Annual total solar radiation:	2,050 kWh/m2
Average annual wind speed:	2 m/s

Heating Design Conditions

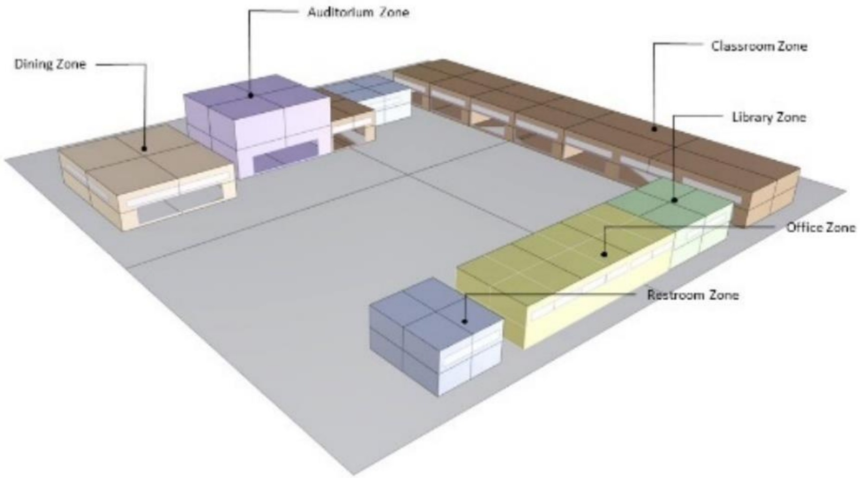
Coldest month:	July
Coldest week:	7/13 - 7/19
Typical winter week:	8/ 3 - 8/ 9
Annual HDD for 18 °C is:	25
Design temperature 0.04 %:	12.5 °C

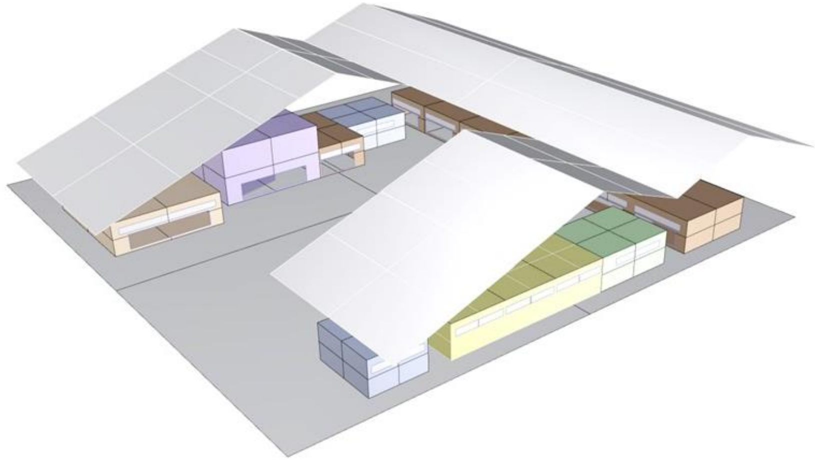
Cooling Design Conditions

Hottest month:	February
Hottest week:	1/13 - 1/19
Typical summer week:	12/22 - 1/ 5
Annual CDD for 10 °C is:	3,872
Design temperature 99.6 %:	29.5 °C



The simulation is grounded on ASHRAE standards, categorizing our location as Zone 2, denoting a hot climate.





Stage 1

In this stage, simplicity and basic materials are utilized for both façades and partitions, without incorporating insulation. To enhance indoor comfort, the design incorporates double windows, allowing for better thermal insulation compared to single-pane windows commonly used in traditional construction. These double windows help reduce heat transfer between the interior and exterior, contributing to a more comfortable indoor environment.

Maintaining consistent cross ventilation and integrating shading elements as the protective "The Skin," we investigate the performance of three distinct façade configurations. These configurations remain unchanged with regards to partitions, slabs, and flooring. In the first choice, we implement a 14 cm CLT for the façade, excluding any insulation. The second alternative involves a double CLT 12 façade coupled with 10 cm of mineral wool insulation. Lastly, the third option encompasses a CLT 12 façade, supplemented by 10 cm of mineral wool insulation and a finishing touch of clay mortar. These three options have been carefully chosen for further consideration, after a comprehensive assessment of numerous alternatives.

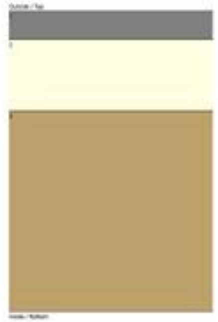
Facade

U-Value[W/(m^2·K)] = 0.802
R-Value[m^2K/W] = 1.077
Thermal Capacitance[kJ/K/m^2] = 112
Embodied Energy[MJ/m^2] = 700
Embodied Carbon[kgCO2/m^2] = 49.7

Partition

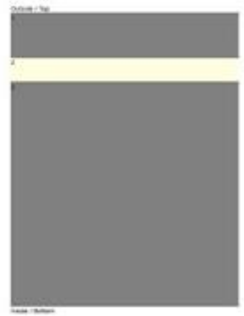
U-Value[W/(m^2·K)] = 0.845
R-Value[m^2K/W] = 0.923
Thermal Capacitance[kJ/K/m^2] = 96
Embodied Energy[MJ/m^2] = 600
Embodied Carbon[kgCO2/m^2] = 42.6

Roof Slab



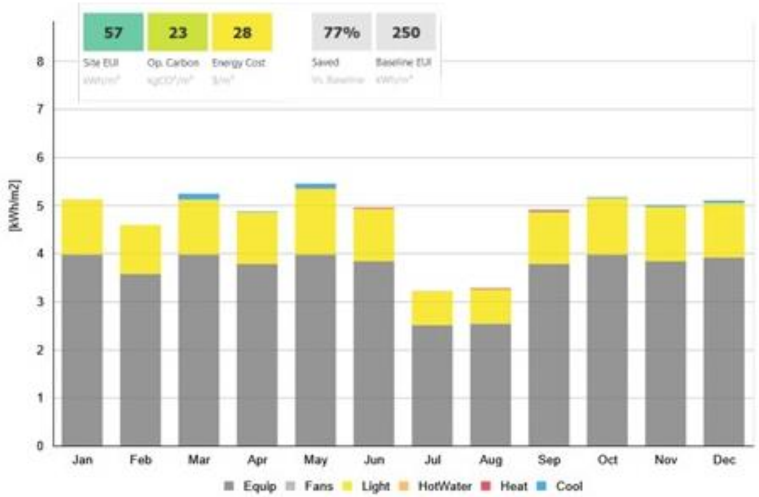
U-Value[W/(m^2·K)] = 0.404
R-Value[m^2K/W] = 2.334
Thermal Capacitance[kJ/K/m^2] = 142.262
Embodied Energy[MJ/m^2] = 700
Embodied Carbon[kgCO2/m^2] = 52.8

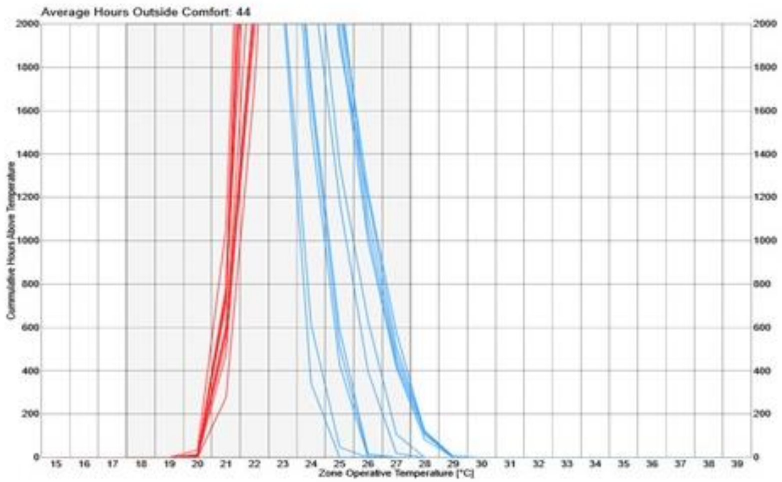
Floor slab



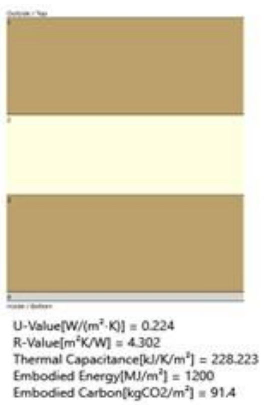
U-Value[W/(m^2·K)] = 0.91
R-Value[m^2K/W] = 0.839
Thermal Capacitance[kJ/K/m^2] = 510.046
Embodied Energy[MJ/m^2] = 435.72
Embodied Carbon[kgCO2/m^2] = 50.973

Option1: The graphical representations illustrate that by solely incorporating a 14 cm CLT (Cross-Laminated Timber) layer, we achieve an Energy Use Intensity (EUI) of 57, accompanied by 44 hours of discomfort due to outdoor conditions falling outside the comfort range.





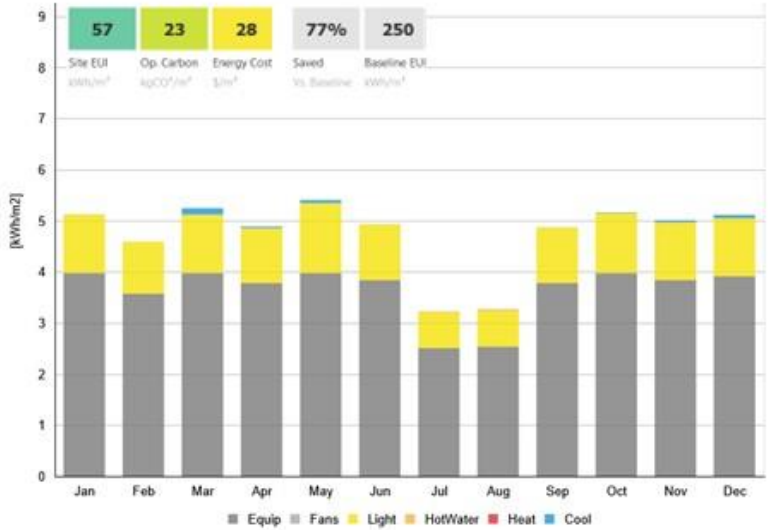
Facade

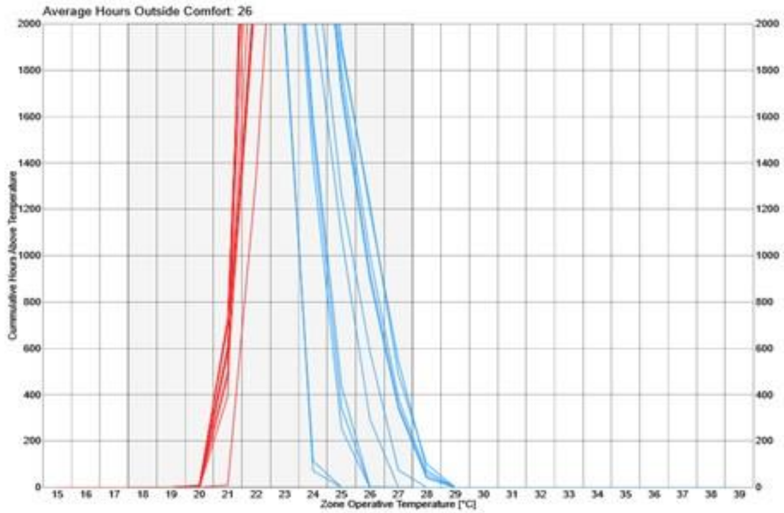


Partition

Roof Slab

Floor slab





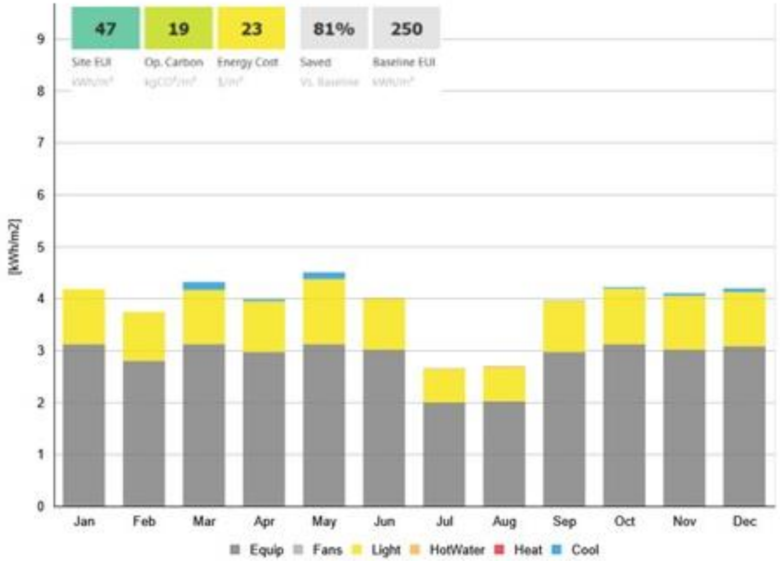
Option2: The graphical representations illustrate that by double CLT12 and 10cm insulation with clay mortar finishing, we achieve an Energy Use Intensity (EUI) of 57, accompanied by 26 hours of discomfort due to outdoor conditions falling outside the comfort range.

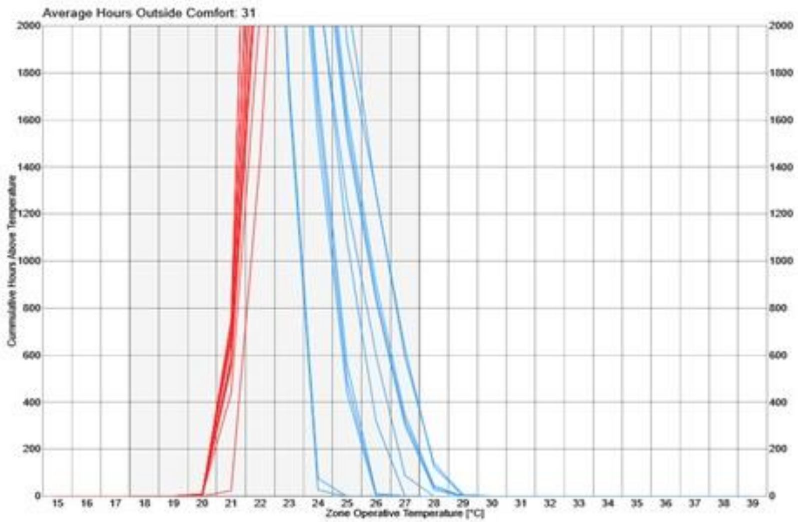
Facade

Partition

Roof Slab

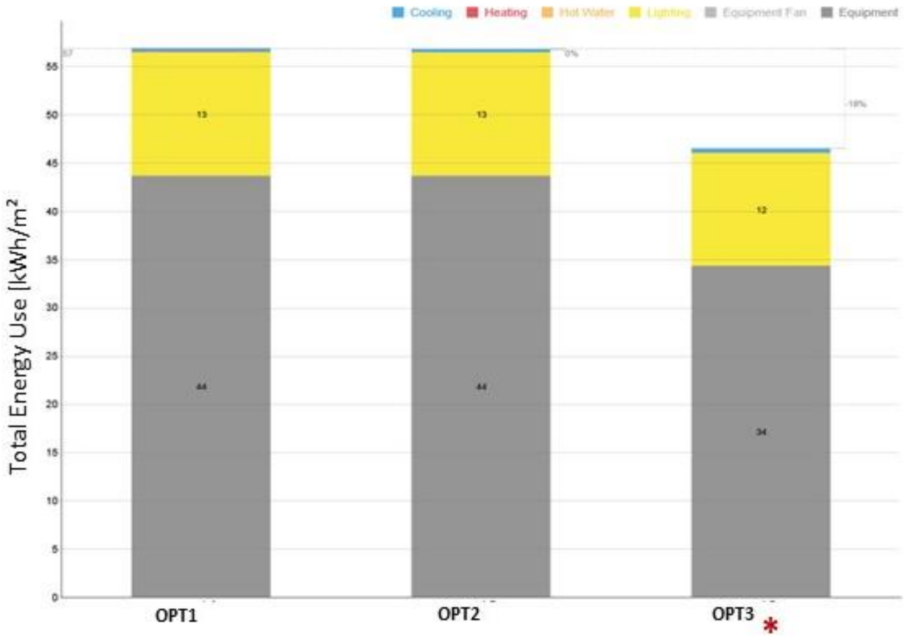
Floor slab

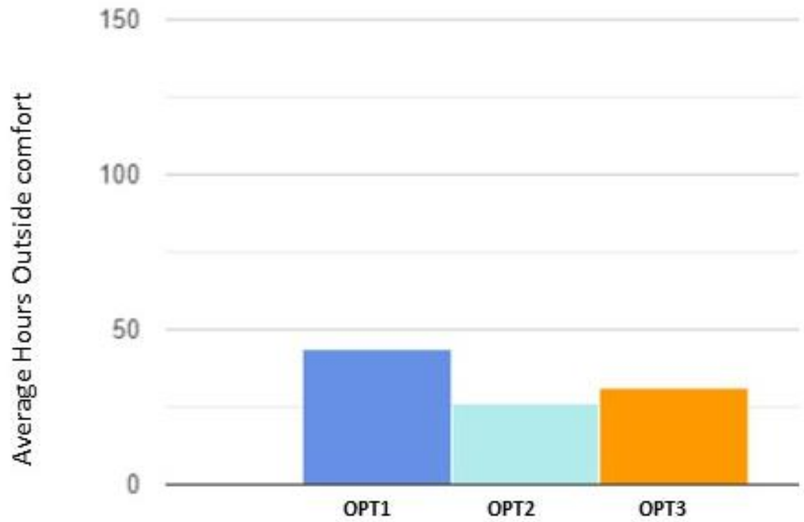




Option3: The graphical representations illustrate that by CLT12 and 10cm insulation with clay mortar finishing, we achieve an Energy Use Intensity (EUI) of 47, accompanied by 31 hours of discomfort due to outdoor conditions falling outside the comfort range.

Comparison

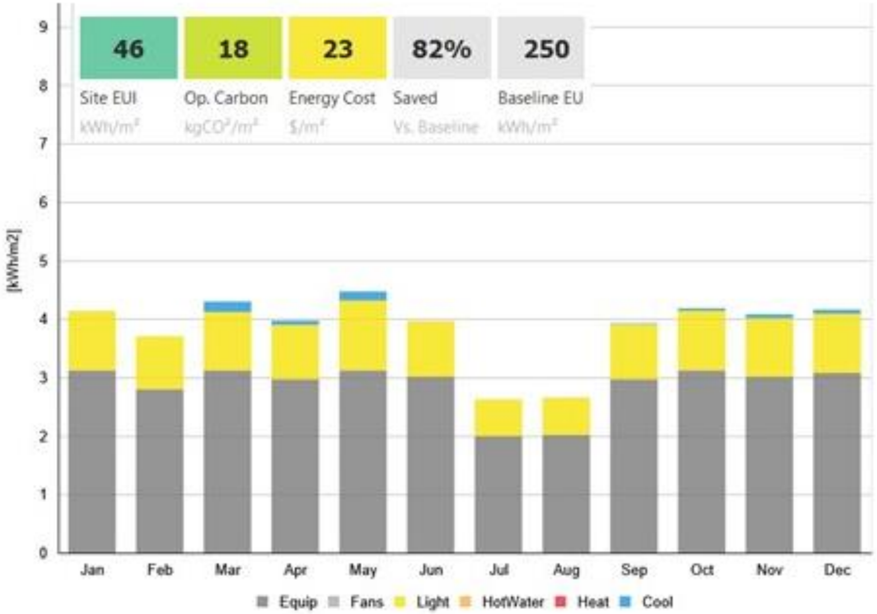


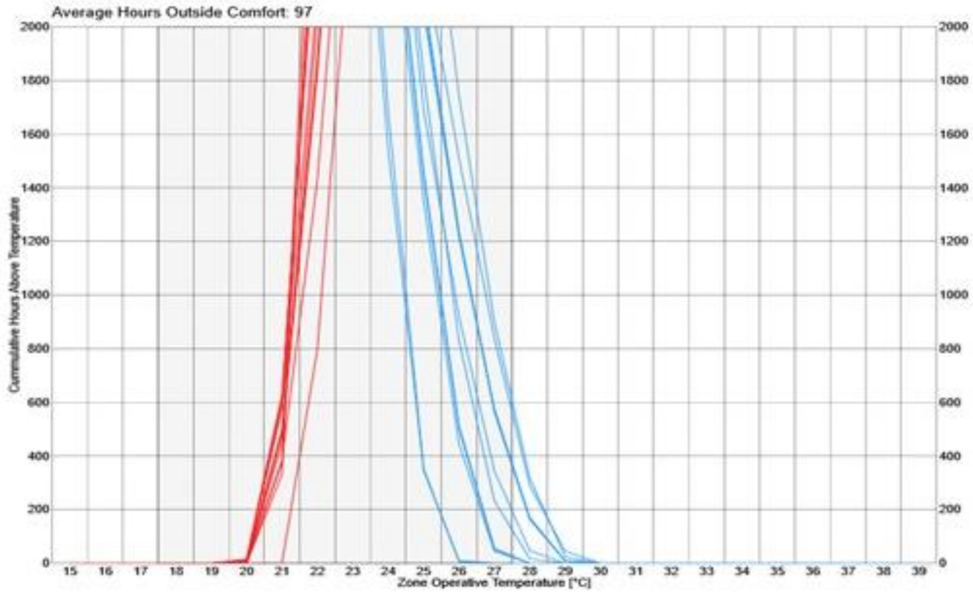


Evaluating these three alternatives, it becomes evident that option 3 demonstrates superior performance in terms of Energy Use Intensity (EUI). On the other hand, when focusing on comfort considerations, option 2 emerges as a favorable selection. However, when aiming to strike a harmonious balance between EUI efficiency, comfort optimization, and economic viability, our preference gravitates towards option 3. This entails integrating CLT12, 10 cm of mineral wool insulation, and a clay mortar finishing for the façade.

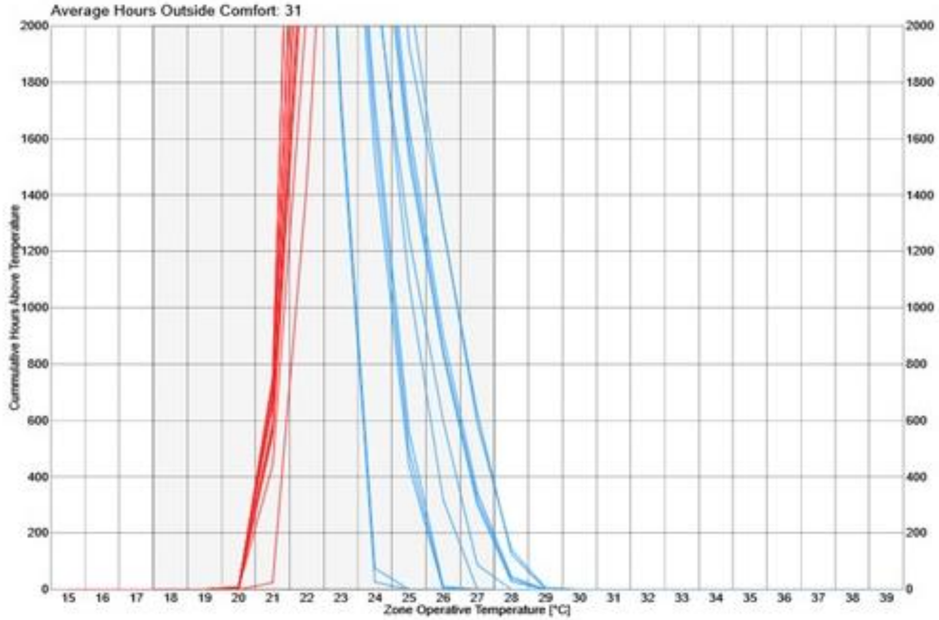
Stage 2

Having determined the suitable material in the preceding stage, and maintaining constant cross ventilation, we now explore the influence of "The Skin" on both Energy Use Intensity (EUI) and comfort, specifically in terms of shading. This analysis involves three distinct steps: the absence of shading, the implementation of shading option 1, and the utilization of shading option 2. Notably, these two shading options have been derived from the previously conducted design process.

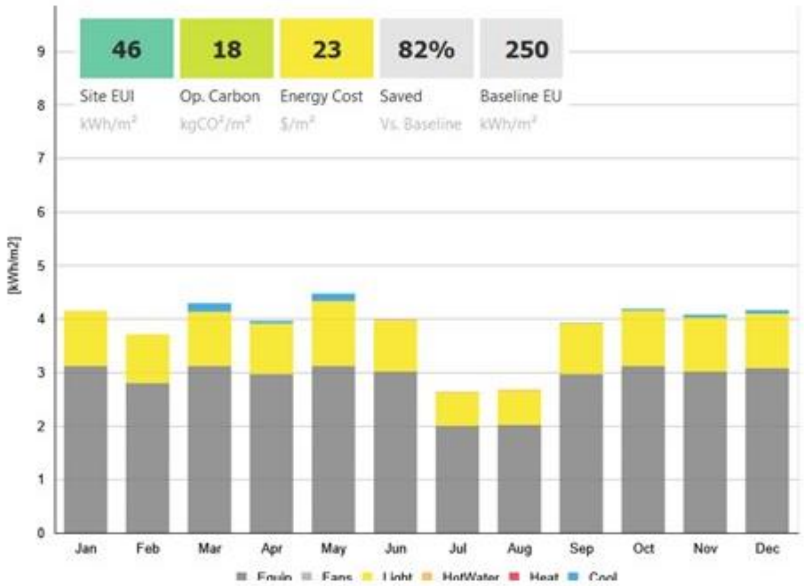


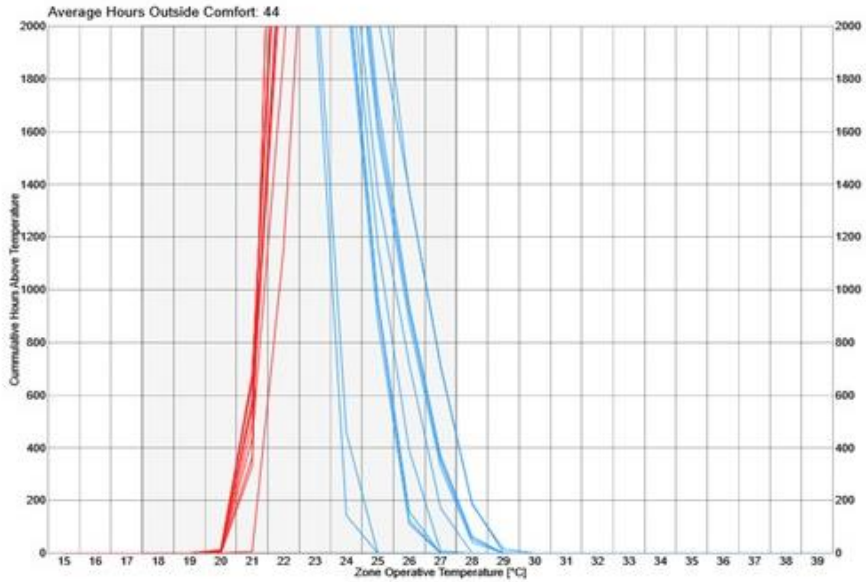


No Shading: In this context, it becomes evident that despite achieving a commendable EUI of 46, the absence of shading significantly impacts the occupants' comfort levels, leading to 97 hours falling outside the comfort range.



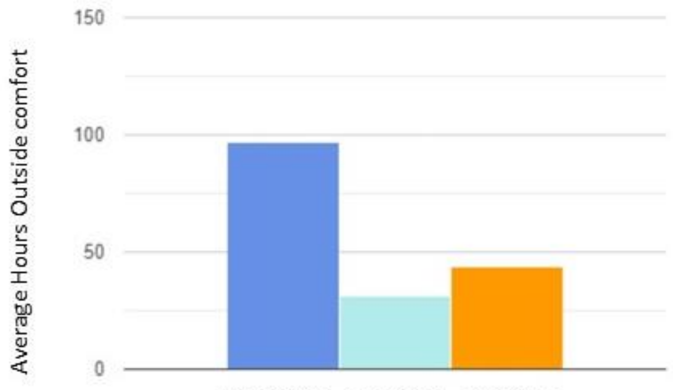
Shading 1: Upon incorporating shading option 1, a notable reduction in discomfort hours is observed, with the count decreasing to 31 hours. Interestingly, this improvement in comfort is achieved while maintaining an EUI nearly identical to the previous value.

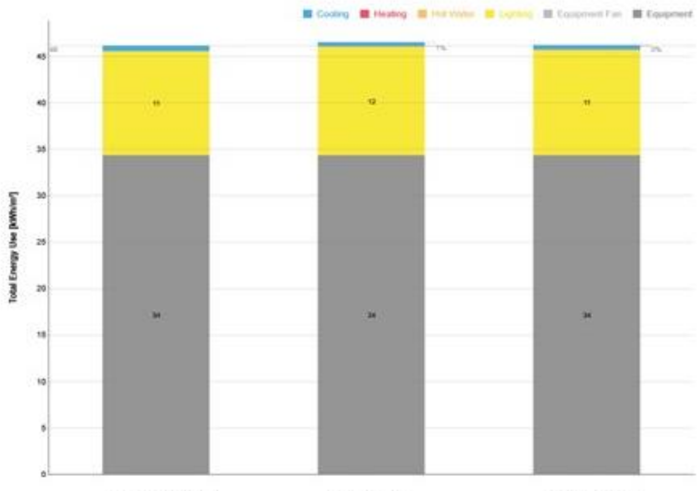




Shading 2: Opting for the second shading option yields a substantial reduction in discomfort hours, reducing them to approximately 44 hours. However, when compared to the previous scenario, there is a slight increase in these discomfort hours. Notably, the Energy Use Intensity (EUI) remains unchanged at 46.

Comparison





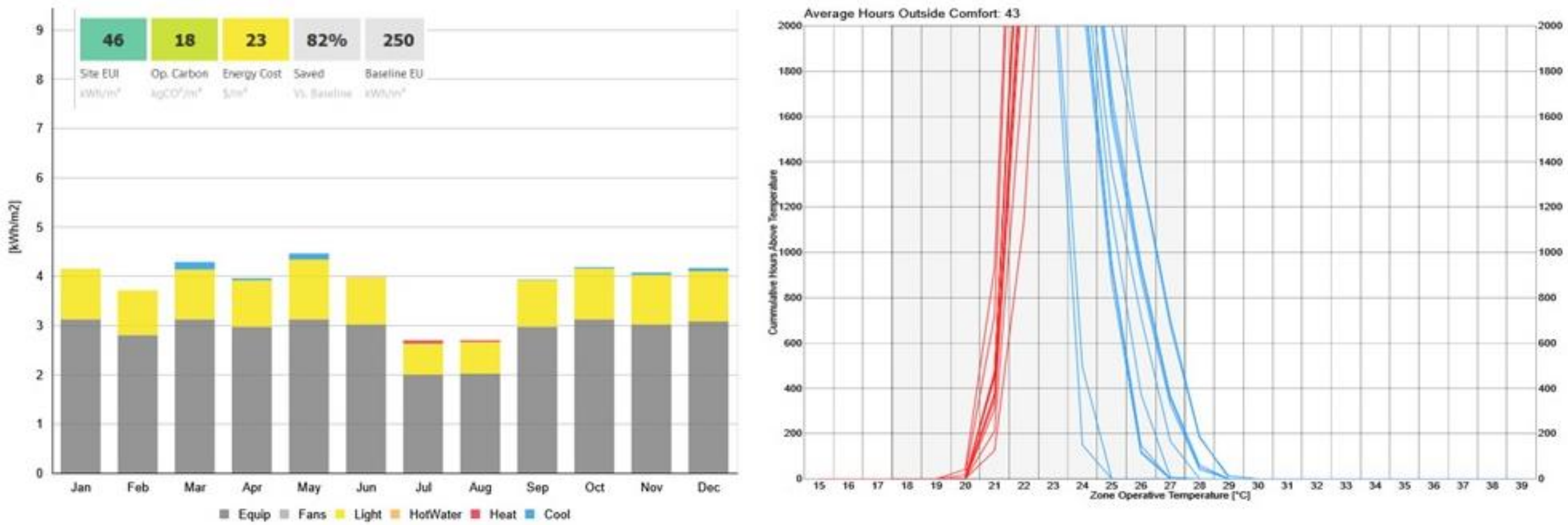
SHADING 1

SHADING 2

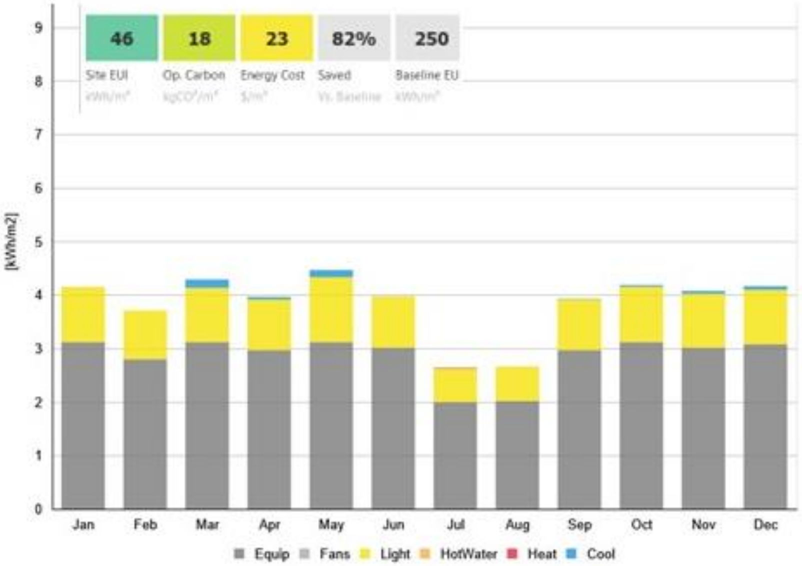
Upon careful evaluation of these three options, it becomes clear that "The Skin" plays a crucial role in enhancing both energy efficiency and comfort, similar to its impact on daylighting. When contrasting shading options 1 and 2, the graphical representation illustrates that shading option 1 yields the lowest discomfort hours. However, taking into account the harmony between architectural principles and energy considerations, option 2 is favored. It's important to note that the disparity in comfort levels between the two options is minimal.

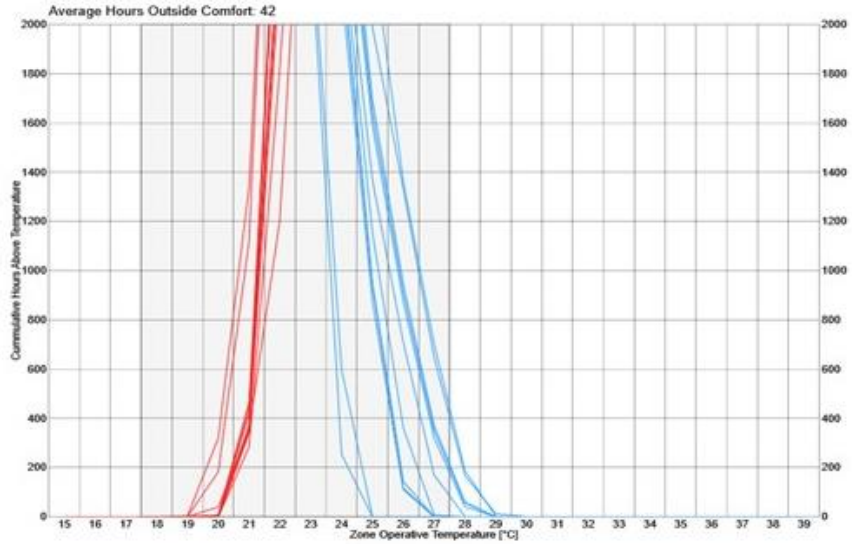
Stage 3

The primary ventilation strategy employed in this design is crossed ventilation, capitalizing on the natural airflow patterns prevalent in the region. By strategically placing clerestory windows on opposite sides of the building and movable louvers implemented in the exterior wall, a continuous exchange of fresh air is facilitated, maintaining a well-ventilated interior, and dissipating any accumulated heat. This passive approach to ventilation eliminates the need for mechanical ventilation systems, leading to reduced energy consumption and operational costs. In pervious stages we have maintained a constant natural ventilation system. However, in this current stage, we are evaluating various Air Changes per Hour (ACH) rates to determine their effects and benefits. The recommended Air Changes per Hour (ACH) rate for a classroom can vary based on factors such as the size of the classroom, the number of occupants, the intended use of the space, and local building codes or guidelines. Nonetheless, following a broad recommendation by ASHRAE, classrooms often adhere to an ACH range of 3 to 6. In our investigation, we initiated with 0.5 ACH, subsequently raised it to 1, then 5, and finally tested the upper limit of 10 ACH.

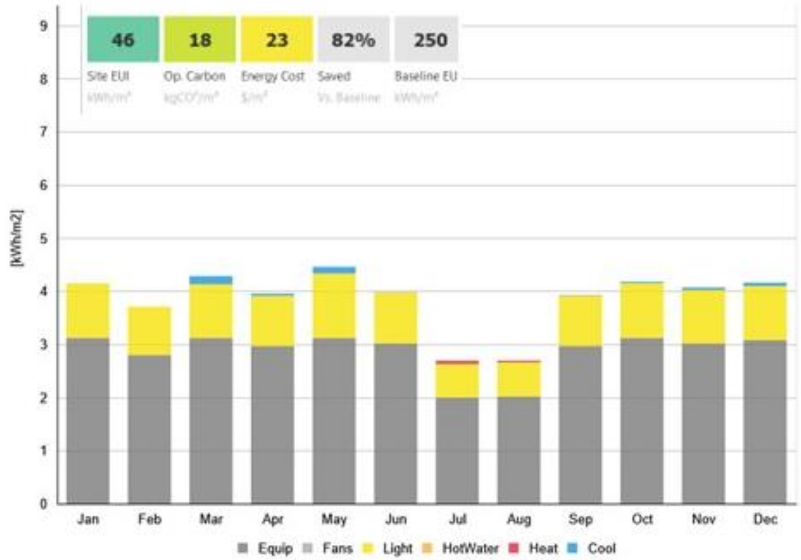


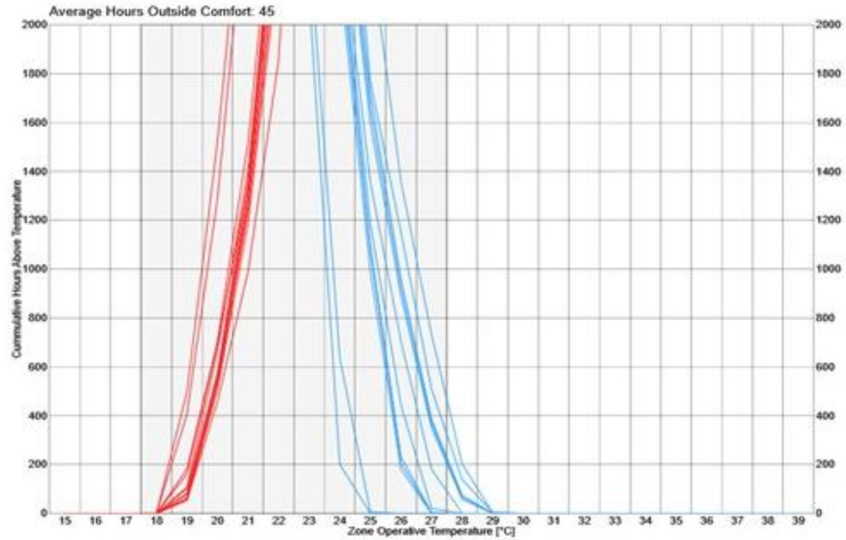
0.5 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 46 and a total average of 43 discomfort hours.



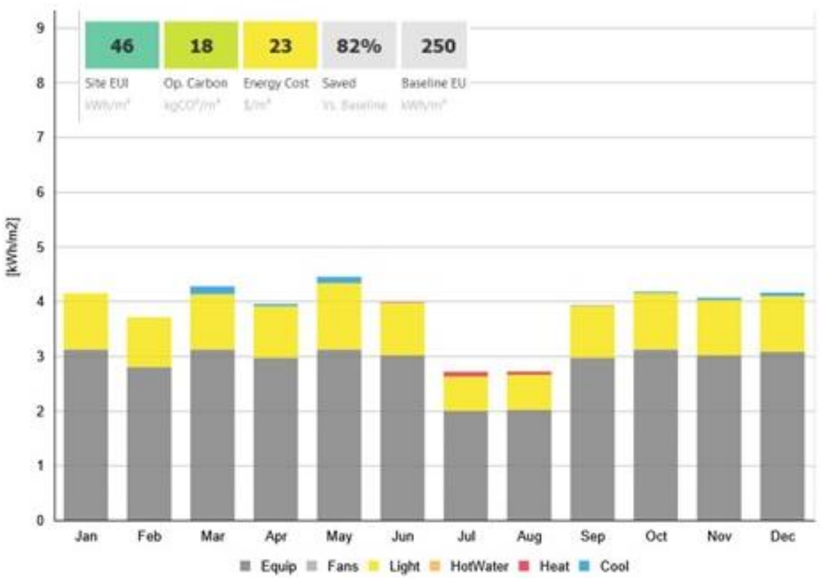


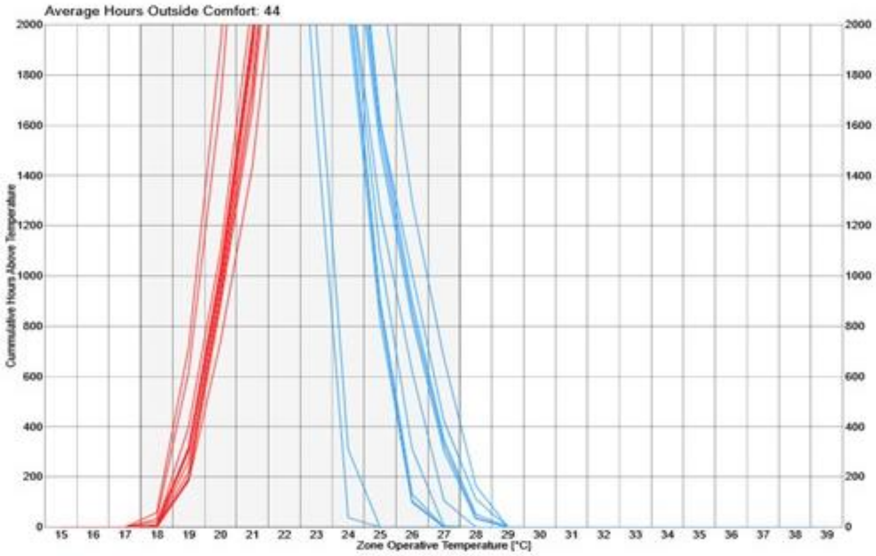
1 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 46 and a total average of 42 discomfort hours.



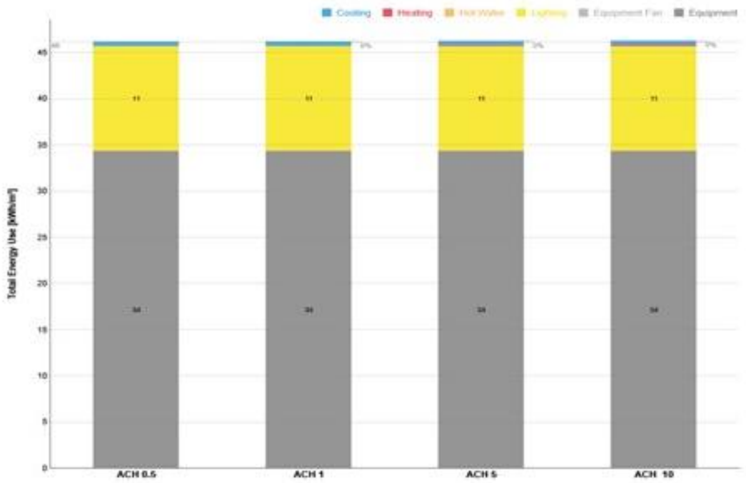


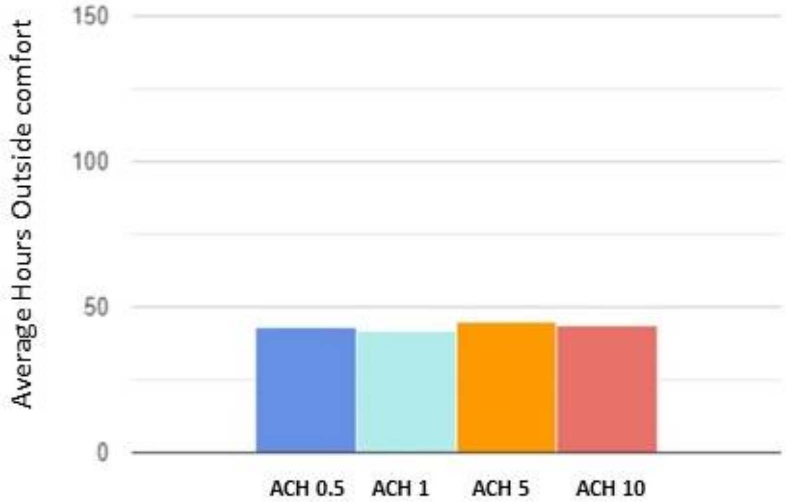
5 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 46 and a total average of 45 discomfort hours.





10 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 46 and a total average of 44 discomfort hours.





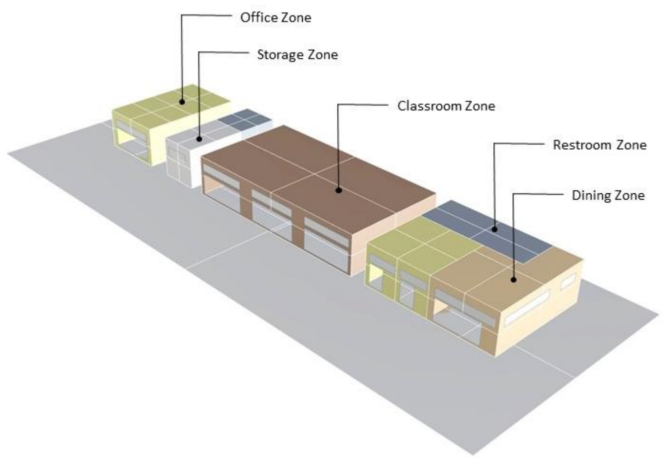
Through a comparison of all four phases, a consistent EUI of 46 was maintained. Similarly, the discomfort hours showed minimal variation, ranging from 42 to 46 across the phases. Following ASHRAE guidelines, an ACH of 5 was selected based on these observations.

We introduced mechanical ventilation fans in the final stages to assess their impact on energy consumption and comfort. Interestingly, despite this addition, there was no significant change observed in the Energy Use Intensity (EUI) and the duration of discomfort, indicating that these factors remained consistent.

Conclusion:

Following an extensive series of simulations, we have refined our options to these four stages. The objective is to identify the optimal solution for our building, one that simultaneously minimizes Energy Use Intensity (EUI) and keeps the hours of discomfort to a minimum. This will be achieved by carefully weighing and balancing all design and economic considerations.

4.5.3. ENERGY SIMULATION KINDERGARTEN



Stage 1

Same approach for kindergarten: In this stage, simplicity and basic materials are utilized for both façades and partitions, without incorporating insulation. To enhance indoor comfort, the design incorporates double windows, allowing for better thermal insulation compared to single-pane windows commonly used in traditional construction. These double windows help reduce heat transfer between the interior and exterior, contributing to a more comfortable indoor environment.

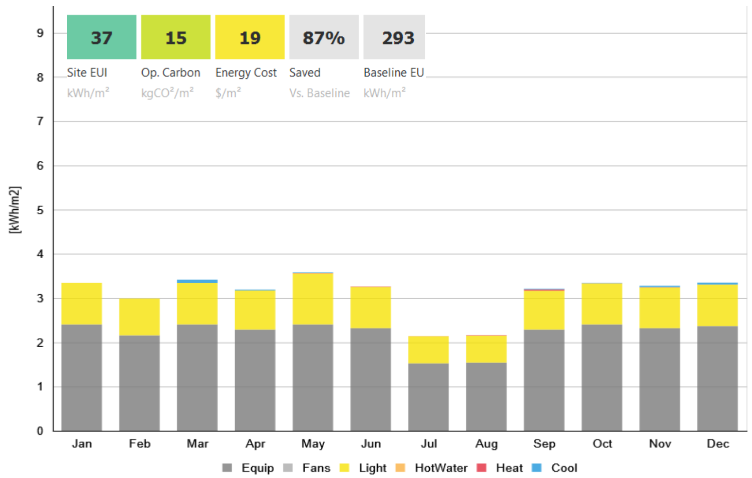
Maintaining consistent cross ventilation and integrating shading elements as the protective "The Skin," we investigate the performance of three distinct façade configurations. These configurations remain unchanged with regards to partitions, slabs, and flooring. In the first choice, we implement a 14 cm CLT for the façade, excluding any insulation. The second alternative involves a double CLT 12 façade coupled with 10 cm of mineral wool insulation. Lastly, the third option encompasses a CLT 12 façade, supplemented by 10 cm of mineral wool insulation and a finishing touch of clay mortar. These three options have been carefully chosen for further consideration, after a comprehensive assessment of numerous alternatives.

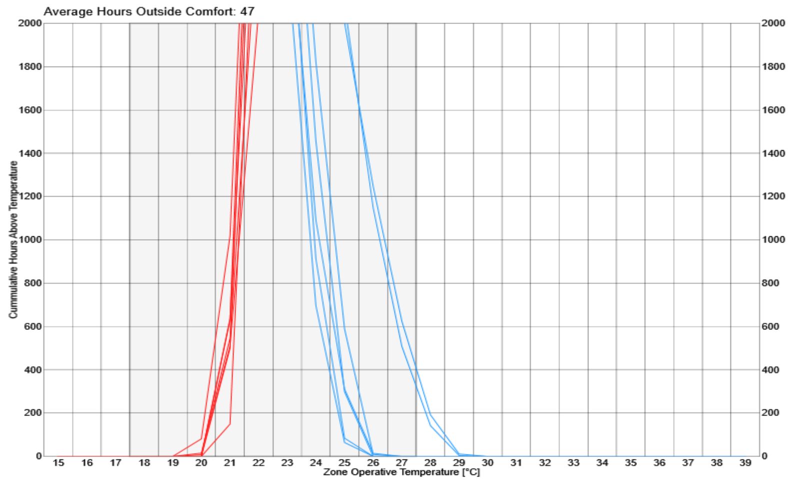
Facade

Partition

Roof Slab

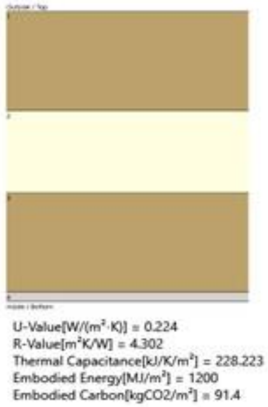
Floor slab





Option1: The graphical representations illustrate that by solely incorporating a 14 cm CLT (Cross-Laminated Timber) layer, we achieve an Energy Use Intensity (EUI) of 37, accompanied by 47 hours of discomfort due to outdoor conditions falling outside the comfort range.

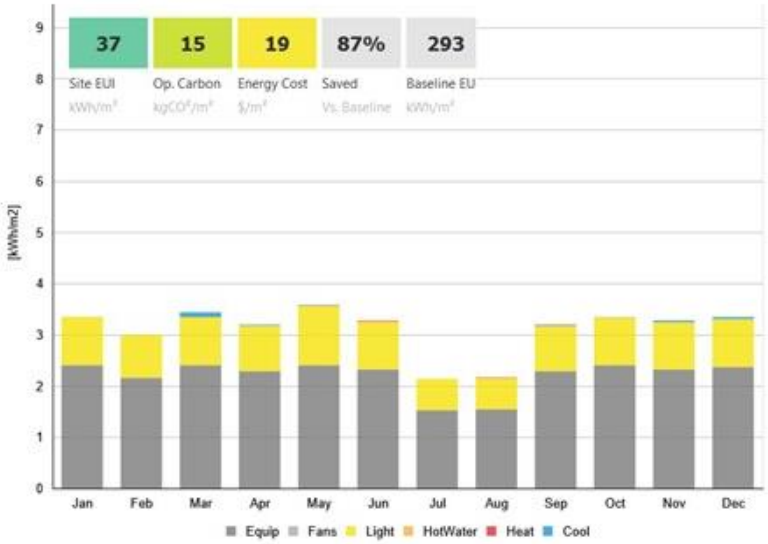
Facade

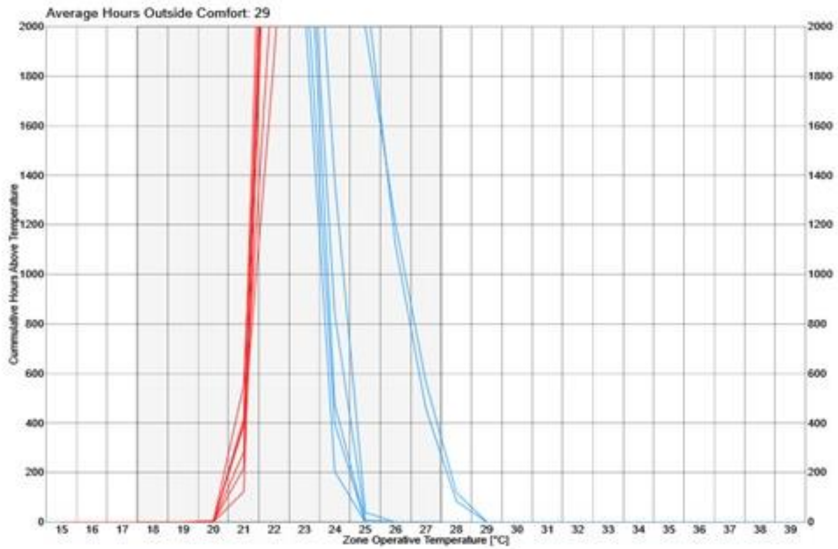


Partition

Roof Slab

Floor slab





Option2: The graphical representations illustrate that by double CLT12 and 10cm insulation with clay mortar finishing, we maintain an Energy Use Intensity (EUI) of 37, accompanied by 29 hours of discomfort due to outdoor conditions falling outside the comfort range.

Facade

U-Value[W/(m²·K)] = 0.282
R-Value[m²K/W] = 3.379
Thermal Capacitance[kJ/K/m²] = 132.223
Embodied Energy[MJ/m²] = 600
Embodied Carbon[kgCO2/m²] = 48.8

Partition

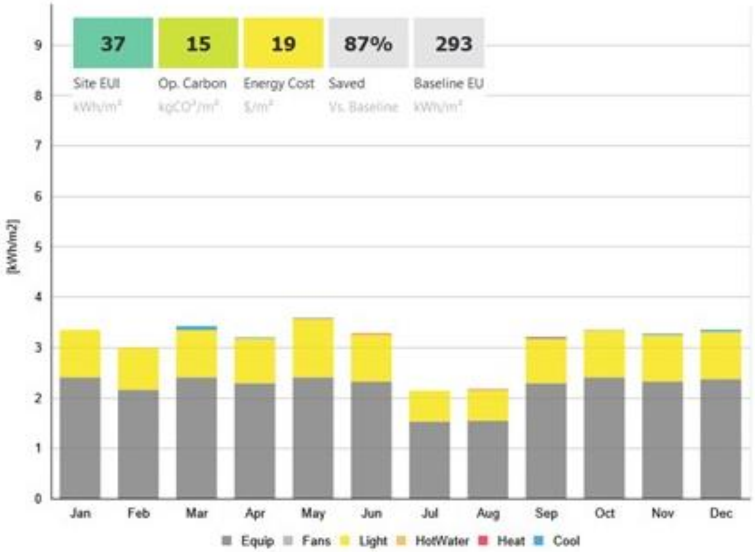
U-Value[W/(m²·K)] = 0.845
R-Value[m²K/W] = 0.923
Thermal Capacitance[kJ/K/m²] = 96
Embodied Energy[MJ/m²] = 600
Embodied Carbon[kgCO2/m²] = 42.6

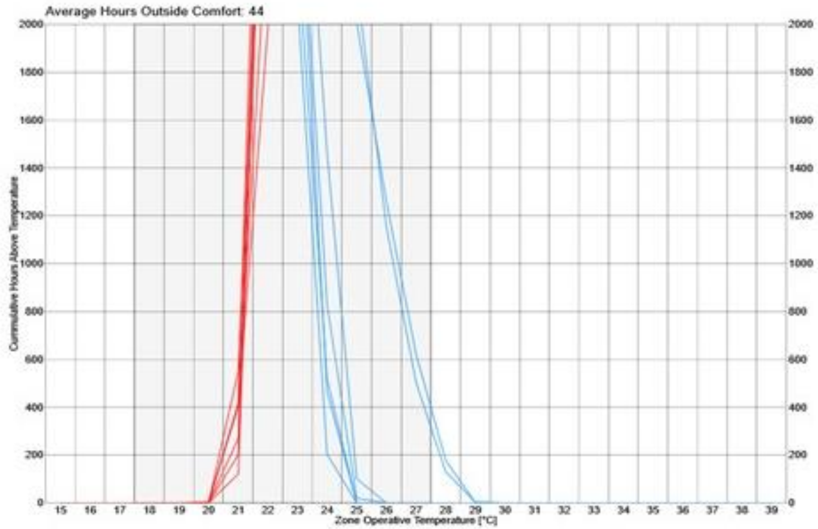
Roof Slab

U-Value[W/(m²·K)] = 0.404
R-Value[m²K/W] = 2.334
Thermal Capacitance[kJ/K/m²] = 142.262
Embodied Energy[MJ/m²] = 700
Embodied Carbon[kgCO2/m²] = 52.8

Floor slab

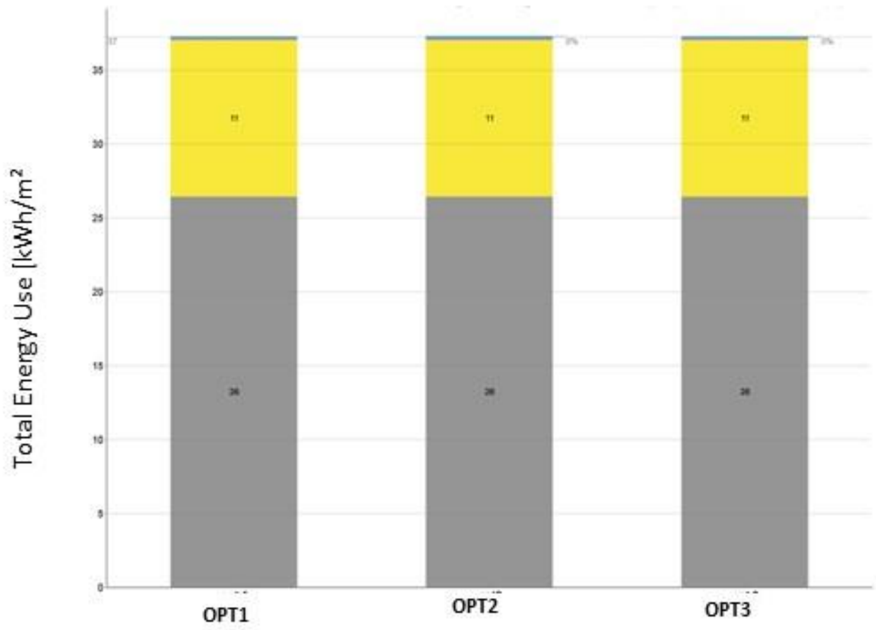
U-Value[W/(m²·K)] = 0.91
R-Value[m²K/W] = 0.839
Thermal Capacitance[kJ/K/m²] = 510.046
Embodied Energy[MJ/m²] = 435.72
Embodied Carbon[kgCO2/m²] = 50.973

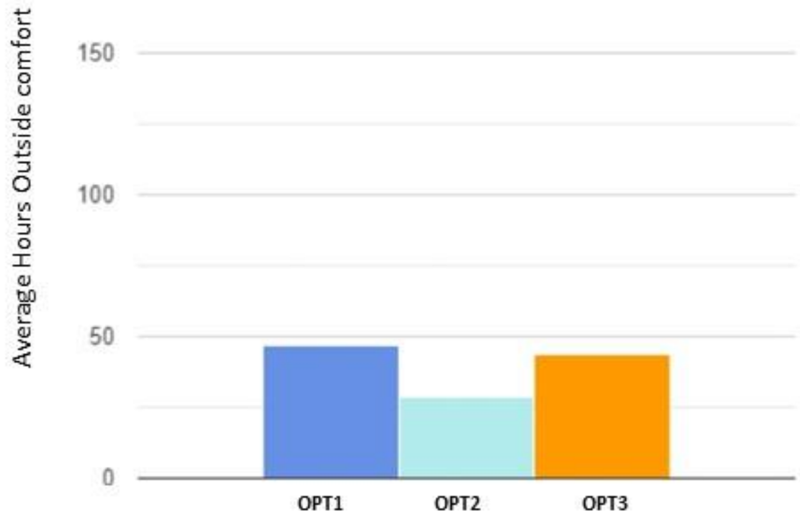




Option3: The graphical representations illustrate that by CLT12 and 10cm insulation with clay mortar finishing, an Energy Use Intensity (EUI) of 37 remains, accompanied by 44 hours of discomfort due to outdoor conditions falling outside the comfort range.

Comparison

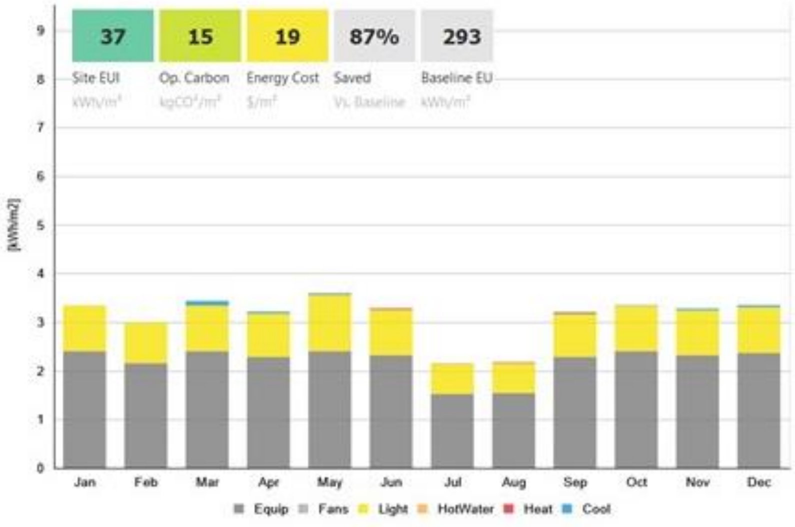


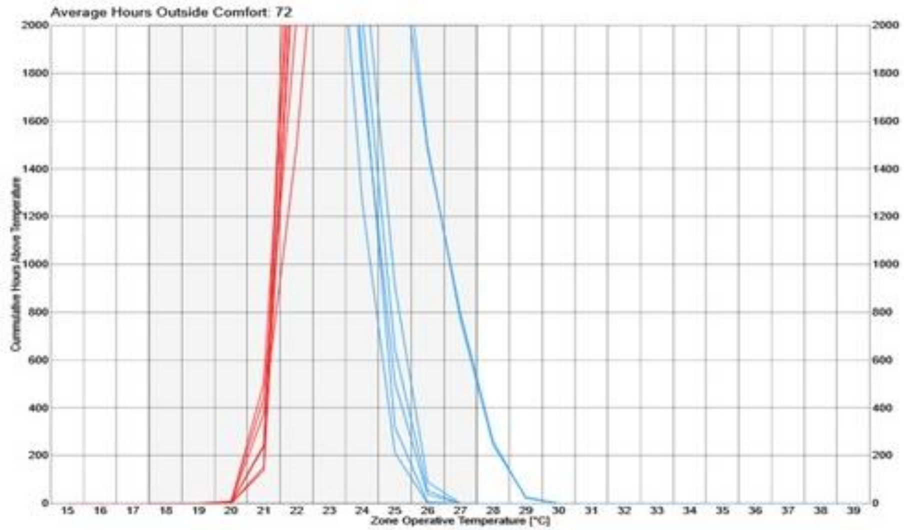


Evaluating these three alternatives, it becomes evident that all options demonstrate the same performance in terms of Energy Use Intensity (EUI). On the other hand, when focusing on comfort considerations, option 2 emerges as a favorable selection. However, when aiming to strike a harmonious balance between EUI efficiency, comfort optimization, and economic viability, our preference gravitates towards option 3. This entails integrating CLT12, 10 cm of mineral wool insulation, and a clay mortar finishing for the façade.

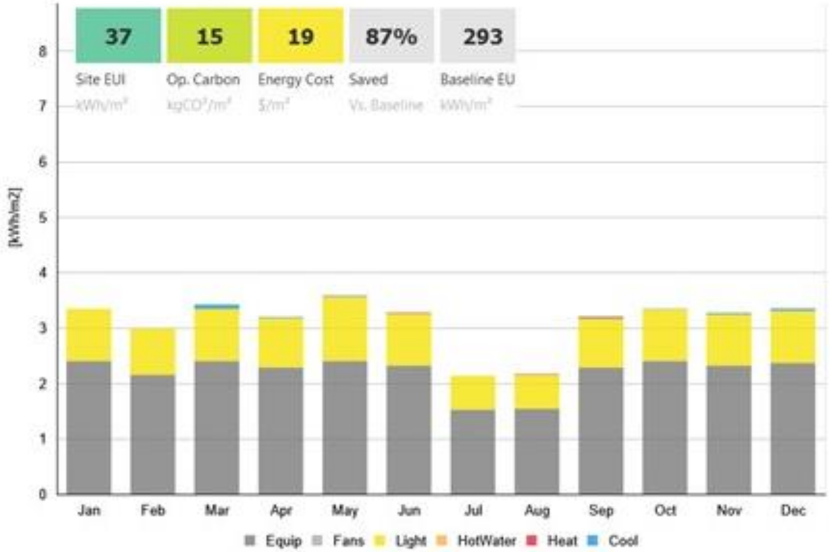
Stage 2

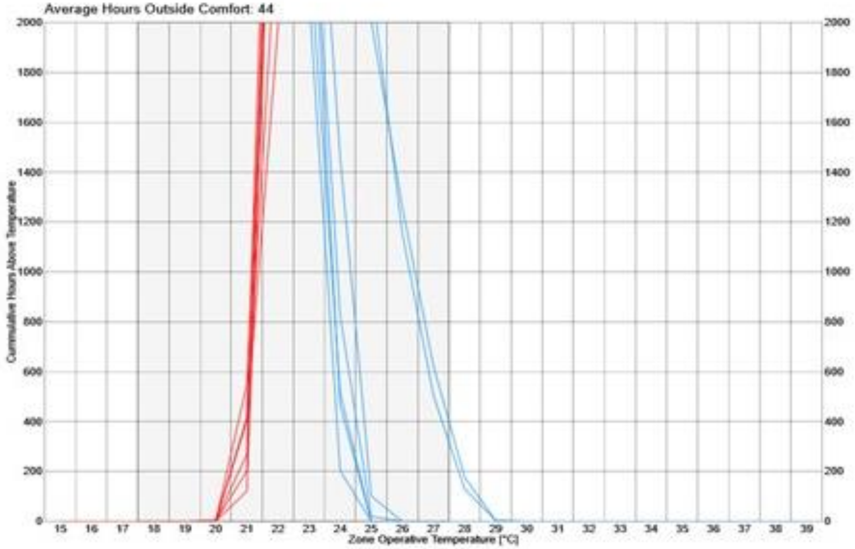
Having determined the suitable material in the preceding stage, and maintaining constant cross ventilation, we now explore the influence of "The Skin" on both Energy Use Intensity (EUI) and comfort, specifically in terms of shading. This analysis involves two steps: the absence of shading, and the implementation of shading.





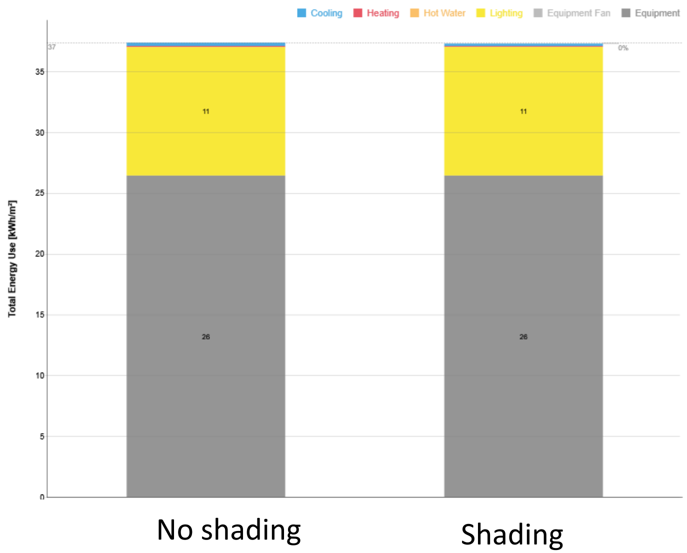
No Shading: In this context, it becomes evident that despite achieving a commendable EUI of 37, the absence of shading significantly impacts the occupants' comfort levels, leading to 72 hours falling outside the comfort range.

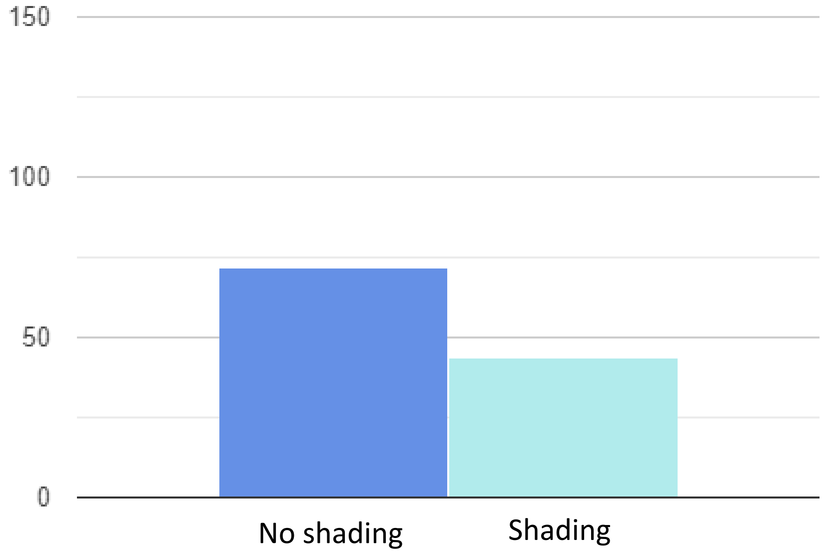




With Shading: Upon incorporating shading, a notable reduction in discomfort hours is observed, with the count decreasing to 44 hours. Interestingly, this improvement in comfort is achieved while maintaining an EUI nearly identical to the previous value.

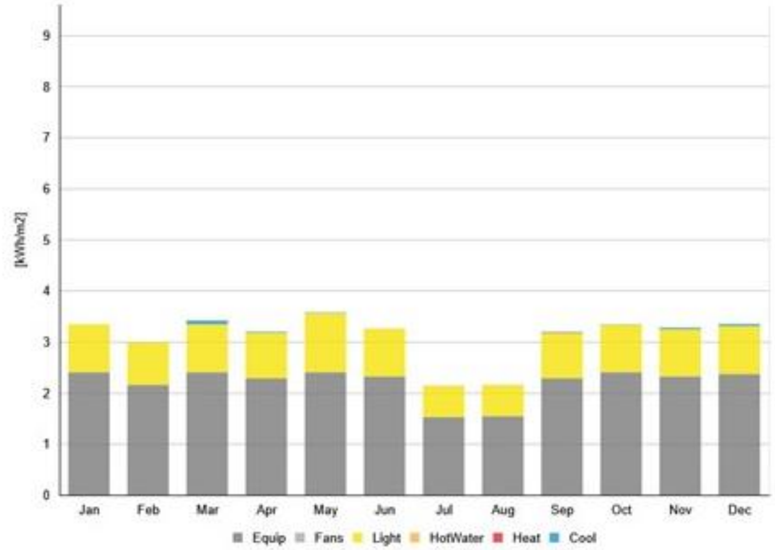
Comparison: Upon careful evaluation of these three options, it becomes clear that "The Skin" plays a crucial role in enhancing both energy efficiency and comfort, similar to its impact on daylighting.

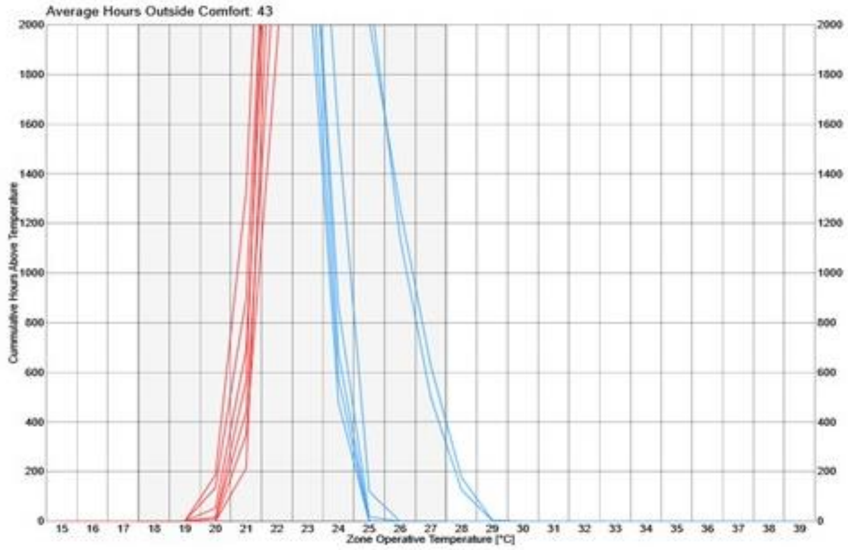




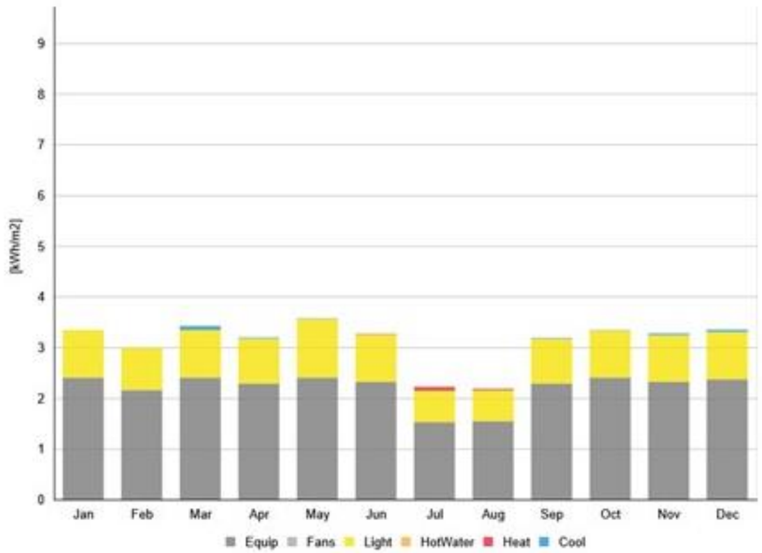
Stage 3

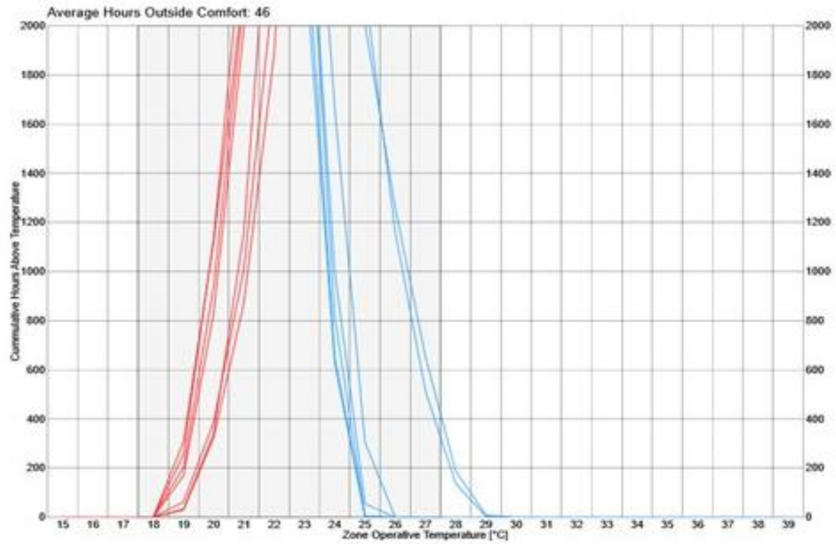
The primary ventilation strategy employed in this design is crossed ventilation, capitalizing on the natural airflow patterns prevalent in the region. By strategically placing clerestory windows on opposite sides of the building and movable louvers implemented in the exterior wall, a continuous exchange of fresh air is facilitated, maintaining a well-ventilated interior, and dissipating any accumulated heat. This passive approach to ventilation eliminates the need for mechanical ventilation systems, leading to reduced energy consumption and operational costs. In pervious stages we have maintained a constant natural ventilation system. However, in this current stage, we are evaluating various Air Changes per Hour (ACH) rates to determine their effects and benefits. The recommended Air Changes per Hour (ACH) rate for a classroom can vary based on factors such as the size of the classroom, the number of occupants, the intended use of the space, and local building codes or guidelines. Nonetheless, following a broad recommendation by ASHRAE, spaces for children aged 2-6 often adhere to an ACH range of 4 to 6. In our investigation, we initiated with 1 ACH, subsequently raised it to 4, and finally tested the upper limit of 6 ACH.



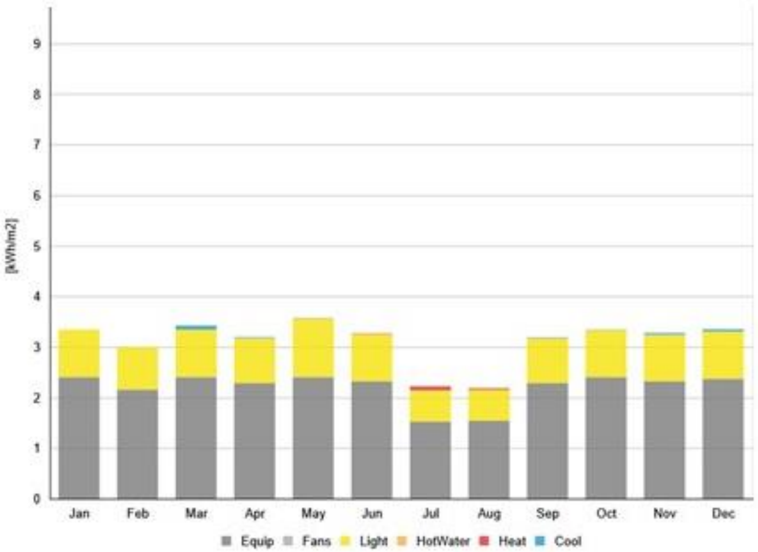


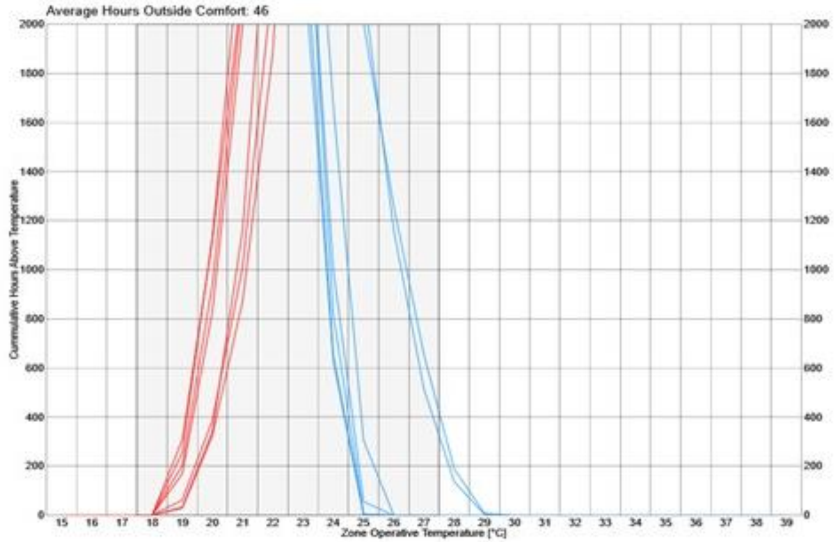
1 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 37 and a total average of 43 discomfort hours.



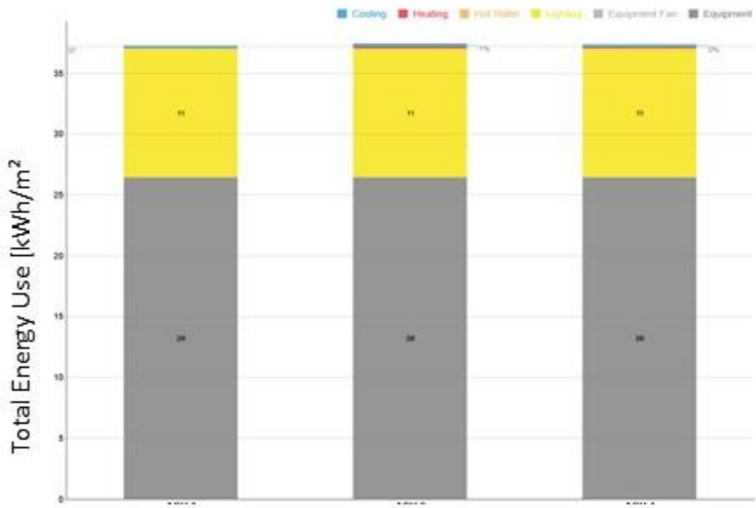


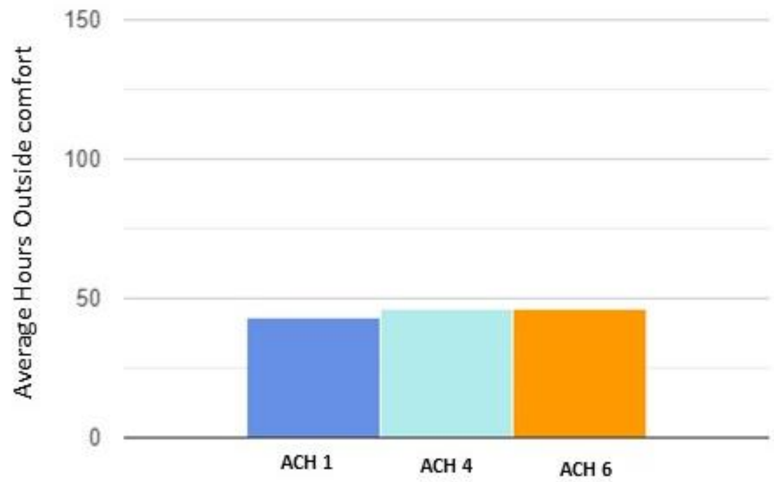
4 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 37 and a total average of 46 discomfort hours.





6 ACH: During this phase, achieving an Energy Use Intensity (EUI) of 37 and a total average of 46 discomfort hours.





Comparison:

Through a comparison of all four phases, a consistent EUI of 37 was maintained. Similarly, the discomfort hours showed minimal variation, ranging from 43 to 46 across the phases. Following ASHRAE guidelines, an ACH of 6 was selected based on these observations.

We introduced mechanical ventilation fans in the final stages to assess their impact on energy consumption and comfort. Interestingly, despite this addition, there was no significant change observed in the Energy Use Intensity (EUI) and the duration of discomfort, indicating that these factors remained consistent.

Conclusion:

Following an extensive series of simulations, we have refined our options to these four stages. The objective is to identify the optimal solution for our building, one that simultaneously minimizes Energy Use Intensity (EUI) and keeps the hours of discomfort to a minimum. This will be achieved by carefully weighing and balancing all design and economic considerations.

4.6. DAYLIGHT ANALYSIS

Daylight analysis plays a crucial role in the design of a school as it directly impacts the well-being, comfort, and performance of students and teachers. The availability of natural light in educational spaces has been recognized as a fundamental aspect of creating a healthy and conducive learning environment. Here are some key reasons why daylight analysis is important in designing a school:

Firstly, natural light promotes the health and well-being of students and staff by regulating circadian rhythms and improving mental health. Secondly, ample natural light positively affects academic performance, enhancing concentration and learning outcomes. Additionally, daylight analysis contributes to energy efficiency by reducing reliance on artificial lighting, resulting in cost savings and environmental benefits. Lastly, optimizing natural light in school design ensures visual comfort by minimizing glare and shadows, creating an ideal learning environment.

In conducting daylight analysis for the design of a school, we employ advanced software tools such as Climate Studio, which aligns with the LEED 4.1 (Leadership in Energy and Environmental Design) standards. The daylights analysis is calculated based on certain factors which are:

- **SPATIAL DAYLIGHT AUTONOMY (sDA):** Spatial Daylight Autonomy (sDA) examines whether space receives enough daylight during standard operating hours (8 a.m. to 6 p.m.) on an annual basis using hourly illuminance grids on the horizontal work plane. Floor areas, or grid points, in the building model that achieve 300 lux (based on legislation) for at least half of the analysis hours count as meeting the daylighting threshold. As a result, sDA values can range from zero to 100 percent of the floor area in ques t ion. sDA > 75% “preferable” from users 5 5 < sDA > 74% “acceptable” from users Lighting designers should aim to achieve sDA values of 75 percent or higher in regularly occupied spaces , such as an open- plan office or class room, and at least 55 percent in areas where some daylight is important.

- **Annual Sunlight Exposure (ASE):** With higher levels of daylight sufficiency comes the potential for glare and solar heat gain. That's where Annual Sunlight Exposure (ASE) steps in. Meant to complement sDA, ASE is intended to help designers limit excessive sunlight in space. While ASE is a crude proxy for glare phenomena, it measures the presence of sunlight using annual hourly horizontal illuminance grids rather than luminance measures, so it is technically not a glare metric. ASE uses a simulated 1,000 lux as an indicator value for sunlight, but the simulated value can differ significantly from what is measured in the physical world, which considers secondary bounce-off surfaces.

Like sDA, ASE values range from zero to 100 percent, with the latter suggesting that the entire floor area of the space in question exceeds the simulated value of 1,000 lux for at least 250 hours per year. Thus, to reduce the potential for glare and thermal stress, designers should aim for low ASE values. We consider ASE<10% acceptable.

- **Daylight Factor (DF):** percentage-based metric that measures the ratio of interior illuminance to exterior illuminance under overcast sky conditions. It assesses the amount of natural light available in space and helps determine its usability by comparing it to a predefined threshold. DF analysis informs design decisions regarding window placement and size, aiming to achieve adequate and comfortable lighting levels. It is important to note that DF does not consider variations in daylight availability throughout the day or year. Considering range between 2-5.

- **The Annual Glare-Daylight Factor (sDG):** is a metric that combines the evaluation of glare and daylight availability in a space. It considers the Daylight Glare Probability (DGP) and Spatial Daylight Autonomy (sDA) to assess the balance between glare control and sufficient daylight throughout the year. The sDG value, expressed as a percentage, helps designers optimize the design to minimize glare potential while ensuring comfortable daylight levels. Please note that the sDG metric may not be widely standardized or included in all daylight analysis software or certification systems. sDG<35% best class, <40% good, <45% reasonable.

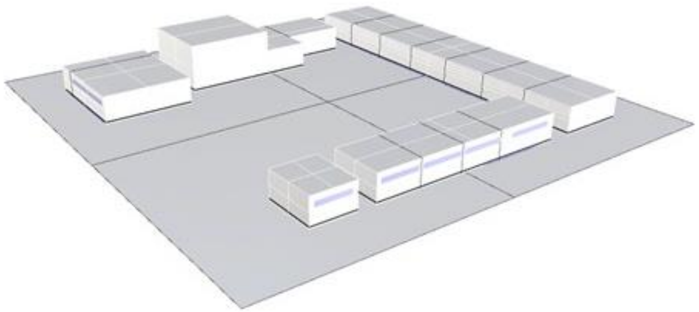
4.6.1. PRIMARY SCHOOL

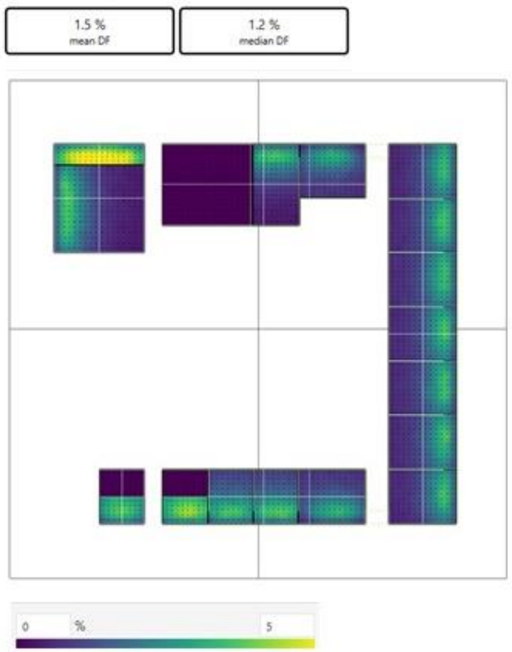
Stage 1

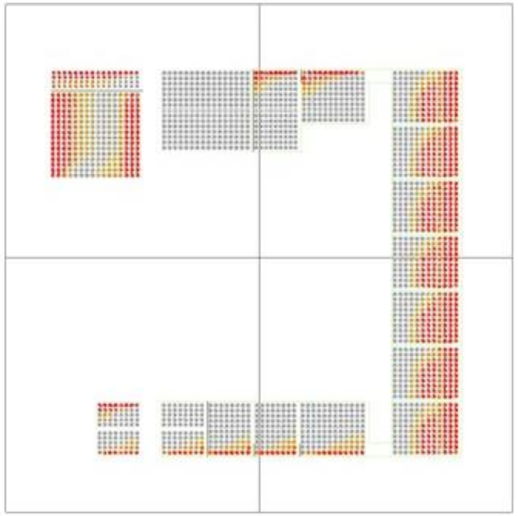
Primary School- Ground Floor (Before adding the Skin)
Annual Glare-Daylight Factor

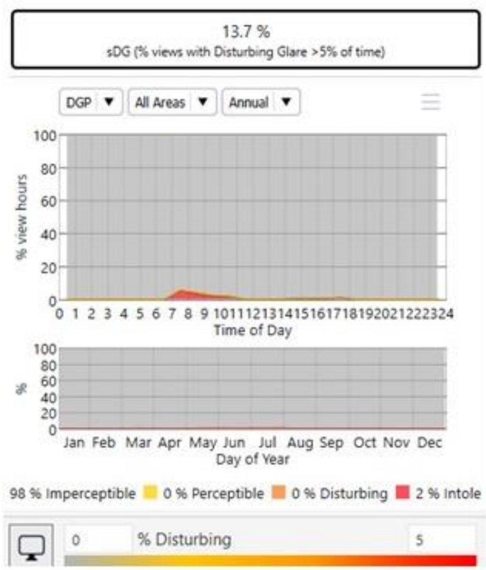
Primary School- Ground Floor

- Adding clerestory windows
- No shading
- No roof (The skin)









Annual Glare:
sDG lower than 35%: best class

- Max glare is about 14% cause it's not in operating hour it's not problematic. Although it can be controlled by adding the Skin.

Daylight Factor:
Around 2.5% acceptable

55

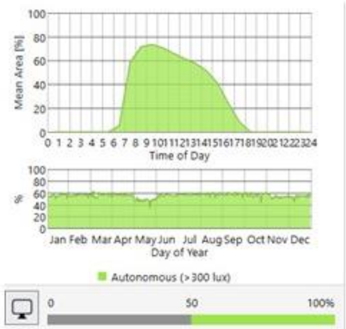
Primary school, Stage 1

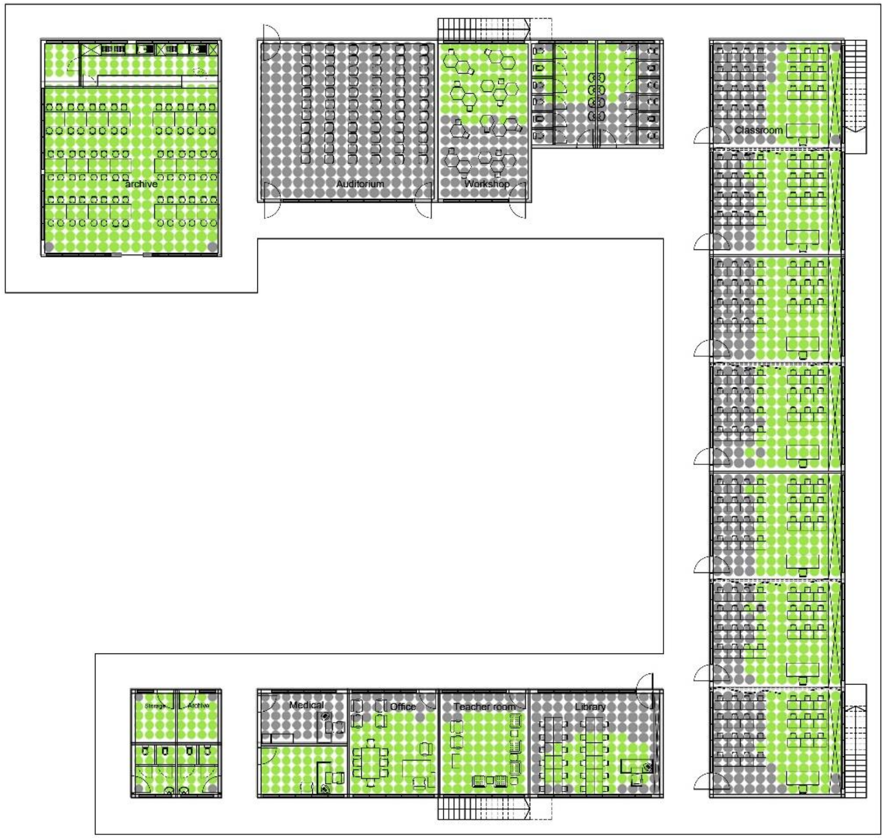
Primary School- Ground Floor (Before adding the Skin)
Daylight (sDA and ASE)

Primary School- Ground Floor

- Adding clerestory windows
- No shading
- No roof (The skin)

sDA:
Between 55 and 74% acceptable
we can reach higher sDA by adding more windows.
ASE:
Need to be lower than 10%





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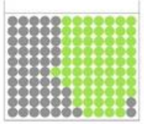
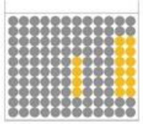
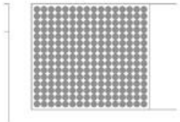
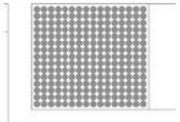
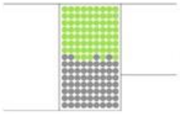
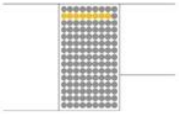
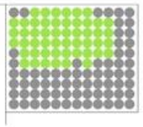
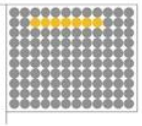
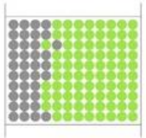
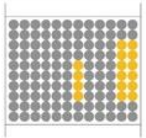
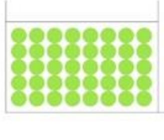
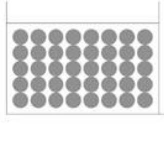
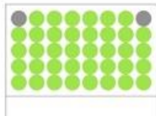
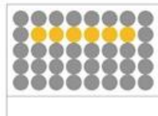
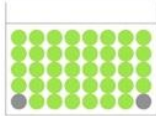
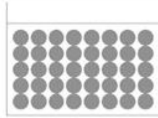
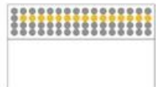
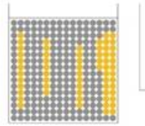
Class 1	N		54.17 %		13.33 % *
Seminar	N		0.00 %		0.00 %
Workshop	N		50.37 %		5.93 %
WC-2	N		42.50 %		5.83 %
Class 2	N		69.17 %		13.33 % *

Space ID & Description	Shading	0 50%	sDA	0 250 hrs	ASE
Medical 2	N		100.00 %		0.00 %
Archive and Storage	N		95.00 %		15.00 % *
WC	N		95.00 %		0.00 %
Kitchen	N		100.00 %		23.44 % *
Dining	N		99.22 %		24.22 % *

***Problematic spaces**

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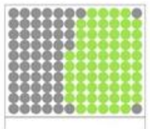
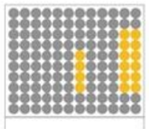
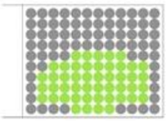
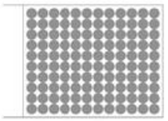
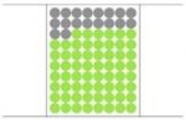
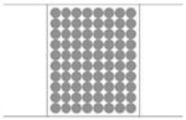
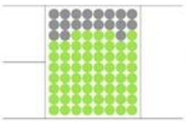
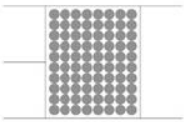
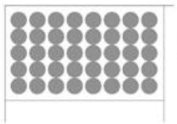
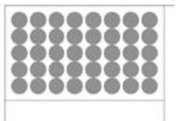
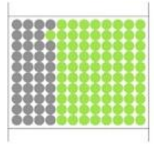
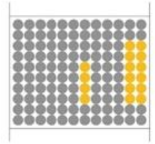
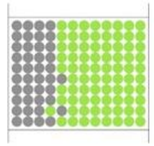
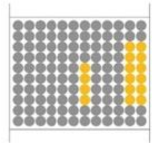
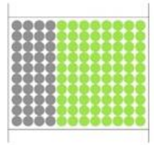
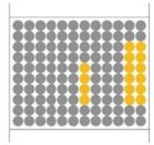
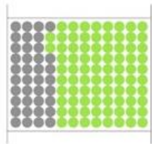
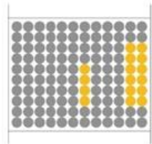
Class 7	N		51.67 %		13.33 % *
Library	N		40.00 %		0.00 %
Office 1	N		77.50 %		0.00 %
Office 2	N		76.25 %		0.00 %
Medical 1	N		0.00 %		0.00 %

Space ID & Description	Shading	0 50%	sDA	0 250 hrs	ASE *
Class 3	N		67.50 %		13.33 %
Class 4	N		65.83 %		13.33 %
Class 5	N		66.67 %		13.33 %
Class 6	N		68.33 %		13.33 %

***Problematic spaces**

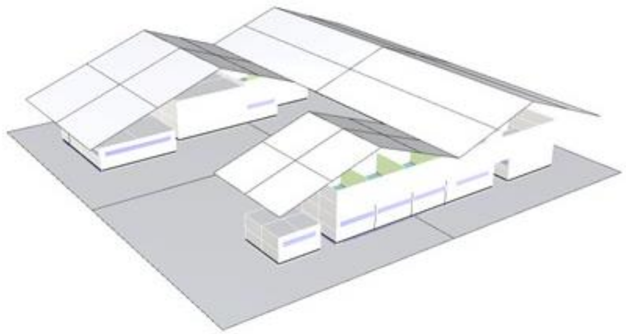
Primary school

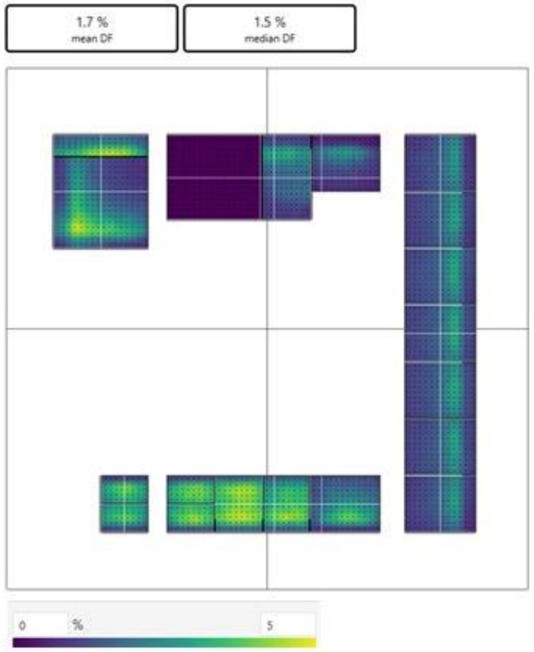
Stage 2

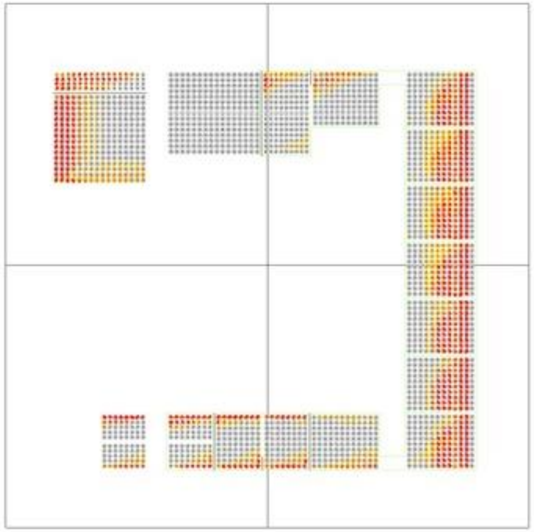
Primary School- Ground Floor (Adding the Skin and more windows)
Annual Glare-Daylight Factor

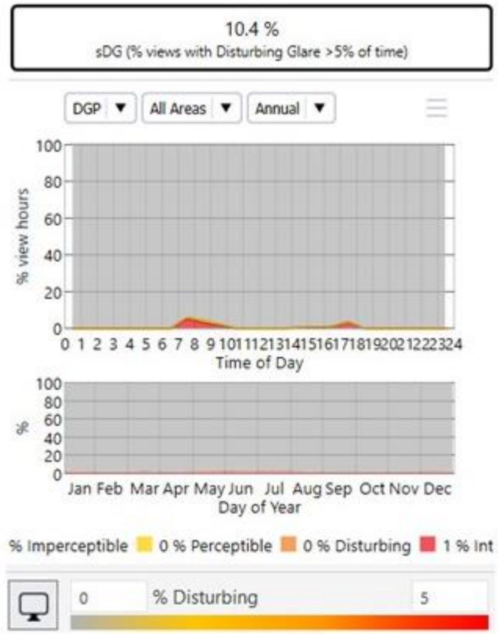
Primary School- Ground Floor

- Adding The Skin
- Adding more windows
- No shading









Annual Glare:
sDG lower than 35%: best class

- Decreasing of sDG by adding the roof about 4%.

Daylight Factor:
Around 2.5% acceptable

61

Stage 2

Primary School- Ground Floor (Adding the Skin and more windows)

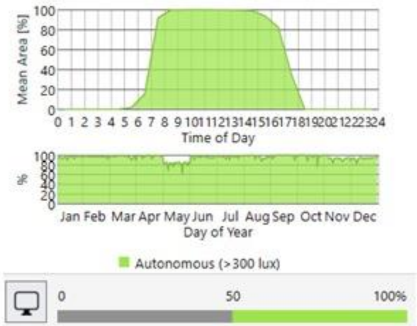
Daylight (sDA and ASE)

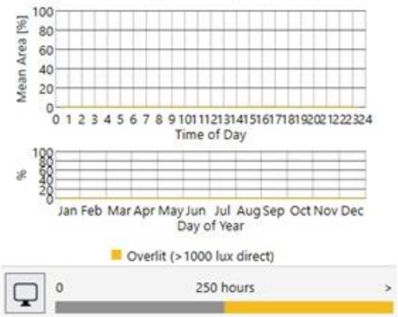
Primary School- Ground Floor

- Adding The Skin
- Adding more windows
- No shading

sDA:
Between 55 and 74% acceptable
In creasing sDA up to 86.7% by adding more openings.

ASE:
Lower than 10%, Decreasing to 5% by having the roof.



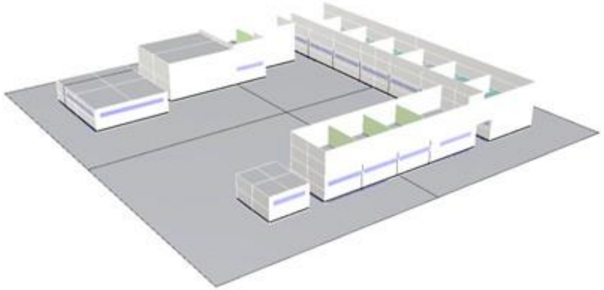


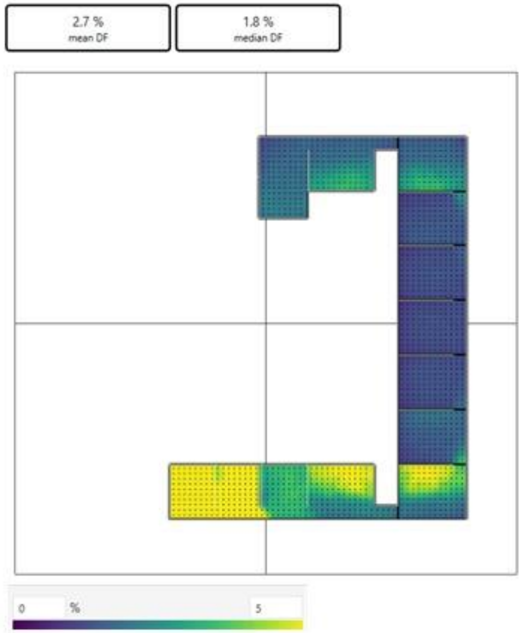
Stage 2-First floor

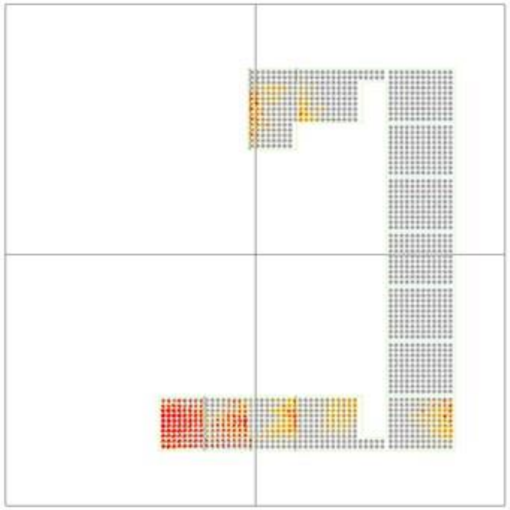
Primary School- First Floor (Adding the Skin and more windows)
Annual Glare-Daylight Factor

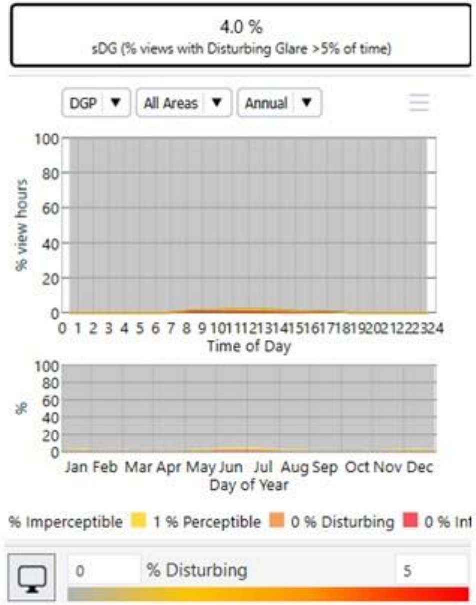
Primary School- First Floor

- Adding The Skin
- Adding more windows
- No shading









Annual Glare:

sDG lower than 35%: best class

Daylight Factor:
Around 2.5% acceptable

63

Stage 2- First floor

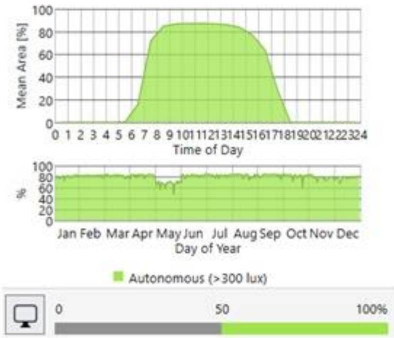
Primary School- First Floor (Adding the Skin and more windows)
Daylight (sDA and ASE)

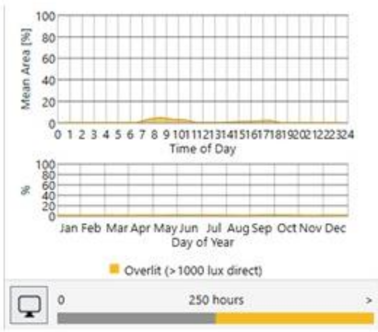
Primary School- First Floor

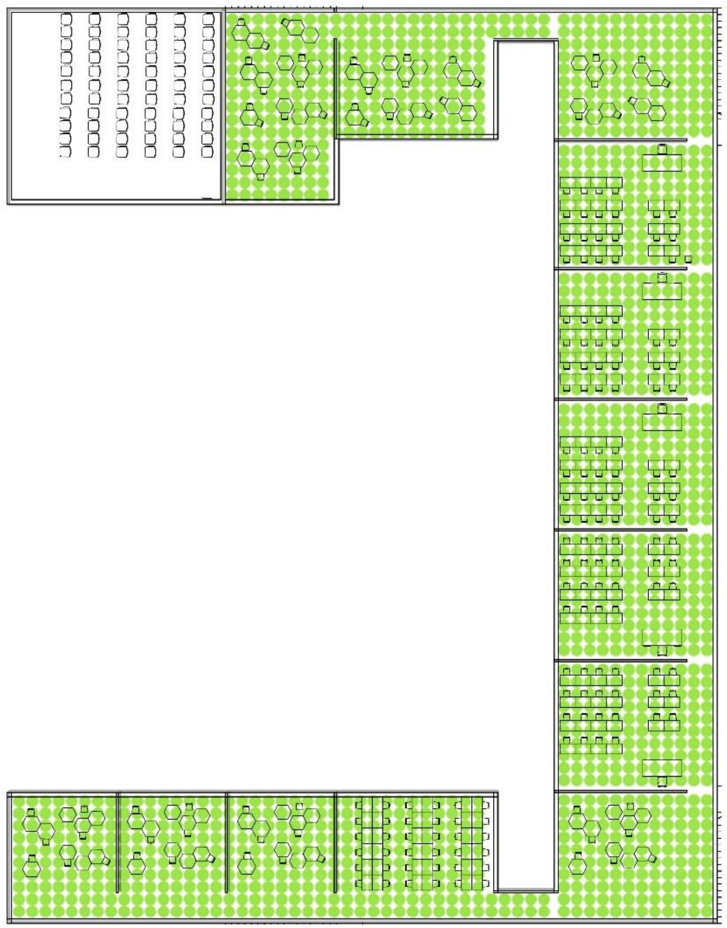
- Adding The Skin
- No shading

sDA:
Between 55 and 74% acceptable
Max Daylight considering semi open space

ASE:
Lower than 10%







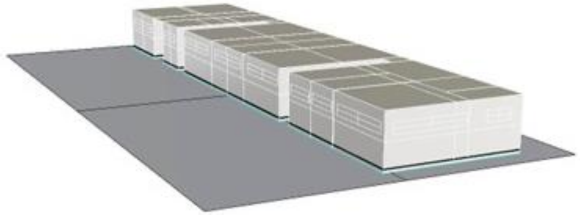
4.6.2. KINDERGARTEN

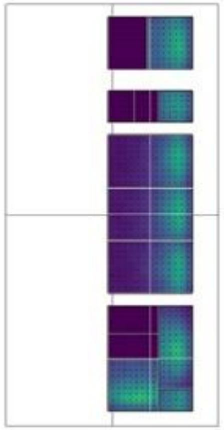
Stage 1

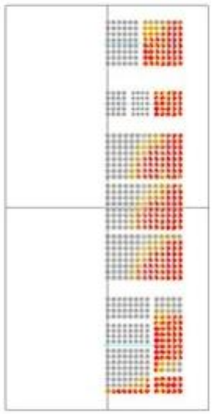
Kindergarten-Ground Floor (Before adding the Skin)
Annual Glare-Daylight Factor

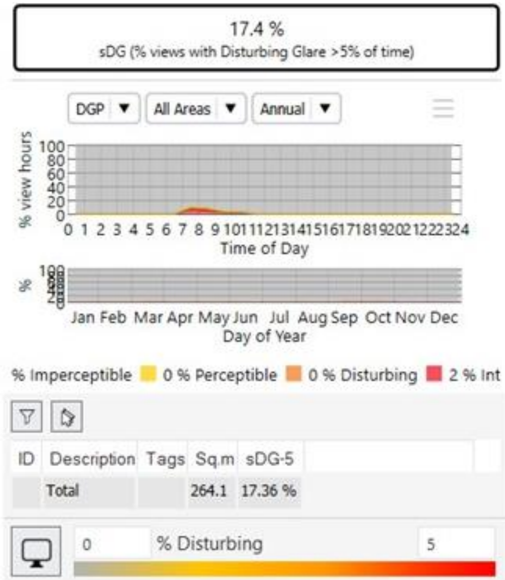
Kindergarten- Ground Floor

- Adding clerestory windows
- No shading
- No roof (The skin)









Annual Glare:
sDG lower than 35%: best class

- Max glare is about 17% cause it's not in operating hour it's not problematic. Although it can be controlled by adding the Skin.

Daylight Factor:
Around 2.5% acceptable

65

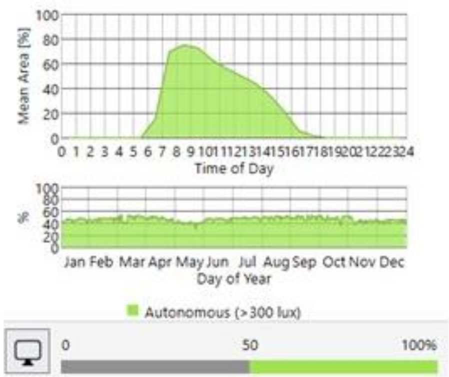
Kindergarten-Ground Floor (Before adding the Skin)
Daylight (sDA and ASE)

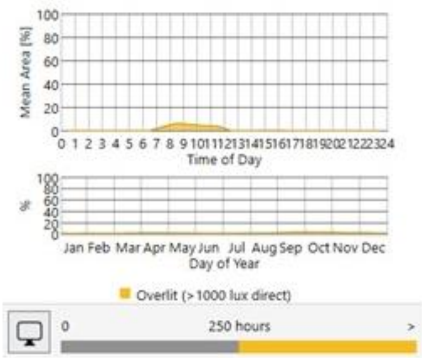
Kindergarten- Ground Floor

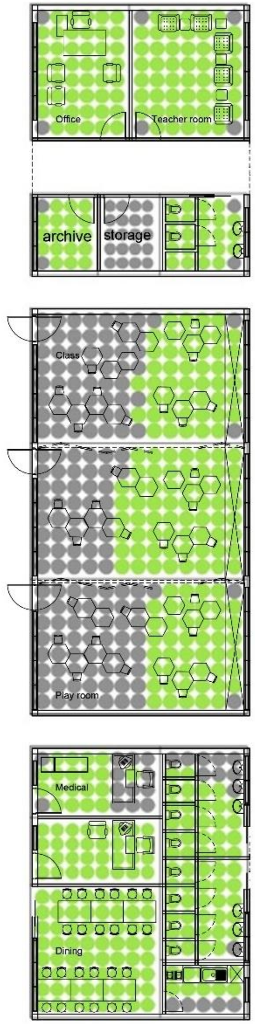
- Adding clerestory windows
- No shading
- No roof (The skin)

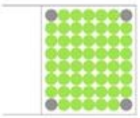
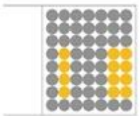
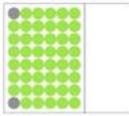
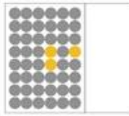
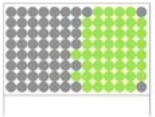
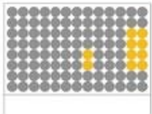
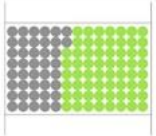
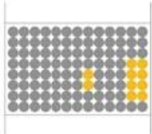
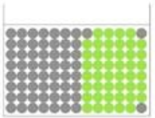
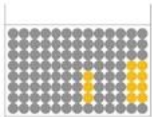
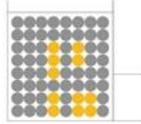
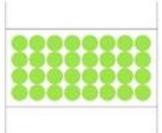
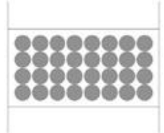
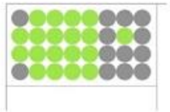
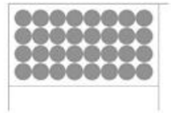
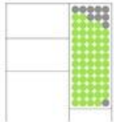
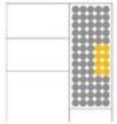
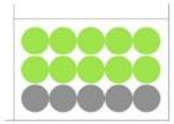
sDA:

Between 55 and 74% acceptable
We can reach higher sDA by adding more windows.
ASE:
Need to be lower than 10%





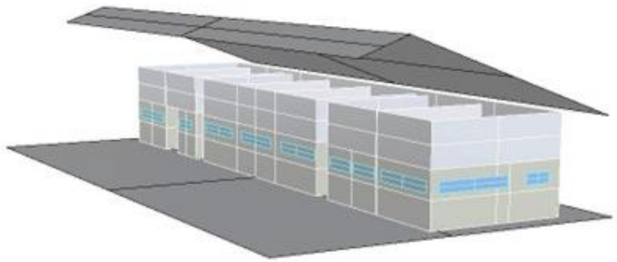


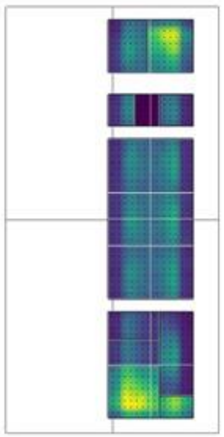
Space ID & Description	Shading	0 50%	sDA	0 250 hrs	ASE
Office 1	N		92.86 %		21.43 % *
Office 2	N		95.83 %		6.25 %
Class 1	N		45.19 %		9.62 %
Class 2	N		59.62 %		9.62 %
Class 3	N		43.27 %		10.58 %
Dining	N		100.00 %		17.19 % *
Medical 1	N		100.00 %		0.00 %
Medical 2	N		59.38 %		0.00 %
WC	N		84.62 %		12.31 % *
Kitchen	N		66.67 %		0.00 %

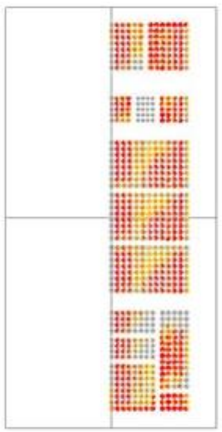
Kindergarten-Ground Floor (Adding the Skin and more windows)
Annual Glare-Daylight Factor

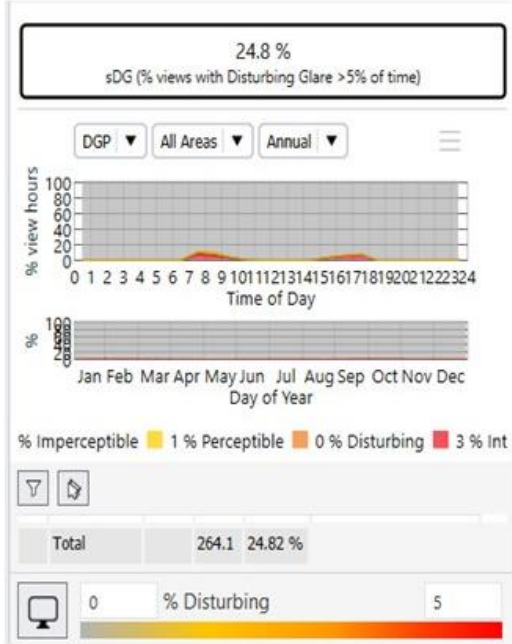
Kindergarten-Ground Floor

- Adding The Skin
- Adding more windows
- No shading









Annual Glare:
sDG lower than 35%: best class

- Increasing in sDG, mostly not in working hour.

Daylight Factor:
Around 2.5% acceptable

70

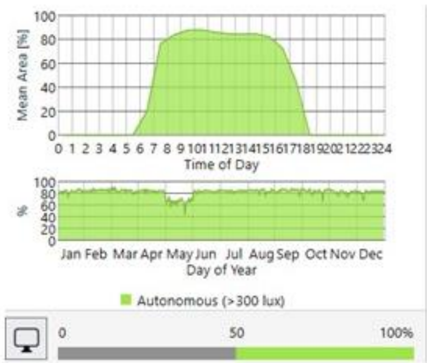
Kindergarten-Ground Floor (Adding the Skin and more windows)
Daylight (sDA and ASE)

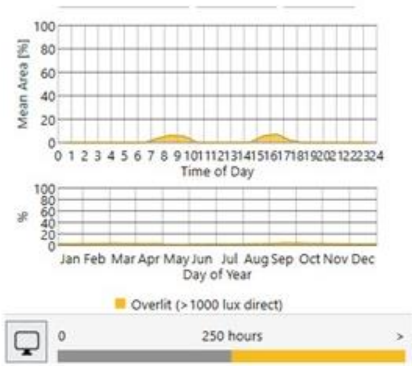
Kindergarten- Ground Floor

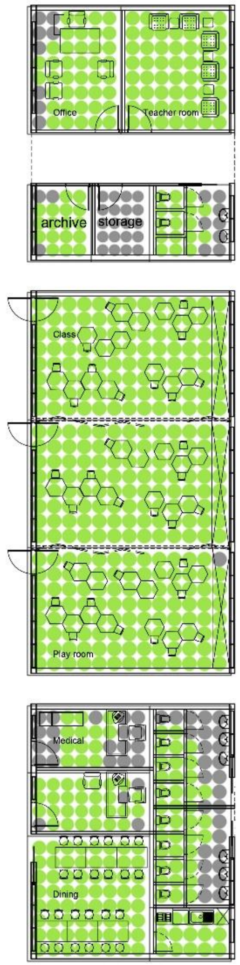
- Adding The Skin
- Adding more windows
- No shading

sDA:

Between 55 and 74% acceptable
Reaching more sDA adding more windows.
ASE:
lower than 10%



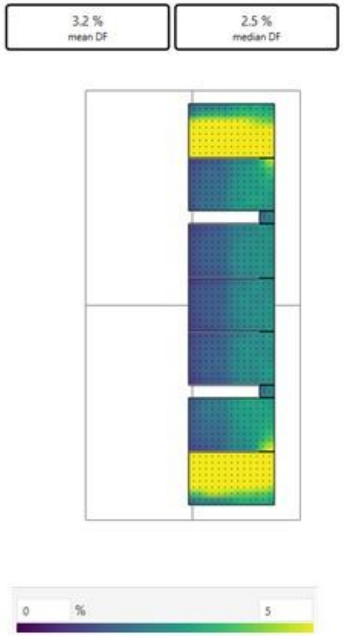


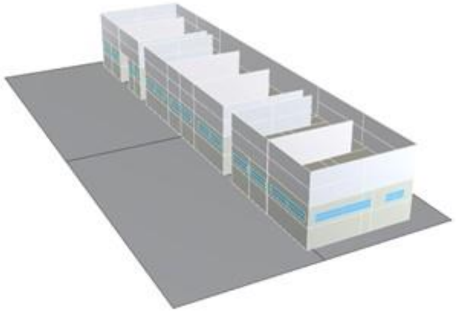


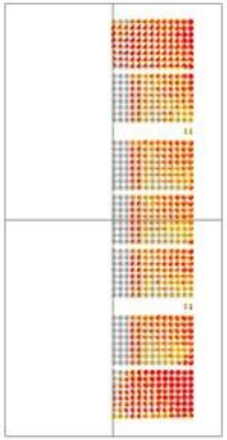
Kindergarten-First Floor (Adding the Skin and more windows)
Annual Glare-Daylight Factor

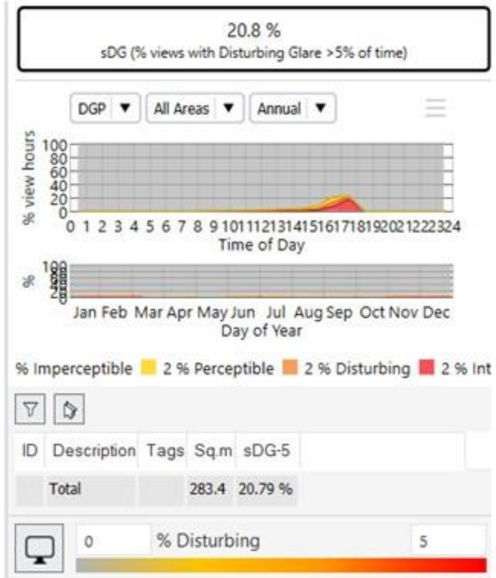
Kindergarten-First Floor

- Adding The Skin
- No shading









Annual Glare:
sDG lower than 35%: best class

Daylight Factor:
Around 2.5% acceptable

75

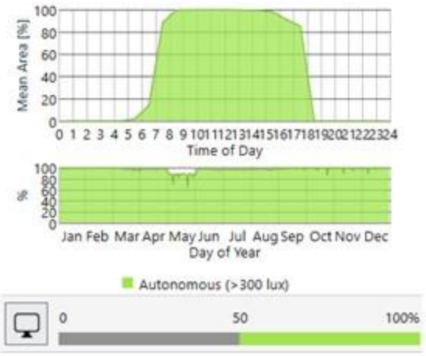
Kindergarten-First Floor (Adding the Skin and more windows)
Daylight (sDA and ASE)

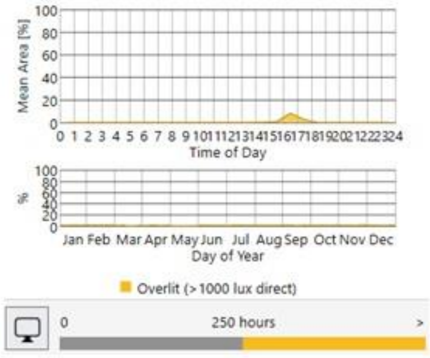
Kindergarten- First Floor

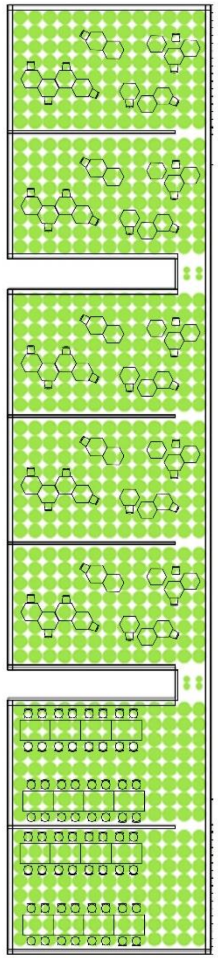
- Adding The Skin
- No shading

sDA:
Between 55 and 74% acceptable
Max Daylight considering semi open space

ASE:
Lower than 10%







4.7. PV PANELS

Solar power is a growing sector in Tanzania. The country has abundant clean energy resources, including wind, hydro and solar, of which the latter has witnessed the fastest growth over the past years. As of 2016, solar is in fact the dominant electricity source in rural areas, which are often unconnected to the national grid. In Tanzania, communities, entrepreneurs, NGO's, international organizations, and the government work together to strengthen the solar sector and improve its accessibility as part of expanding electricity access in the country. Implementing solar photovoltaic (PV) panels in the school holds tremendous potential for addressing energy challenges and promoting sustainable development. With the abundance of sunlight across the continent, solar power offers a reliable and renewable energy source that can significantly reduce schools' dependence on conventional fossil fuels. By harnessing the power of the sun, schools can generate clean electricity to meet their energy needs, powering lighting, electronics, and appliances.

PVGIS-5 estimates of solar electricity generation:

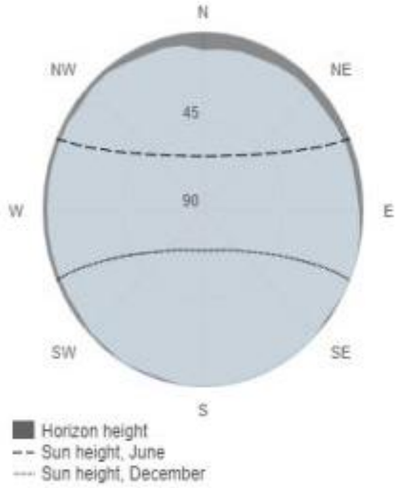
Provided inputs:

Latitude/Longitude:	-3.331,37.347
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed:	30 kWp
System loss:	14 %

Simulation outputs

Slope angle:	20 °
Azimuth angle:	0 °
Yearly PV energy production:	43544.17 kWh
Yearly in-plane irradiation:	1969.09 kWh/m²
Year-to-year variability:	1176.93 kWh
Changes in output due to:	
Angle of incidence:	-3 %
Spectral effects:	-0.35 %
Temperature and low irradiance:	-11.33 %
Total loss:	-26.29 %

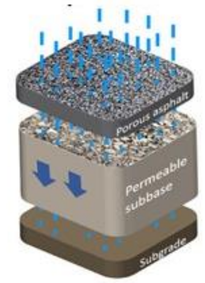
Outline of horizon at chosen location:



Monthly energy output from fix-angle PV system:

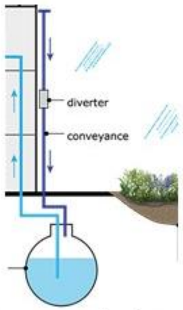
Monthly in-plane irradiation for fixed-angle:

4.8. WATER MANAGEMENT



Permeable sidewalk

The permeable pavement's ability to absorb rainwater and allow it to evaporate helps to cool the sidewalk surface and surrounding environment.

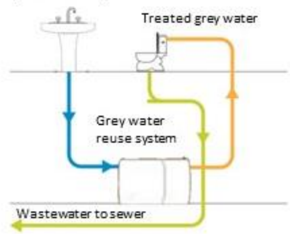


Underground cistern

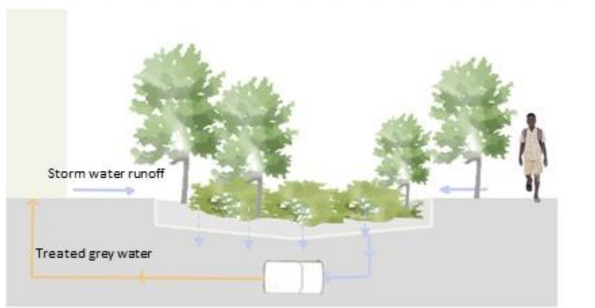
Harvested rainwater from underground storage can be used for landscape irrigation.

Rainwater gutter

It can prevent water damage and protects exterior surfaces. In addition, its connected to collection system for reusing.



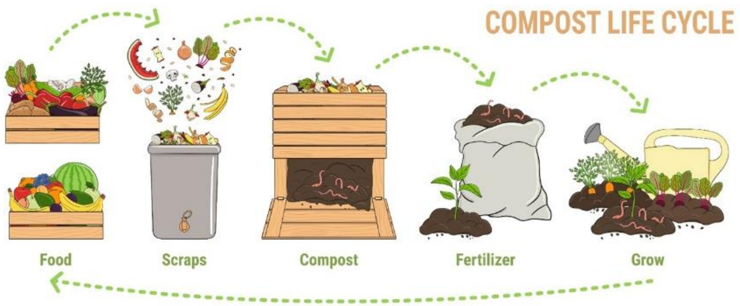
Grey water system



Grey water reuse system

4.9. WASTE MANAGEMENT

The compost cycle is a natural process that transforms organic matter into nutrient-rich compost. Composting can be done on a small scale. Once the compost is ready, it can be added to soil as a natural fertilizer and soil conditioner, enriching soil structure, water retention, and nutrient content. Considering the corn garden, by the composting process which is an essential part of a sustainable waste management strategy and as it reduces the volume of organic waste in landfills, it contributes to improved soil health and plant growth.



CONCLUSION

In conclusion, the design of a flexible school in Tanzania, with a focus on optimizing spaces, sustainable materials, and energy efficiency, holds tremendous promise for the future of education in the region. This innovative approach not only caters to the immediate needs of students but also serves as a beacon of sustainability and resilience. By incorporating adaptable spaces that can evolve with changing educational requirements, utilizing locally sourced, and implementing energy-efficient systems, this school becomes a model of holistic development. It not only fosters a conducive learning environment but also contributes to environmental conservation and energy independence. Such visionary projects not only enrich the lives of students but also inspire a brighter, more sustainable future for Tanzania's educational landscape. Moreover, our endeavor involved crafting a space that could adapt to various requirements over time, exhibiting a remarkable degree of flexibility. The approaches and tactics we employed have the potential to serve as a blueprint for designing structures in rural regions of hot climates in the future. This approach not only upholds traditional architectural typologies but also fosters innovation in sustainable design, leading to cost-effective solutions that minimize energy consumption.

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