Adapting the Affordable Housing Prototype in Indonesia

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Abstract

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Approximately twelve million Indonesian households reported needing a habitable home, a condition that is aggravated by population growth and urbanization. Besides the housing shortage, Indonesia's building and construction sector is inevitably facing climate change, which poses a higher risk of adverse effects to vulnerable communities. With the massive demand and due to a limited budget, a public housing program for low-income people built by the Indonesian government only met the minimum requirements of livable housing but disregarded the need for increased sustainability. Leveraging climate-responsive design to improve housing design and strengthen the community while tackling climate change is crucial.

This research identifies efficient and effective design strategies to achieve indoor thermal comfort, zero net energy building, and a resilient community of public housing in Indonesia. The research methodology involves analyzing case studies to develop passive design patterns that promote energy effectiveness and social well-being. The strategies are classified as building orientation, building form, façade, circulation, and landscape that could optimize thermal comfort and improve the community. However, enhancing affordable public housing performance could be challenging in Indonesia's hot and humid climate if only relying on passive design. The study runs an energy simulation that analyzes how mechanical strategies can support energy efficiency and production. The existing public housing is adapted according to climate-responsive and community-focused design frameworks.

Keywords: affordable housing, tropical climates, thermal comfort, community, case study, energy simulation

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Chapter 1 Introduction

1.1 Problem Statement

Affordable housing provision for low-income households in Indonesia is facing the challenge to solve shortages of housing and to adapt and mitigate the adverse effects of climate change. There are 12,715,302 households that need livable housing and only 60,9 percent of people who already own a house have habitable homes [1]. Statistics Indonesia predicted that urbanization would increase, reaching 66.6 percent in 2035, leading to higher demand for livable housing in metropolitan areas.

Housing development also consumes energy from construction to operational stage; if poorly managed it will aggravate the climate crisis. The building sector, including residential, contributes to global energy use by 34 percent and carbon emissions by 37 percent [2]. The building sector in Indonesia has one of the fastest growth rates, with residential buildings accounting for most of the construction increase and energy use.

In hot and humid countries like Indonesia, the need for space cooling intensified over 60 percent of the energy used in buildings and 70 percent is estimated to come from residential buildings [3]. The electricity demand potentially doubles with rapid urbanization; therefore, this study focuses on the analysis of design strategies which allow airflow to achieve indoor thermal comfort and zero net energy building.

How the housing design improves its community is also one of the aspects to be analyzed. Indonesia is vulnerable to climate change as it is one of the most natural disaster-prone countries in the world [4] and has a high climate risk because of its geographic, climate, social, and economic conditions [5]. A strong community is essential for resilience in tackling climate change, especially for low-income people.

This study aims to delve into Indonesia's existing multi-story public housing, specifically focusing on the prototype, which is a four-story building designed for low-income families. This thesis urges that the existing public housing design prototype needs to be improved and adapted with climate-responsive and community focused-design frameworks.

1.2 Background

The 1945 Constitution of The Republic of Indonesia ensures people's rights to have a place to live and have a good and healthy living environment. Through the Ministry of Public Works and Housing, the Indonesian government enhances access to the habitable home with various strategic programs, including public housing for low-income people, using the national budget. However, public housing only meets the minimum livable housing requirements: durable, sufficient living space, and adequate water and sanitation.

Students at Religious Boarding Schools

University Students

Low-income Families

Civil Servants

Figure 1. Various Existing Public Housing Prototype and the Target Beneficiaries

Indonesia is involved in the Paris Agreement which aims to support the global temperature rise limit of 1.5 C and decarbonize entirely by 2050. However, Indonesia's Nationally Determined Contribution (NDC) is still rated critically insufficient [6]. The building sector in Indonesia can save up to 38 percent of energy by strengthening the Mechanical Engineering and Plumbing Systems (MEPs) and improving the building envelope [7].

More than business as usual in multi-story public housing is strongly needed to solve the complexity of livable housing and climate change issues in Indonesia. This study aims to answer a big question on the significance of climate-responsive design in improving housing performance and strengthening the community to tackle climate change.

1.3 Claim

This thesis argues that the current public housing design in Indonesia only focuses on filling the huge gap between supply and demand of affordable housing and disregards the three fundamentals of sustainable development: environmental, social, and economic. First introduced in the finance and business field by Elkington's Triple Bottom Line, this concept awakens serious sustainability concerns that considers not only profit but also people and planet, which also can be applied in building and construction. This thesis proposes a new framework for how climate responsive and community focused design could be used to improve thermal comfort, zero net energy, and quality of life.

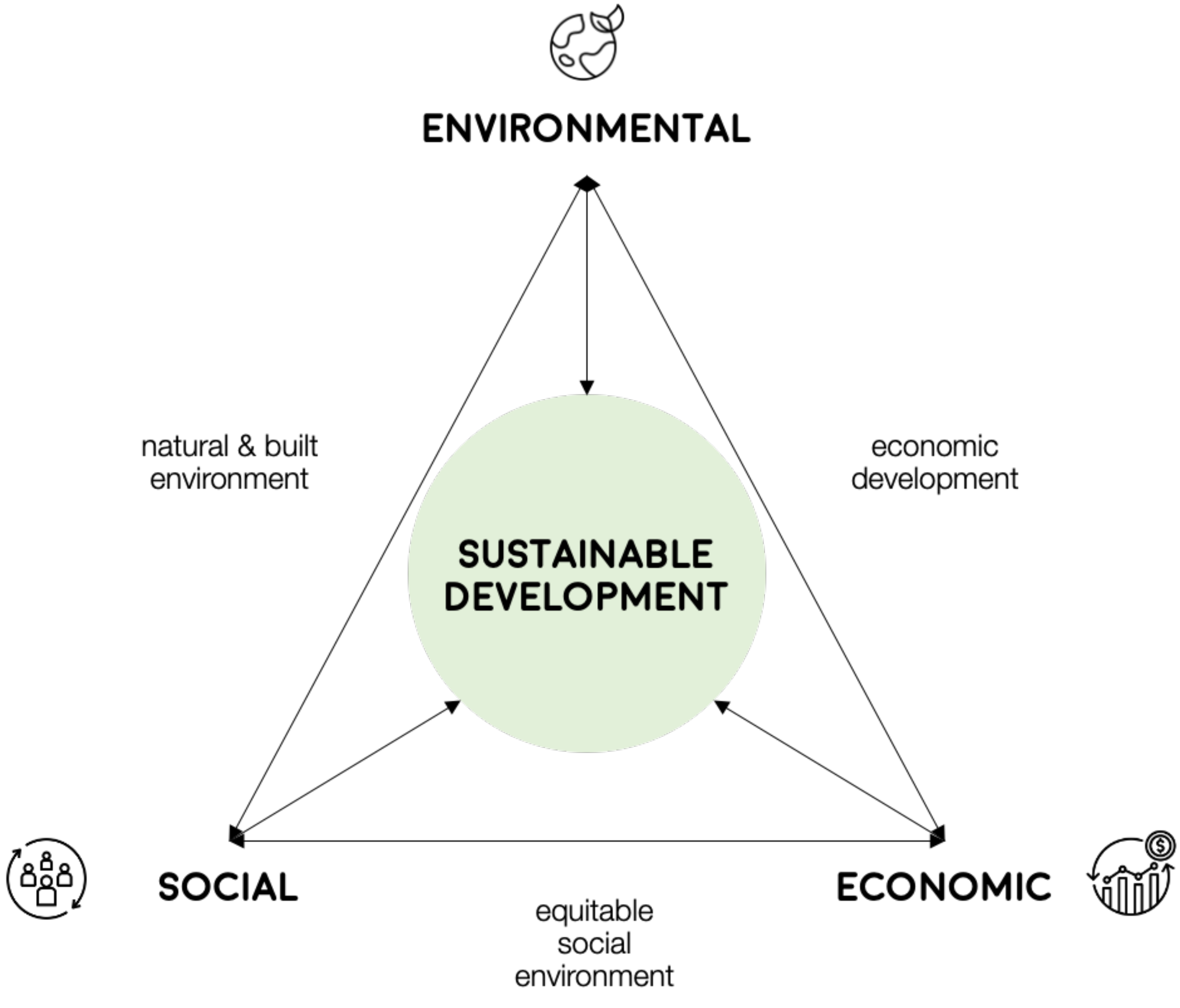


Figure 2. Sustainable Development

Chapter 2 Framework

2.1 Affordable Housing in Indonesia

For those with low incomes, the rising cost of housing and the lack of affordable housing are critical concerns. Low-income households need government assistance to purchase housing. Many factors, including the scarcity of land for development, the rising cost of building supplies, and stagnant household wages, contribute to housing prices. However, solving these problems takes much work. It is challenging to lower household expenses while raising household earnings; also, household expenses and incomes grow slowly over time [8]. Thus, public housing is developed for various target beneficiaries, including low-income families, to ensure that these families have access to affordable livable housing.

2.1.1 Public housing

The Ministry of Public Works and Housing of the Republic of Indonesia is responsible for building public housing using the national budget. Public housing that is built includes multi-story housing and single-family houses. The existing design of multi-story housing has four distinct types with various building heights. The types are differentiated based on target beneficiaries. The target beneficiaries of this housing program are students at religious boarding schools, university students, low-income families, and civil servants.

Each year, the Ministry will massively build all the housing types throughout Indonesian cities. The public housing provision needs to involve a synergy between the central government and regional governments. The local government submits a proposal and fulfills requirements including clean and clear land, before they can be a part of this program. The proposals are reviewed and approved by the Ministry. The construction of the housing will then start, and after it is completed, the public housing will be managed by the local government. Public housing is treated as rental housing; the local government runs the operation of the property with very low rental fees.

2.1.2 Low-income

People who need government assistance to obtain a house are regulated through the Decree of the Minister of Public Works and Housing Number 411 of 2021. They are considered “low-income” if their income is up to Rp 6 million per month for a single person, and Rp 8 million per month for married couples. These income limits are applied in all Indonesian provinces except Papua and West Papua, where the maximum income limit for a single person is Rp 7.5 million per month and Rp 10 million per month for married couples.

2.1.3 Sustainable housing for low-income households

The term “sustainability” is defined as development “[meeting] the needs of the present generation without compromising the ability of future generations to meet their own needs” [9]. Since most low-income households have limited access to affordable housing, sustainable low-cost housing is the only way to address the housing backlog. Expanding sustainable housing is a potential solution to the enormous housing demand, especially for low-income people. However, research from Choguill argues that the housing sector cannot stand alone. It is deeply interconnected with urban development issues [10]. Sustainable housing is a part of sustainable development and starts from the concept of sustainability of human settlements. In addition, when developing suitable sustainable housing solutions, the local context is always crucial, including factors like the climate, the effectiveness of local government, and the degree to which local communities can be involved [11]. Thus, to achieve sustainability and successfully meet the housing needs of the poor, housing policy must be integrated, economically and technically feasible, socially fair, and environmentally adaptable.

However, sustainable housing provision requires high costs if we use the current business models. Again, the institutions play a significant role in supporting innovative business models that allow for affordable zero-energy housing [12]. Institutional barriers have multiplier effects on developing sustainable housing: quality performance, energy efficiency, and affordability [13]. All the findings from previous studies reflect the current state of public housing policy in Indonesia. Thus, evaluating the Indonesian government's housing program is important.

2.1.4 Residents' well-being in affordable housing

Residents' satisfaction is an essential indication used by planners, architects, developers, and policymakers. A low-cost housing provided by the government that has not met family housing needs, comfort, social, cultural, and religious needs can affect the residents' well-being and quality of life [14]. Besides protecting the people against hazards and providing them a safe environment for sleep, personal hygiene, and food storage, a house also needs to provide a comfortable environment for relaxation and social exchange with friends, family, and others [15]. Therefore, public agencies that are responsible for affordable housing should pay careful attention to the satisfaction that includes sheltered (dwelling unit features and dwelling unit support services) and non-sheltered aspects (public facilities, social environment, and neighborhood facilities).

2.2 Low-Income Neighborhood

Urban areas in Indonesia grapple with a myriad of environmental challenges, including rapid urban expansion, insufficient waste management, groundwater contamination, and freshwater resource shortages. Despite these adversities, the city still grapples with the spread of irregular settlements that are integral parts of urban development, often referred to as *kampung*. *Kampung* are human settlements built by residents to address housing challenges due to the government's failures in providing affordable housing alternatives to meet increasing demand [16]. This settlement was constructed without adhering to building codes and urban regulations. It may be legal if built on owned land or illegal if constructed on others' property. However, *kampung* demonstrates admirable resilience, playing an essential social, economic, and political role in the city's functioning. This phenomenon, known as "middling urbanism"—a term used to describe the dynamic spatial and temporal relationship intertwined with the formalized city—signifies the complex nature of these settlements [17].

Figure 3. Irregular Settlement in Jakarta. (Photos by Tetsu Ozawa)

This study has taken research by Hutama (2019) about Kampung Code in Yogyakarta as an example of the *kampung* condition [18]. The aim was to dissect the relationship between *kampung* and Indonesia's existing public housing prototype. This comparison analysis is a crucial step in understanding the physical characteristics and social life of *kampung* that have been or need to be adapted to the prototype.

2.2.1 Physical characteristics

Yogyakarta, one of the major cities in Indonesia, is home to Kampung Code, which is situated along the riverbank and near the business district, traditional markets, and train stations. This settlement, a registered slum, houses about 10,059 inhabitants (2596 households) within 25.69 hectares (63.48 acres). In contrast, the prototype that became the subject of this study has capacity for 240 inhabitants (60 households) within 3,280 square meters (0.81 acres). The affordable housing, built by the government to address this uninhabitable settlement, offers a glimmer of hope to provide livable housing. This prototype has higher density and better quality of basic structure and infrastructure, potentially transforming the living conditions in the *kampung* settlements.

Table 1. Physical Characteristics Comparison

Characteristic	**Kampung Code**	**Existing Prototype**
Population	10,059 inhabitants 2,596 households	240 inhabitants 60 households
Land Area	63.48 acres	0.81 acres
Density	158.46 inhabitants/acres 40.89 households/acres	296.3 inhabitants/acres 74.07 households/acres
Characteristic	**Kampung (in general)**	**Existing Prototype**
Location	Living on or near unprotected high-risk zones	Land owned by municipalities and following urban regulations
Structural quality of housing	Living in temporary and/or dilapidated structures	Concrete structure and following building code
Overcrowding	Proportion of households with more than two persons per room	4 people in each dwelling unit
Infrastructure	Inadequate drinking water supply and sanitation	Adequate water supply and sanitation
Environment quality	Lack of natural lighting and ventilation	Healthier environments allow daylight and cross-ventilation

2.2.2 Social life

People residing in a *kampung* originate from diverse cultural backgrounds, contributing to the neighborhood's multi-dimensional identity. The high population density and limited open space in *kampung* have led the community to transform and adapt urban spaces to accommodate social interaction. As a result, although urban *kampungs* have limited open spaces, they boast abundant social public spaces. Social spaces in Kampung Code, also commonly found in other *kampung*, are streets/alleys, community buildings, open spaces, local shops and taverns, in-house terraces, guard posts, and riverbanks. These social spaces are configured in highly locally integrated areas where the dwellers' outdoor activities mainly occur. The dwellers can easily see each other, which encourages them to participate in social interactions. In comparison, the prototype has fewer spaces formally used for community gatherings: outdoor area, multifunction room, common balconies, and prayer room.

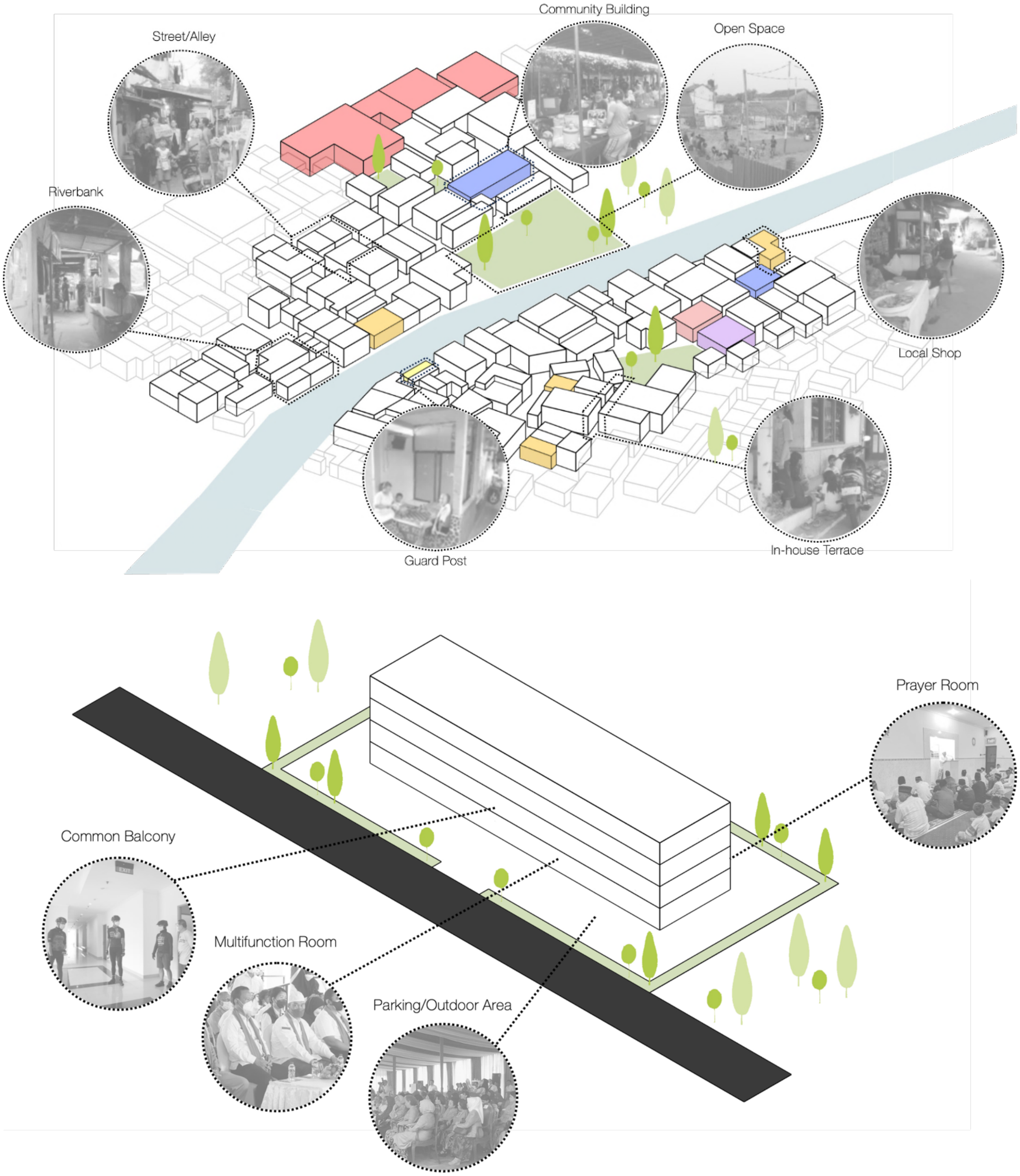


Figure 4. Community Spaces Comparison: (a) Kampung; (b) Existing Prototype

2.2.3 Relation between community and space organization

Housing transformation is necessary to create a personalized environment for low-income households relocating from irregular settlements to public housing. The organization of a living space should meet the user's needs and space requirements and consider the evolving relationships with neighbors [19]. Mahmud (2001) cited in Masud (2019) summarizes factors that affect the physical organization of spaces in the low-income settlements, which should be considered in the transformation, including income/occupation, education, family structure and settlement density, religion/culture, neighbor's relations and unity, and duration of stay in the settlement.

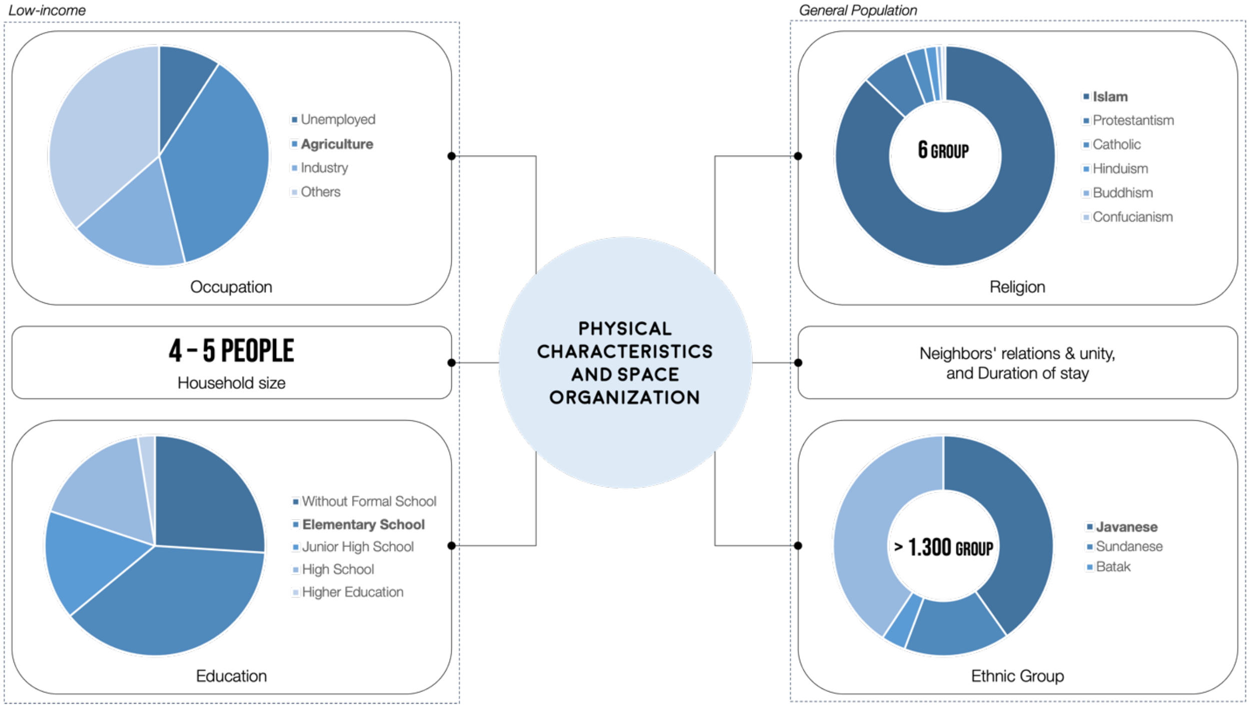


Figure 5. Factors that Affect the Space Organization

According to Statistics Indonesia, around 37 percent of low-income people have an occupation in agriculture, and 36 percent have informal jobs. It shows an opportunity to provide a shared space that can improve the community's economy. The low-income families do not have high education, 38 percent only pass the elementary level, and 26 percent have no formal schooling. The education levels of the inhabitants may not directly affect the quality of the dwellings. Still, it indirectly influences people's consciousness about a better living environment to support sustainability. The average low-income household size is four to five people, so two-bedroom units are used in the design prototype. However, the dwelling units' flexibility and changing possibilities are critical for increasing family space needs. Moreover, Indonesia is a multicultural country with more than 1,300 ethnic groups and six religions. Each ethnicity and religion have cultural events that should be accommodated in the housing.

2.3 Indonesia Climatic Conditions

Indonesia is located right on the equator, so the sun's path is almost equal on the north and south sides. This geographic condition of Indonesia affected its climatic condition, giving it a very hot and humid tropical climate. This study took Jakarta to analyze the climate condition in Indonesia using Climate Consultant with ASHRAE Standard 55-2004.

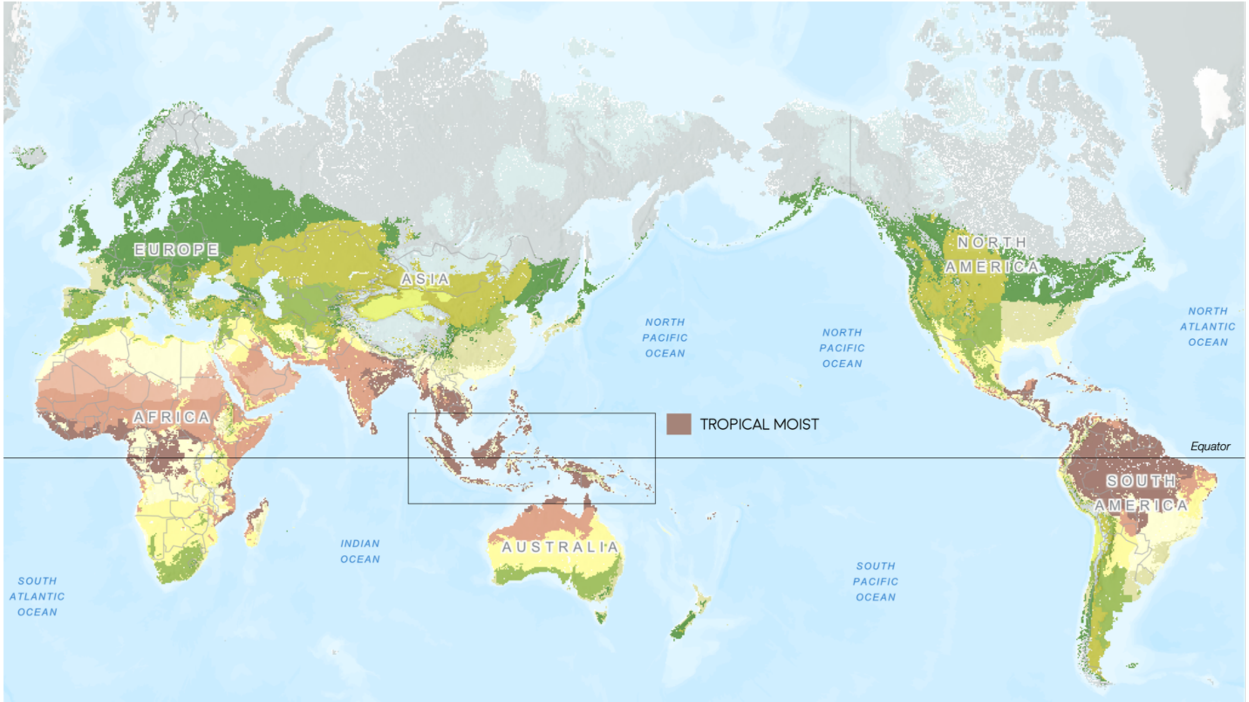


Figure 6. Geographic and Climatic Condition of Indonesia

2.3.1 Adaptive Thermal

Thermal comfort is a condition of a person's satisfaction with the thermal environment in space that may vary or be subjective [20]. Thermal comfort is influenced by environmental variables (air temperature, radiant temperature, air speed, and humidity) and personal factors (metabolic rate and clothing insulation) [21]. Thermal comfort standards often prescribe uniform comfort zones for universally applied temperatures. However, it's crucial to consider the cultural, climatic, social, and contextual dimensions of thermal adaptation comfort to avoid creating an exaggerated "need" for cooling [22]. The fundamental principle of the adaptive model is that occupants are active participants in determining their thermal preferences rather than passive recipients of the building's indoor thermal environment.

There are three primary modes of adaptation: physiological, behavioral, and psychological [23]. Physiological adaptation or acclimatization involves biological responses from prolonged exposure to relatively extreme thermal conditions. For example, individuals in hot climates develop an increased tolerance for warmer temperatures. Behavioral adaptation refers to any action a person takes to alter their body's thermal balance, such as choosing clothing for its thermal insulation and increasing air speed within a naturally ventilated space. Lastly, the psychological dimension involves altered perceptions and reactions to physical conditions based on experience and expectations. Therefore, indoor temperature falling outside ASHRAE Standard 55-2004 comfort zones, used in Climate Consultant for initial climate analysis, may be acceptable in buildings with natural or hybrid ventilation systems.

Expectation for indoor comfort will be dependent on outdoor temperature. The range in thermal comfort levels in naturally ventilated buildings showed much more variation, suggesting that occupants preferred conditions that more closely reflected outdoor climate patterns. This could be because they have more control over their environment or are accustomed to experiencing more variable conditions in such buildings. Thermal adaptation has been considered, in addition to the standard used in the climate file-based analysis below, to determine design strategies for the proposed design.

2.3.2 Climate Analysis

- **Temperature Range**

Indonesia lacks reliable thermal comfort [24]. The existing national standard, SNI 6390:2011, specifies only one range of comfortable temperatures, 77.9 °F (25.5 °C) with a range of +1.5 °C. Previous thermal studies found that the neutral temperatures in Indonesia were about 80.6 to 82.4 °F (27 to 28 °C). The chart below shows Indonesia has warm temperatures throughout the year, ranging from 66 to 92 °F (18.8 to 33.3 °C) and no high diurnal temperature range. Brager, G.S. and de Dear, R.J. (2000) recalculated the adaptive model for naturally ventilated buildings based on mean monthly outdoor air temperature. The mean monthly outdoor air temperature is 82 °F (27.78 °C), so that indoor comfort temperature with 90 percent acceptability limits can be wider than the standard, from 69 to 81 °F (20.5 to 27.2 °C) to 75.2 to 84.2°F (24 to 29 °C).

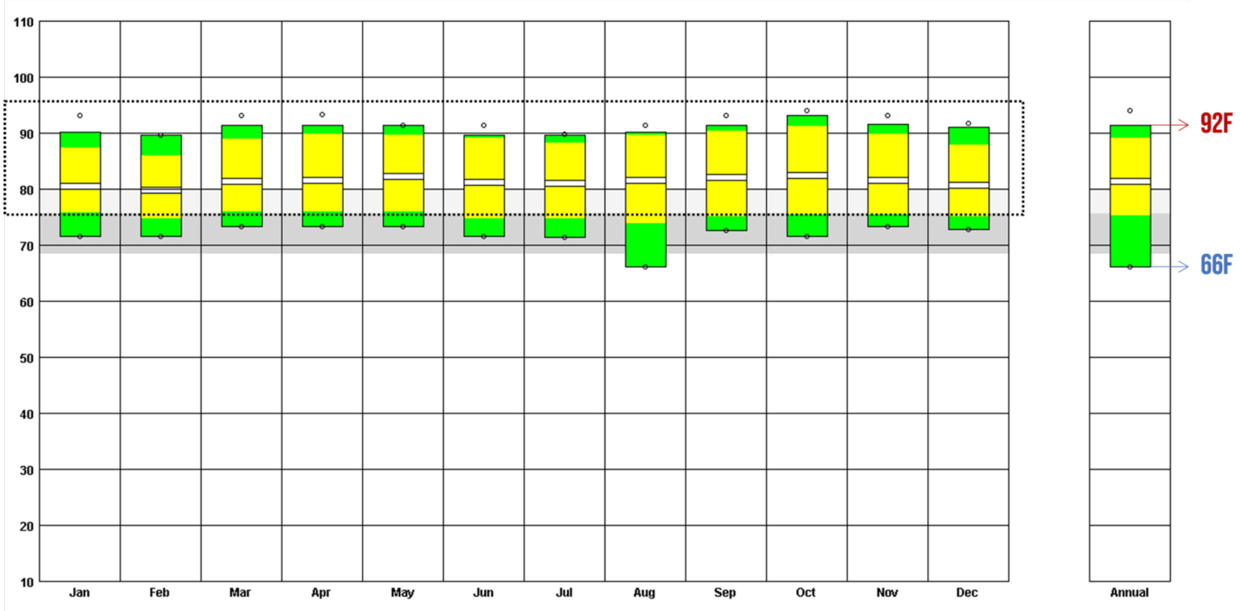


Figure 7. Temperature Range Chart

- **Sun Shading Chart**

The sun's position is high right above the building. The sun shading chart below indicates only 21.4 percent of the time between December and June and even lower by 17.8 percent between June and December when the temperature is considered comfortable (yellow dots). This condition is only found in the early morning. However, shade will help prevent the building from overheating, even in the comfort range. Therefore, this chart suggests that shade is strongly needed throughout the year.

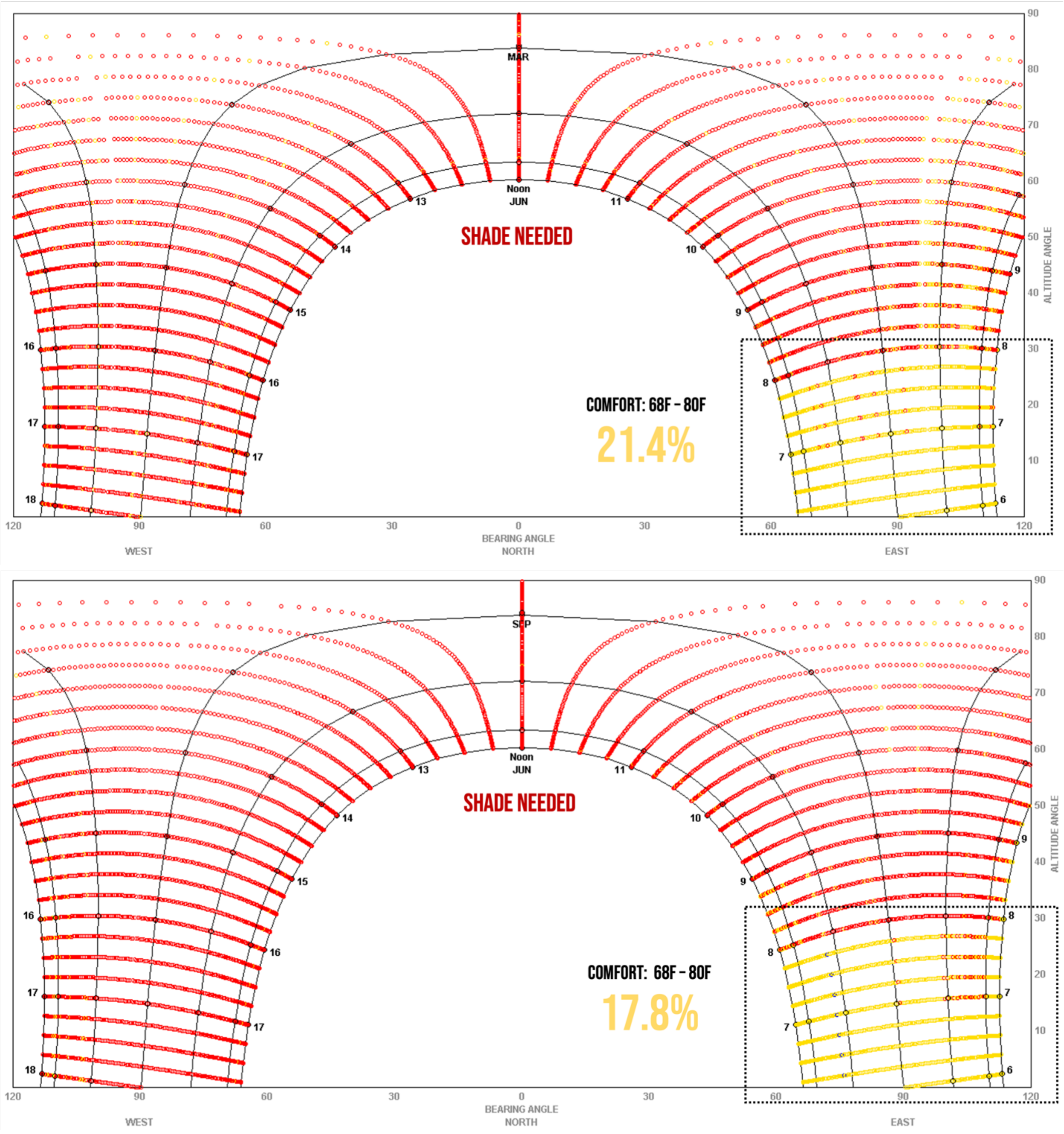


Figure 8. Sun Shading Chart: (a) December to June; (b) June to December

- **Timetable Plot**

The day and night hours are generally the same annually. Curved yellow lines in the timetable plot show when sunrise and sunset occur for each month in this latitude. This chart indicates dry bulb temperature with only two distinct colors, light blue and red when the window should be shaded. There is no significant gap between those different temperature ranges. However, it also concludes that thermal comfort happens from midnight to early morning.

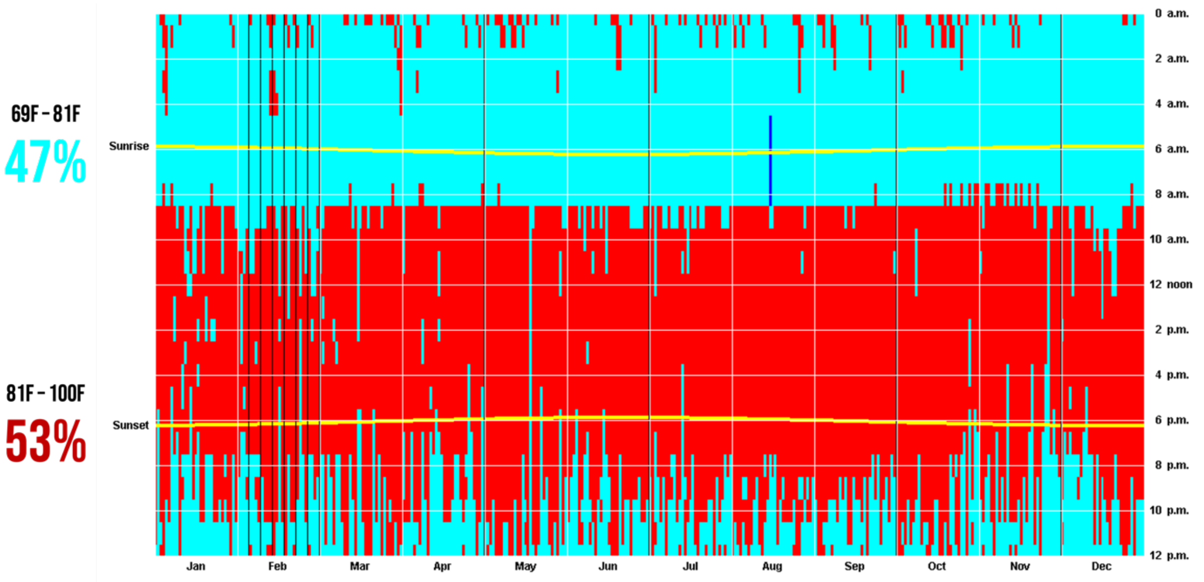


Figure 9. Timetable Plot

- **Wind Wheel**

The first wind wheel chart plotted the conditions for all months and all hours. The outermost ring in the wind rose, showing no prevailing wind direction throughout the year. The next ring shows red and some light blue, indicating the wind mostly brings hot air while cool breeze only comes from the south. The next ring is primarily dark green, pointing out that the wind brings high humidity by 70 percent. Lastly, the three triangles in the innermost circle show the velocity of the wind is moderate without a dominant direction.

The initial analysis of the first wind rose indicates the potential to use cool air to lower the building's temperature. This study identifies a specific time when the building can benefit from a cool breeze from any direction, which is at 5 a.m. The second wind rose shows that the cool wind in the morning predominantly comes from the south and southwest. Therefore, in addition to using shades, this study found another passive design strategy: morning flushing, which can help discharge heat daily.

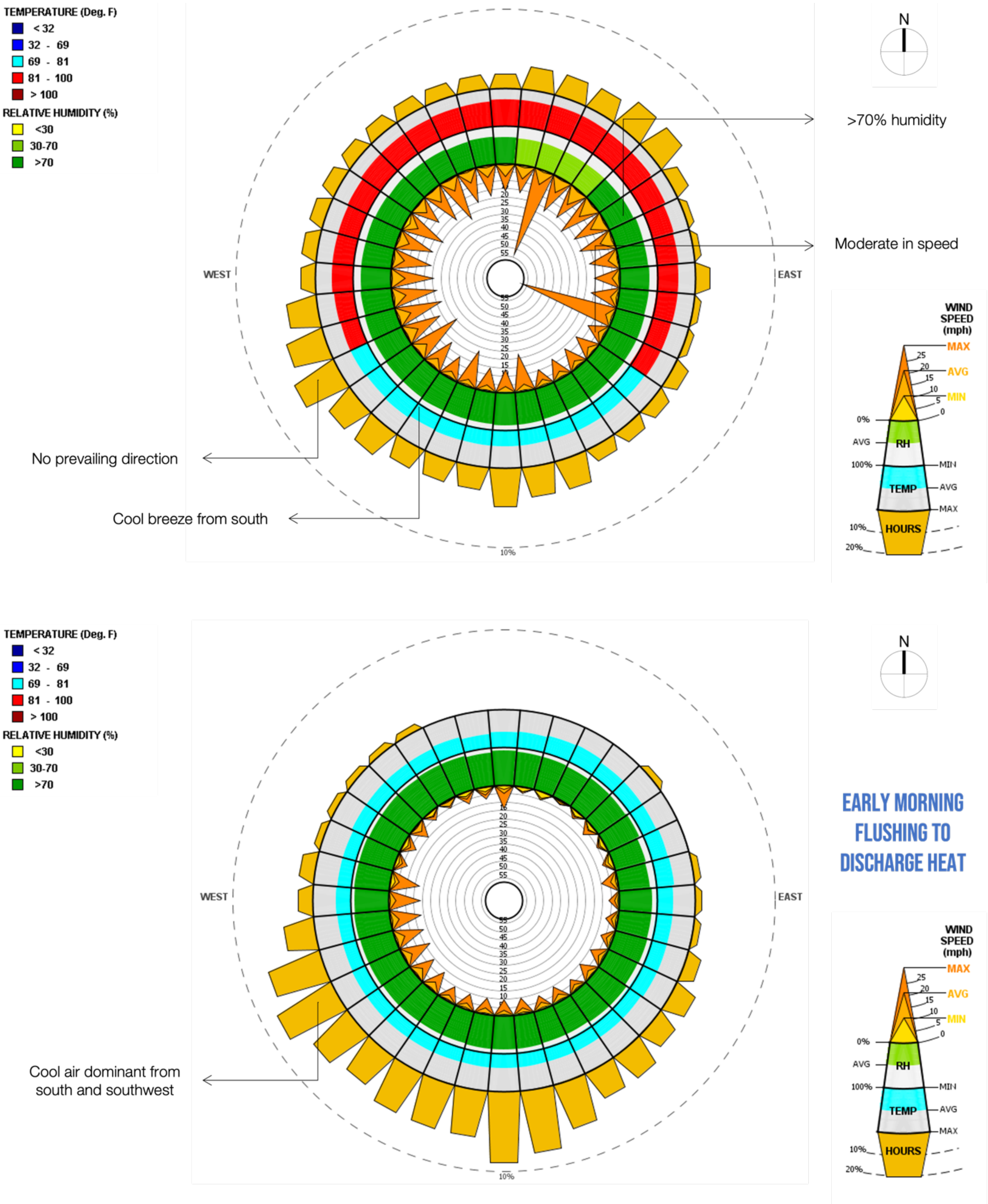


Figure 10. Wind Wheel Chart: (a) All Hours; (b) 5 A.M.

- **The Psychrometric Chart**

The psychrometric chart displayed three different climate attributes to show if humans will be comfortable in spaces with these characteristics. It also recommends designing building envelopes that modify these external climate conditions to create comfortable indoor environments. Three strategies suggested are cooling, dehumidification, and sun shading. The best single design strategy is cooling, which accounts for 64.8 percent of the hours. It indicates that achieving thermal comfort in a hot and humid climate is challenging for Indonesia if only relying on passive strategies. Mechanical cooling is still needed to increase indoor comfort. However, to minimize the energy used for mechanical cooling, this strategy must be combined with other cooling strategies by protecting the building with sun shading and reducing overheating with morning flushing. With high humidity, a dehumidification system is also suggested to achieve thermal comfort.

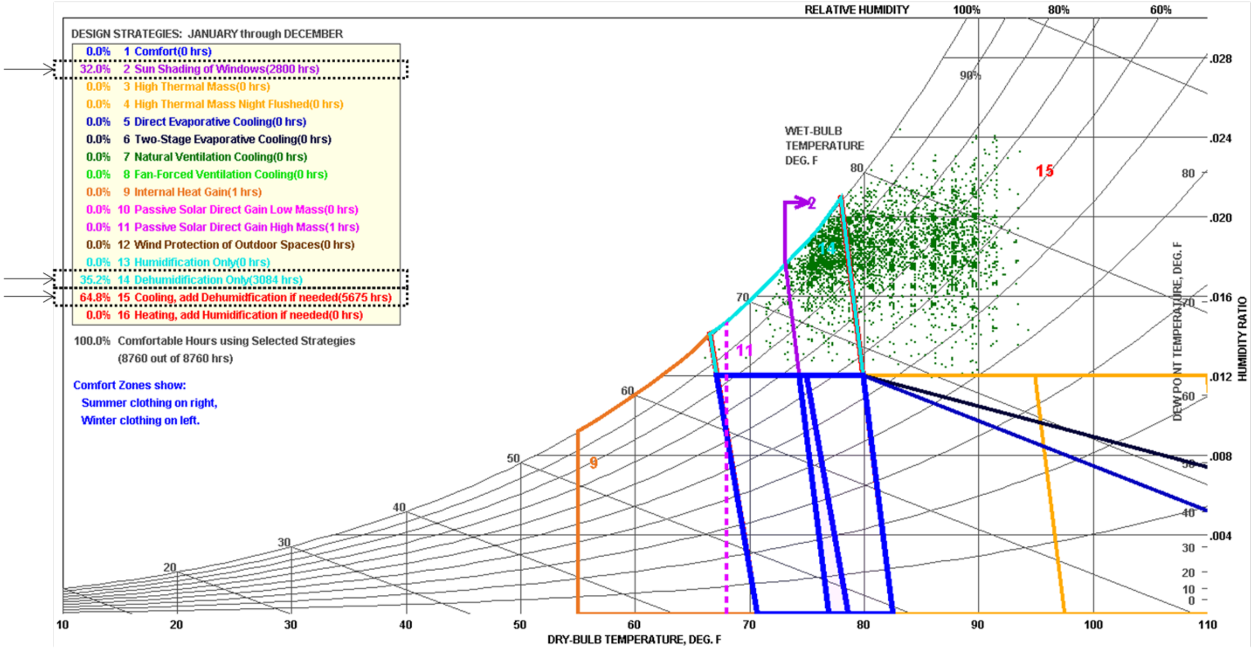


Figure 11. Psychrometric Chart

2.4 Sustainable Development Dimensions

Based on community and climate analysis, this study concludes that the environmental, social, and economic dimensions of sustainable development have been formed in irregular settlements of low-income households, which need to be preserved in the new proposed prototype design.

2.4.1 Environmental

Irregular settlements might not have good building structure and infrastructure because of the high density. Housing, with 1 to 3 floors, attached, forming a block with their frontages facing the street. The geometry of *kampung*, the angle of the sky opening, and the block's orientation towards incoming winds influence the thermal environment: direct solar radiation and wind speed [25]. *Kampung* also has relatively low energy without mechanical cooling. However, the high density provides benefits by shielding the homes from overheating and bringing comfort to the pedestrian level of outdoor places for social and economic activities.

2.4.2 Social

Community space organically formed in *kampung* shows the enormous potential that affordable housing can still accommodate. They used their terrace, streets, and every open and shared space as places for community gathering, which can stimulate every dweller to participate and create a lively neighborhood. However, the cultural needs and possibilities of growing families must be included in the design.

2.4.3 Economic

Low-income residents benefit the most from public space, boosting not only social but also economic quality of life. However, formal public spaces can be wasted, especially in low-income communities. We need to consider programming the space to generate enough income to pay for themselves, for their basic upkeep, and to ensure their basic needs [26]. A productive public space with programmed activities is crucial. For instance, accommodate the local shop's activities, provide workshops to improve the skills of the residents, and encourage food cultivation among those who have a background in agriculture.

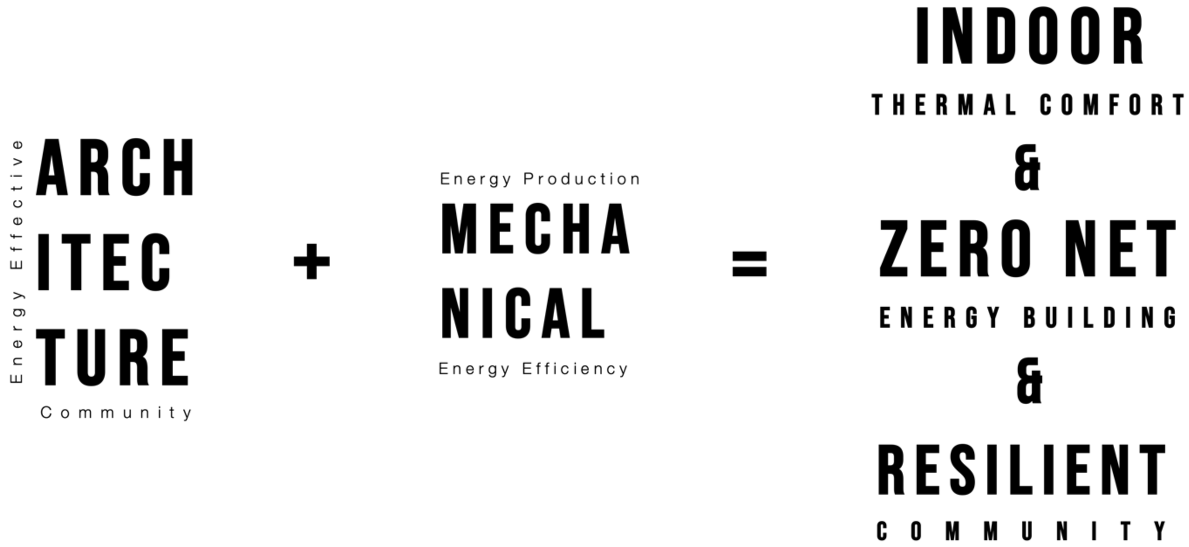


Figure 12. Thesis Framework

Chapter 3 Design Framework

3.1 Case Study Analysis

This research used a case study methodology to find passive design patterns that can be adapted for occupants' comfort, energy efficiency and to strengthen the community. The case study steps include collecting, compiling, and sorting data on fifteen case studies of multi-story housing in Singapore, Thailand, and Vietnam, countries with similar climate conditions to Indonesia. The fifteen case studies were selected randomly and were part of a study of large numbers of cases. The residential building chosen could be public or market-rate housing, either low-rise, mid-rise, or high-rise building, and proof of sustainable design practice. The analysis was a diagrammatic analysis using a series of drawings and focused on two aspects: strategies to achieve thermal comfort and design for improving social life.

3.1.1 Design Strategies to Improve Building Performance in Tropical Climate

A building has four types of comfort: thermal, visual, acoustic, and olfactory [27]. However, the most influential one is thermal comfort because humans spend at least 90% of their time inside buildings [28]. Therefore, a considerable portion of the energy used by buildings is used for heating or cooling [29]. Due to the importance of the vast surface areas of building walls in lowering energy consumption, the building shell is a critical aspect of energy efficiency [30]. Several studies offer suitable passive solutions, such as thermal mass and storage potentials, Phase Change Material (PCM), thermal insulation, natural ventilation, Window-to-Wall Ratio (WWR), shading devices, and green facades.

A study investigates the climatic characteristics of regions in Indonesian to create a passive house design guideline for Indonesian residential buildings [31]. The results advise using high wind speeds to overcome humidity issues, shading devices to lessen solar gain, natural ventilation, and open areas for year-round air movement and protection from hot winds. Another study in Nigeria, which has a primarily tropical climate, implies that the key to lowering the region's overall energy use is the capacity to minimize mechanical cooling to provide the level of comfort required by the residents [32]. It also finds that changing building orientation can significantly reduce thermal discomfort and has no economic implications for the occupants. Moreover, using passive design and optimizing shading to lower the number and frequency of air-conditioning units in a home can result in potential savings over time. These findings were used as initial parameters to examine the case studies.

3.1.2 Climatic Conditions in Singapore, Thailand, and Vietnam

Singapore is located approximately 85 miles (137 kilometers) from the equator [33], and the closest land distance to Indonesia's border is to Batam Island, by only around 25.9 miles (41 kilometers). Because it is near the equator, the length of its day is constant throughout the year. Its geographical conditions influence the climatic conditions in Singapore. In Singapore, the minimum temperature ranges between 73.4 to 77 °F (23 to 25 °C) at night, and the maximum is about 87.8 to 91.4 °F (31 to 33 °C) during the day. The annual relative humidity in Singapore is 74% and reaches 91%. Rainfall is plentiful in Singapore as it rains 167 days of the year. Moreover, the most prominent winds in Singapore are from the northeast and the south, and the average speed is 9.7 mph (4.34 m/s). The winds are lighter at night and stronger during the day.

Thailand's location between vast land and water areas makes it uniquely influenced by seasonal monsoons. Thailand experiences six months of rainfall, three months of dry and cooling breezes, and three months of heat [33]. The average temperature ranges from 64.4 to 100.4 °F (18 to 38 °C), with relative humidity ranging between 59% and 87%. The wind has a moderate speed of around 13.75 mph (6.15 m/s).

Lastly, Vietnam has both tropical and temperate zones. In the northern regions, the average temperature ranges from 71.6 to 81.5 °F (22 to 27.5 °C) in the summer to 59 to 68 °F (15 to 20 °C) in the winter, while the southern areas have a hotter and narrower range [34].

Table 2. Climatic Conditions Comparison from Climate Consultant

Climatic Condition	**Indonesia**	**Singapore**	**Thailand**	**Vietnam**
Average Temperature	78.72 °F (25.96 °C)	81.82 °F (27.68 °C)	80.33 °F (26.85 °C)	76.62 °F (24.79 °C)
Humidity	68% - 91%	74% - 91%	59% - 87%	63% - 88%
Wind Speed	10.93 mph (4.89 m/s)	9.7 mph (4.34 m/s)	13.75 mph (6.15 m/s)	16.12 mph (7.21 m/s)
Precipitation	109.08 inch (2770.85 mm)	97.95 inch (2487.96 mm)	62.99 inch (1600.1 mm)	69.56 inch (1767.05 mm)

3.1.3 Multi-story Housing Case Study

Fifteen case studies include various housing types and project scales. Three are public housing, and the other twelve are market-rate housing. Most of the projects used prefabrication concrete material and were completed before 2018. The area of these projects varies from 2,203 square feet to 861,112 square feet, with building heights ranging from 3 to 66 floors. The total number of dwelling units starts from 7 units to 1,072 units. Therefore, the density is also significantly different from the lowest density, 15.82 dwelling units/acres, to the highest density, 580 dwelling units/acres. These case studies have many common shared spaces, such as a courtyard, playground, sky terrace, roof terrace, commercial, education, and sports area.

The study includes five case studies in Singapore: Punggol Waterway Terraces, SkyVille, Goodwood Residence, Seletar Park Residence, and The Interlace. These are scattered throughout Singapore. The other five are case studies in Thailand: The Met, Saladaeng One, Siamese Gioia, Mori Haus, and Hasu Haus. Lastly, there are five case studies in Vietnam, which are on a smaller scale than those in Singapore and Thailand. The Vietnamese case studies are CC Residences, Ariosa Apartments, Lao Cai Worker's House, Green Peace Village, and Binh Thanh Apartment. By analyzing projects of various scales, this study seeks to demonstrate that the passive design strategies identified can be applied to multi-story housing in a tropical climate.

Figure 13. Fifteen Case Studies

3.1.4 Passive Design and Community Strategies

The case study focuses on two main areas: thermal comfort and community. It analyzed these through diagrammatic drawings to understand the strategies used for sun shading and natural ventilation to achieve thermal comfort, aligning with the previous climate analysis conclusion in Chapter 2. Additionally, the study examined the shared community spaces in the case studies to understand how they can improve social interaction and create a lively community.

- **Sun Shading**

The sun's position in the countries near the equator is overhead at noon. It makes nearly twelve hours of day and night throughout the year, providing abundant natural light and excessive solar radiation. Residential buildings that must face long hours of exposure to solar heating that causes temperature gain inside the building [35]. Building orientation is vital in thermal comfort and optimizing protection from direct sunlight. However, optimizing all facade orientations is needed in tropical regions due to the relatively high solar radiation and long duration of daytime. Shading systems, classified as interior or outdoor, can prevent unwanted daylight that causes high internal temperatures [36]. Venetian blinds and roller screens are interior shading devices, while louvers, light shelves, and awnings are external. These shading devices come in various materials, sizes, and shapes and can be categorized as fixed, manual, or movable.

- **Natural Ventilation**

Natural ventilation is one of the main techniques to moderate temperature in buildings in tropical climates. Many studies have shown that it reduces operating costs, provides better thermal comfort, and improves indoor air quality. The efficiency of natural ventilation in reducing the cooling load in tropical climates is highly dependent on factors such as the outdoor micro-climate, the nature of the terrain, innovative techniques, and the design of building elements [37]. The principle of natural ventilation is the driving forces to control and distribute temperature and airflow, including wind-driven force, buoyancy-driven force, and combination [38]. Natural ventilation systems in wind-driven force comprise wind towers, wind catchers, fenestration, wing walls, wind cowls, rotating wind cowls, and exhaust cowls. The systems in thermal buoyancy-driven force consist of a Trombe wall, double-skin façade, solar (thermal) chimney, solar walls, and atrium. In addition, hybrid solutions includes heat recovery ventilation (HRV), an earth-air heat exchanger (EAHE), and nocturnal cooling applications (NC).

- **Community Shared Space**

Living in multi-story residential buildings can be challenging for residents, leading to social isolation and affecting their overall quality of life. Interacting with neighbors improves people's health and well-being and supports community development [39]. Neighborhood and spatial characteristics influence social interaction. However, most social interactions occur in the circulation areas, including corridors, lifts, lobbies, and entrances, negatively impacting residents' privacy, safety, and cleanliness of the shared space. Therefore, the design needs to enhance the circulation area with a more appropriate designated space for social interaction.

3.1.5 Passive Design Strategies Pattern

The fifteen case studies have various specifications, building forms, scales, configurations, and programming. However, they have similar passive design strategies to address the need for thermal comfort in hot and humid climates and energy efficiency for cooling while strengthening the community. Each passive design strategy is delivered differently. Most of those strategies have different positive impacts, but some also have additional value.

This study concludes that it is ideal for a building to be located on the site elongated in an east-west direction, with longer north and south facades, so that it does not get direct solar heat and radiation or receives glare. North and south-facing facades can provide a much more comfortable indoor environment than east and west-facing facades. If a building has an east and west orientation, having an operable façade screen could help control the intensity of heat gains brought into the dwelling units. However, building shades are not always in the form of operable façade screens. They could be self-shading by the building massing and projecting balconies.

All the case studies allow cross ventilation on their dwelling units. Some case studies use single-loaded corridors so that their dwelling units are one-thick. Projects that use a double-loaded corridor still have two openings adjacent to walls for cross ventilation because of the horizontal voids. Moreover, the building orientation also plays a vital role in responding to the dominant wind direction. It is recommended that the building be oriented to a shorter axis aligned with the direction of the prevailing winds. Besides these natural ventilation systems, greenery and vegetation could also create a good climate filter and reduce heat from the building site to achieve thermal comfort.

From the case study analysis, the landscape area is classified into four: natural environment, courtyard, sky terrace, and roof terrace. There are case studies integrated with conservation greenery. Their building orientation has a specific focal point to connect the residents with nature. The steep building form is also affected by the presence of the natural environment, and it responds to the terrain to build a deeper connection to the landscape. It could also create private or public open space on the rooftop. At the same time, all the case studies have configurations, hexagonal-shape and U-shape, which encircle the central common spaces. This encircling layout plan is used for community gatherings while providing passive cooling strategies.

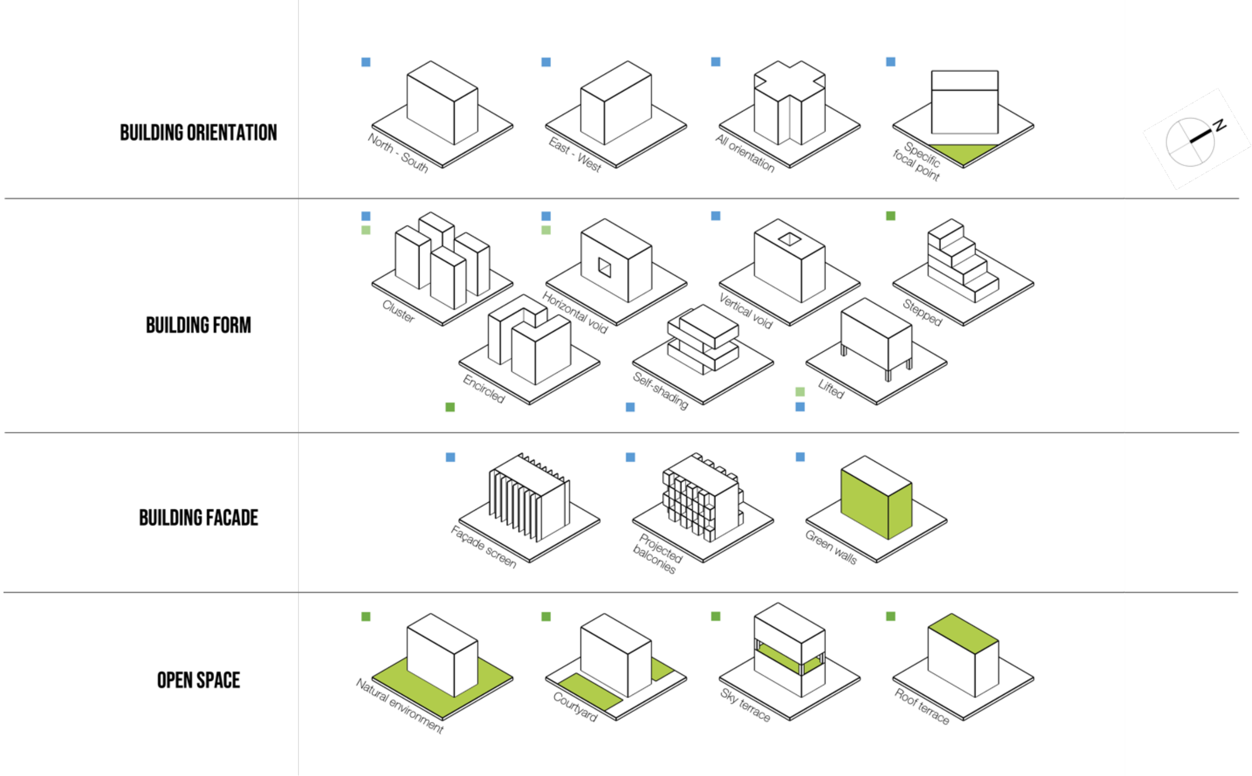


Figure 14. Case Study Design Pattern

The analysis classified the passive design strategies into four categories: building orientation, building form, building façade, and open space. Comparing the passive design strategies used by fifteen case studies focusing on two aspects, this study found strategies that could synergize occupants' comfort and community: group or cluster, void (especially horizontal void), and lift.

- **Group or Cluster**

Group or cluster is an important principle that is used by all case studies to ensure the success of their passive design strategies. The idea of dividing the dwelling units into some groups creates a smaller hierarchy within the large scale of the building. The cluster configuration in each case study allows natural airflow, maximizes daylight, and avoids too much heat from the sun while providing access to the designated view of the landscapes for each dwelling unit. Moreover, the space connecting these clusters creates many open-air voids that allow light and air, resulting in shared space areas that are entirely naturally lit and ventilated.

The spatial cluster has a strength and vital function in drawing people together into neighborly contact [40]. Alexander et al. (1977) suggest that the size of the cluster that could work best is between 8 to 12 units, whereas clusters of 3 to 8 could work perfectly well. All case studies have clusters of a suitable size. Skyville is the best example of physically designing a shared space between the clusters, called tropical community areas or breezeway atria, that knit the groups together right in front of their units.

- **Void**

Voids between the groupings maximize cross ventilation and vertical cooling to all units and corridors compared to conventional double-loaded corridors. With conventional attached row dwelling units, the long party walls create an extended depth that makes many areas poorly lit. The large vertical and horizontal openings integrate with the façade passively illuminated and ventilated dwelling units, circulation areas, and public spaces. Porosity bond producing permeable, breathing architecture. Moreover, the voids filled by the atrium have enormous potential to facilitate and promote social interaction among residents and increase a sense of neighborliness and belongingness, which is essential to social sustainability [41].

- **Lift**

A traditional stilt house is highly climate-adaptable and can be applied to multi-story housing. Floors constructed raised above the ground allow better natural ventilation and help ventilate underneath the housing, creating a natural cooling effect. This stilt structure also offers more shade and sun, allowing air to flow and being used as a community-shared space. This approach is exemplified in three projects located in Thailand. Each project features an expansive communal area that seamlessly integrates with the natural surroundings, promoting both air circulation and shaded spaces for comfort.

3.2 Energy Simulation

The project used to model the perimeter zone is the existing prototype located in Jakarta, Indonesia. The analysis was conducted on the south façade of one dwelling unit. The project is usually built in a low-density area, so the context added for the simulation is an assumption.

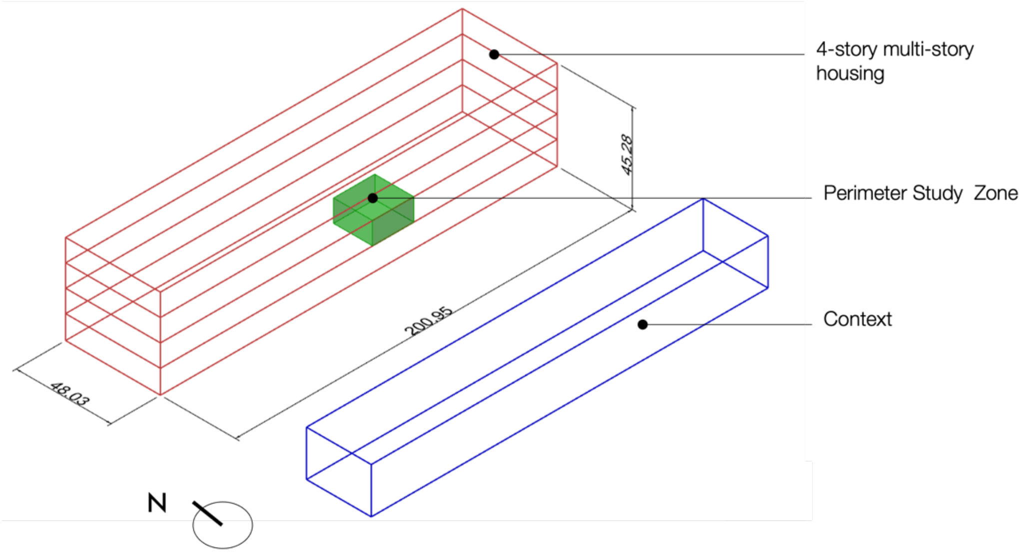


Figure 15. The Project

Two combinations of casement and awning windows are in the bedrooms, and one fixed louver window is in the services area. Each window has a concrete canopy slab to provide shade. The building's columns and beams are visible outside and are part of the façade.

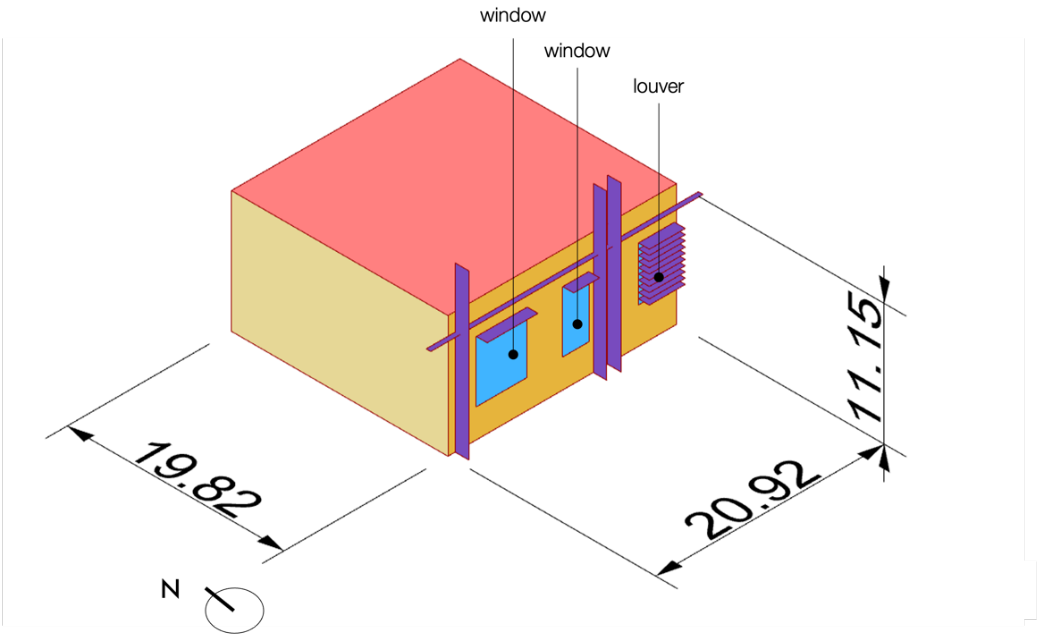


Figure 16. The Perimeter Zone Massing

Table 3. Perimeter Zone Baseline Conditions

Variables	**Baseline Conditions**
Massing	Perimeter Zone
Location	Jakarta, Indonesia
Program	2019 Midrise Apartment
LPD	9.4 W/m2
EPD	6.7 W/m2
Infiltration Rate	0.000569m3/s per m2 of façade
Mechanical Cooling	None
Natural Ventilation	• Window: close • Louver: open
Mechanical Ventilation	None
WWR	Used specific 2 types of windows: 2 windows and 1 louver
Horizontal Shading Depth	• Window: 1 ft and 1 shade • Louver: 1 ft and 10 shade
U-Factor Glass	1.02 Btu/h·ft2·F
SHGC	0.97
Wall Assembly	• 25mm stucco • 100mm brick • 25mm stucco
Window Assembly	Clear 6mm
Ceiling Assembly	• 4 in. normal weight concrete floor • Generic ceiling air gap • 3/8 in. gypsum or plaster board
Floor Assembly	• 3/8 in. gypsum or plaster board • Generic ceiling air gap • 4 in. normal weight concrete floor

The analysis aims to increase thermal comfort and reduce annual energy consumption. According to Energy Star, this project's site EUI should be 44.7 kBtu/sf to get a 100 score.

3.2.1 Baseline Indoor Thermal Comfort

Indoor temperature ranges are divided into three based on ASHRAE standards and adaptive thermal: less than 65 °F (18.3 °C) is cold, 65 to 83 °F (18.3 to 28.3 °C) is considered comfort, and more than 83 °F (28.3 °C) is hot. The baseline's indoor temperature is still dominated by a high temperature of 67.9 percent and comfort of 32.1 percent. The 32 percent of comfort is the lean hotter temperature range between 78 and 83 °F (25.6 and 28.3 °C) and only 0.1 percent between 65 and 78 °F (18.3 and 25.6 °C).

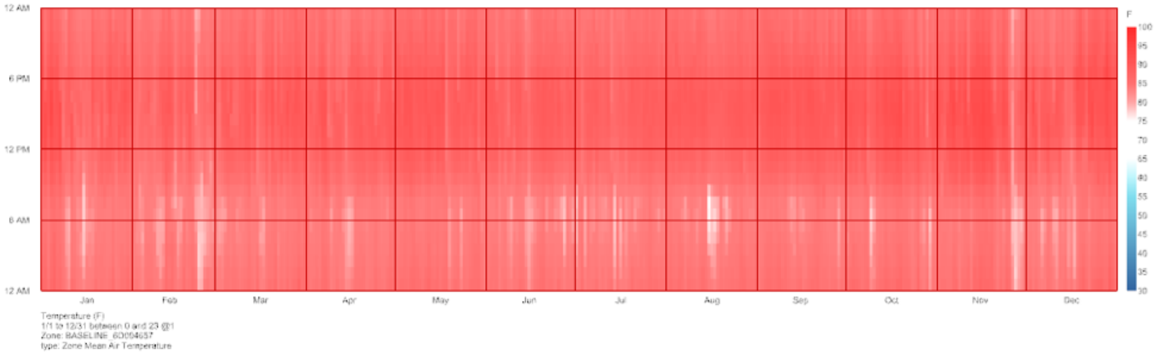


Figure 17. Indoor Temperature Range in Baseline: Unconditioned

3.2.2 Baseline Energy Mass Balance

Besides findings from climate analysis that examine strategies, the Energy Mass Balance Diagram is another diagram that helps discover more suitable variables to stimulate the existing prototype. The energy mass balance from the unconditioned baseline indicates that solar energy is the most significant form of heat gain, and natural ventilation is the most important form of heat loss.

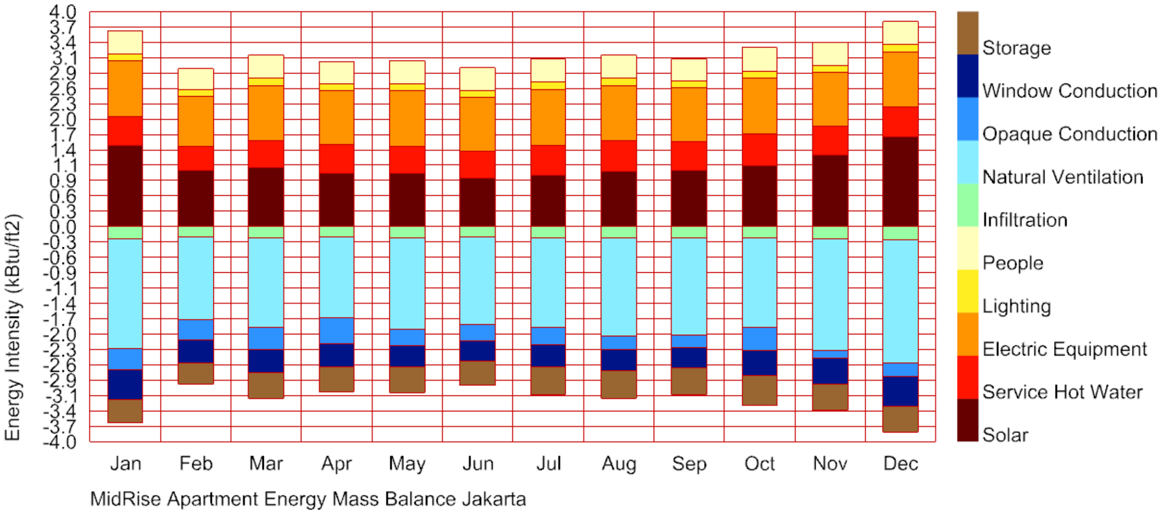


Figure 18. Baseline Energy Mass Balance: Unconditioned

Then, this study ran an energy model with a modified, conditioned baseline with operable ventilation. The chart indicates that mechanical ventilation and infiltration are significant forms of heat gain that can reduce the energy use of mechanical cooling. This modified baseline significantly improves thermal comfort by 81.6 percent but still has some high temperatures.

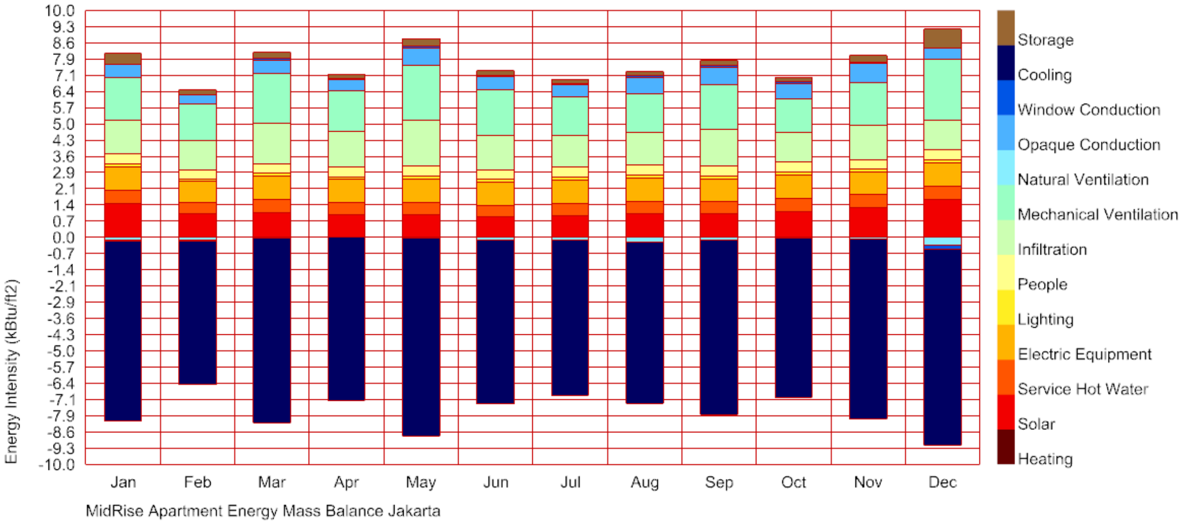


Figure 19. Baseline Energy Mass Balance: Conditioned and Natural Ventilation

3.2.3 Simulation Plan

The simulation starts from the modified baseline conditions with conditioned and natural ventilation on the window and louver. The study uses ad COP of 3 for the cooling. Additionally, based on the energy mass balance, this study adds mechanical ventilation with 70 percent ERV and reduces the infiltration to 0.0003 m3/s per m2 of façade. Lighting Power Density (LPD) and Equipment Power Density (EPD) are also reduced. Solar gain largely contributes to heat gain throughout the year, so this study will examine different orientations and solar heat gain coefficients (SHGC). Considering the suggestion from the psychrometric chart, sun shading is another variable to study. This study simulates different shading depths, the number of shades, and the directions of shades.

Table 4. Simulation Plan

Parameter	**Variables to Study**
Orientation	1) 0 = South (baseline) 2) 90 = West 3) 180 = North 4) 270 = East
Shading Depth (ft) – only for window	1) 1 ft (baseline) 2) 2 ft
Number of Shades – only for window	1) 1 (baseline) 2) 5 3) 10
Direction of Shades – only for window	1) True = Horizontal (baseline) 2) False = Vertical
Solar Heat Gain Coefficient (SHGC)	1) 0.97 (baseline) 2) 0.6 3) 0.25

3.2.4 Results of Analysis

- **Orientation**

This study first tests four different orientations with one horizontal shading with a 1-foot depth, and the SHGC is 0.97. The south orientation significantly improves indoor temperature even though it still is not 100 percent. The south orientation also gives the lowest total EUI by 37.757 kBtu/sf/year.

- **SHGC**

After orientation, this study examines three different SHGCs, one horizontal shading with a 1-foot depth and keeping the orientation to the south. The SHGC by 0.25 provides a better indoor temperature and achieves 100 percent thermal comfort. Lower SHGC also gives the lowest total EUI by 35.059 kBtu/sf/year.

- **Shading**

Lastly, this study simulates different shade depths, the number of shades, and the direction of shades with south orientation and SHGC 0.25. Ten vertical shades with two feet give the lowest total EUI by 34.167 kBtu/sf/year.

- **Parametric Result**

After running the simulation, this study finds that keeping the orientation to the south, having ten vertical shades with a depth of 2 feet, and using 0.25 of SHGC will increase thermal comfort and give the lowest annual EUI.

Table 5. Parametric Result

Variables	**Baseline Conditions**	**Final Design**
Orientation	South	South
Shading Depth	1 foot	2 feet
Number of Shades	1	10
SHGC	0.97	0.25

This energy simulation helps to understand how each design feature affects indoor thermal comfort and annual EUI in the existing prototype. The results improve when combined, and better results are obtained when integrating all the best variables from all parameters conducted in this study. The unconditioned baseline had a low thermal comfort of 32.1 percent. Adding mechanical cooling and natural ventilation can significantly improve thermal comfort. However, the EUI becomes considerably higher. Therefore, this study examines more variables based on climate analysis in Jakarta and energy mass balance from the modified baseline. Solar energy contributes most to heat gains, which can affect the need for mechanical cooling. By keeping the orientation in the south, changing the shading depth to 2 feet, having ten vertical shades, and reducing SHGC, we were able to cut the annual EUI with COP from 51.408 kBtu/sf/year to

34.167 kBtu/sf/year. We can surpass the goal for the EUI, which is 44.7 kBtu/sf/year. Additionally, the final design ensures that the indoor temperature is entirely comfortable.

Figure 20. Simulation Result: (a) Indoor Thermal Comfort; (b) Annual EUI End Use

3.3 Solar Radiation Analysis

Solar radiation is affected by sun angle, cloud cover, a fraction of sky visible from the surface, and a fraction of the surface currently in shadow from other surrounding geometry. When solar radiation hits an object's surface directly, the energy per unit area is significantly higher than when the radiation strikes the surface at an angle [42]. The incidence angle is calculated relative to the surface normal of each plane. Maximum at normal incidence when the incidence angle approached 0 ° and minimum at grazing point when the incidence angle approaches 90 °. At the same time, cloudy skies increase the amount of diffuse solar radiation. Earth's annual solar radiation levels are roughly 1,000 to 1,600 kWh/m2 per year on a horizontal surface.

3.3.1 PV Calculation

Solar radiation analysis was conducted to study which surface and optimum tilt in affordable housing could generate maximum electricity. The simulation is set in Jakarta. This study looks at five surfaces: horizontal, east, west, north, and south. Also, one slope tilts by 30 ° at four orientations: east, west, north, and south. The radiation map range is set from 600 to 1,200 kWh/m2.

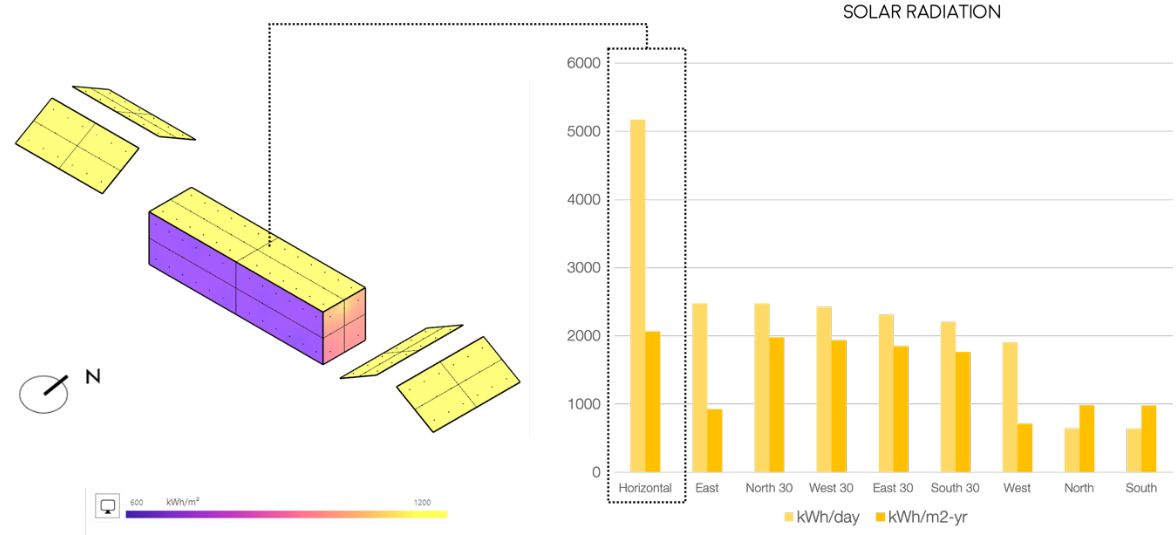


Figure 21. Orientation of Optimum Tilt

The simulation result shows that horizontal surfaces gain maximum solar radiation by 2,069 kWh/m2 per year, surpassing Earth's annual solar radiation levels. Meanwhile, vertical surfaces with a south orientation receive the most negligible radiation, 981 kWh/m2 per year. When the PV panel is tilted by 30°, the surface facing north is the optimum tilt compared to other orientations with the same slope. Still, it has less radiation energy than the horizontal surface.

Electricity production per square meter (kWh/m2) is calculated by multiplying annual solar radiation and PV efficiency. This study assumes the PV efficiency is 0.21. So, PV with a horizontal surface can generate electricity by 434 kWh/m2.

3.4 Adaptive Reuse

More than four hundred affordable housing units with this prototype have been built throughout Indonesia. Without proper management and operation, affordable housing conditions usually return to slums. To solve this issue and with this high amount of housing, this study took adaptive reuse as a design approach that can significantly impact saved embodied carbon emissions and reduce carbon impact.

The scopes of building adaptation projects vary and are often used interchangeably. Adaptive reuse covers building conversion by converting spaces through adding and reusing salvaged materials in a building, structural or non-structural [43]. Adaptive reuse is a form of sustainable urban renewal that prolongs the building's life [44]. Extending the life of a building can be cost-effective because it preserves the existing materials produced, practicing a circular economy. It also reduces construction waste from the demolition of existing buildings. In comparison, constructing a brand-new building can contribute to 49 percent of the total carbon emissions of global new construction between 2020 and 2050 coming from material production and acquisition [45].

Grand Parc Bordeaux in France, a project that won the Pritzker Prize, has transformed 530 homes. It can improve its occupants' space and quality of life through adaptive reuse by preserving the existing attributes and what should be added [46]. This social housing added extensive winter gardens and balconies to allow the residents to enjoy more space, natural light, and mobility. They removed the existing small windows and replaced them with large, glazed sliding doors to the winter gardens. This project excluded interventions on the existing structure, stairs, or floors. Therefore, three rules are applied in the new proposed design in this research: keeping the primary structure, maximizing potential and flexibility, and climate adaptation.

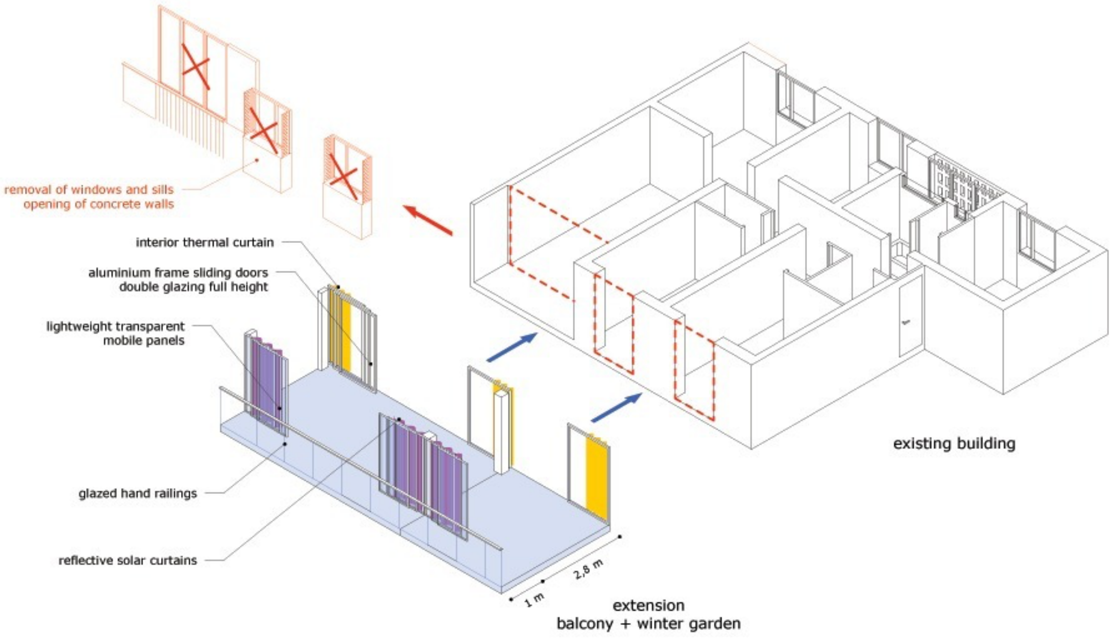
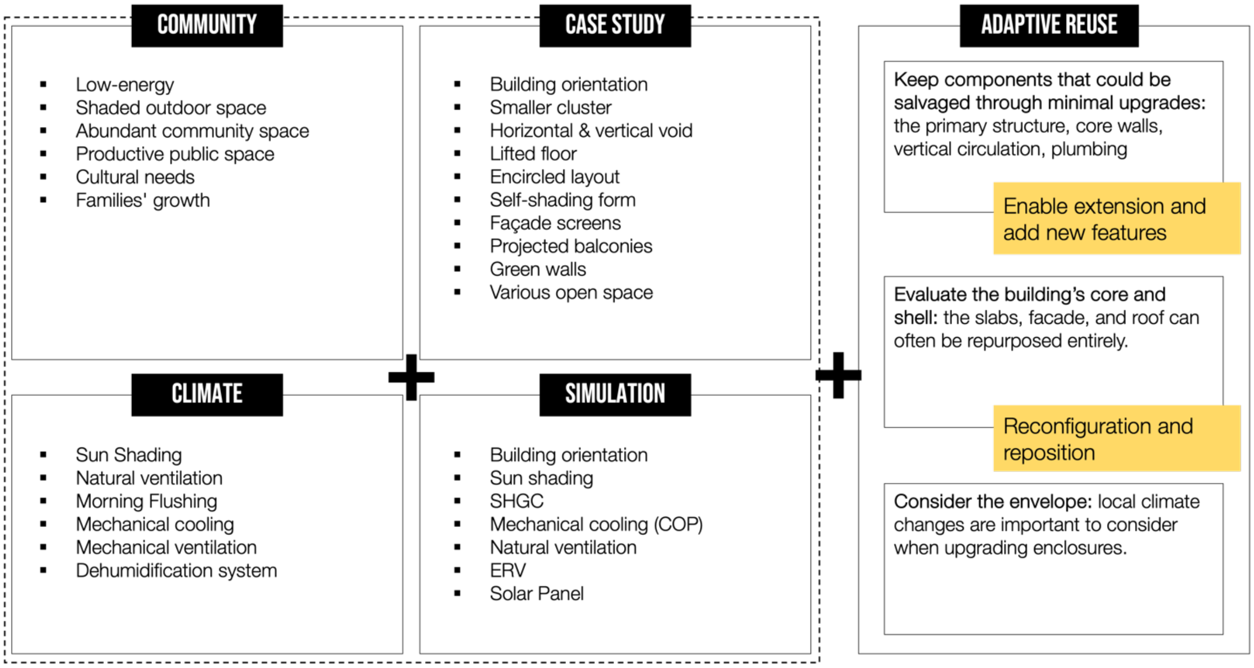


Figure 22. Adaptive Reuse Case Study (Image by Lacaton & Vassal, Druot, Hutin)



COMMUNITY

- Low-energy
- Shaded outdoor space
- Abundant community space
- Productive public space
- Cultural needs
- Families' growth

CASE STUDY

- Building orientation
- Smaller cluster
- Horizontal & vertical void
- Lifted floor
- Encircled layout
- Self-shading form
- Façade screens
- Projected balconies
- Green walls
- Various open space

CLIMATE

- Sun Shading
- Natural ventilation
- Morning Flushing
- Mechanical cooling
- Mechanical ventilation
- Dehumidification system

SIMULATION

- Building orientation
- Sun shading
- SHGC
- Mechanical cooling (COP)
- Natural ventilation
- ERV
- Solar Panel

ADAPTIVE REUSE

Keep components that could be salvaged through minimal upgrades: the primary structure, core walls, vertical circulation, plumbing

Enable extension and add new features

Evaluate the building's core and shell: the slabs, facade, and roof can often be repurposed entirely.

Reconfiguration and reposition

Consider the envelope: local climate changes are important to consider when upgrading enclosures.

Figure 23. Design Framework

Chapter 4 Findings (The Design)

4.1 Existing Prototype

The existing prototype, the subject of this research, is a low-rise four-story building with dimensions of 200.95 by 48.88 feet and a gross floor area of around 40,919 square feet. The site dimension is 270.34 by 131.23 feet, so the total area is 35,305 square feet. This housing is for 60 families with up to 4 people per dwelling unit. Therefore, this prototype can accommodate approximately 240 people.

Figure 24. Baseline Design (Photos by The Ministry of Public Works and Housing)

Each dwelling unit has two bedrooms, one bathroom, one service area used for kitchen and laundry, and a living room that can also be used as a dining area. There are three stairs, one in the middle and two on each side of the building. Each floor accommodates 16 dwelling units, eight units on both sides, and each floor has a shared balcony in the middle of the building. One multifunction room, an office, and a prayer room are on the ground floor. The landscape area uses paving materials for parking or an event.

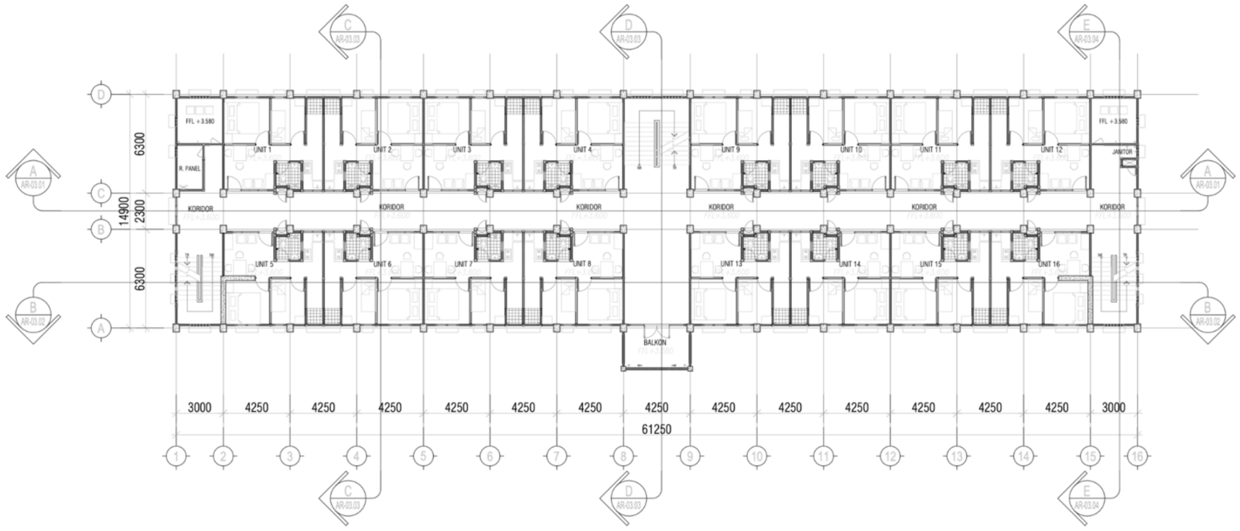


Figure 25. Baseline Floor Plan

4.2 Transformation

Following the three rules of adaptive reuse that this study applied, the transformation was done by subtracting and adding the building form by salvaging the primary structure of the existing prototype.

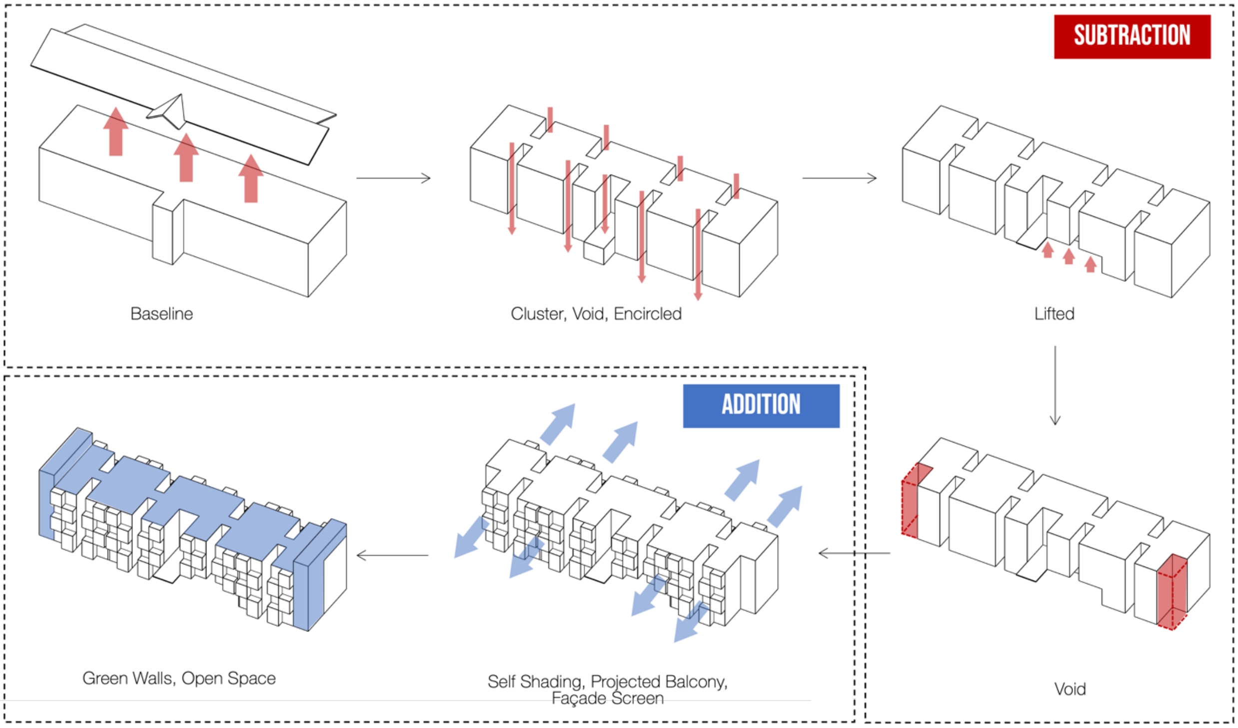


Figure 26. Building Form Transformation Concept

First, this study removes the existing roof of an attic room. Then, the service area on each unit is eliminated to create vertical and horizontal voids. The shared balcony on the third and fourth floors is cut to get an encircled layout surrounding the common area. The concrete slabs that are cut off will be reused as urbanite materials. Next, this study removes the wall in the multifunction room and makes it into a more open common area by leaving only the column. The last subtraction is replacing the solid walls in stairs with more permeable materials on both sides. After the subtraction, this study adds shading devices with self-shading techniques, such as projected balconies and solar screens in the façade. Lastly, this study adds spaces on the roof as a tradeoff of the service area that has been removed and added green walls in the vertical circulation walls.

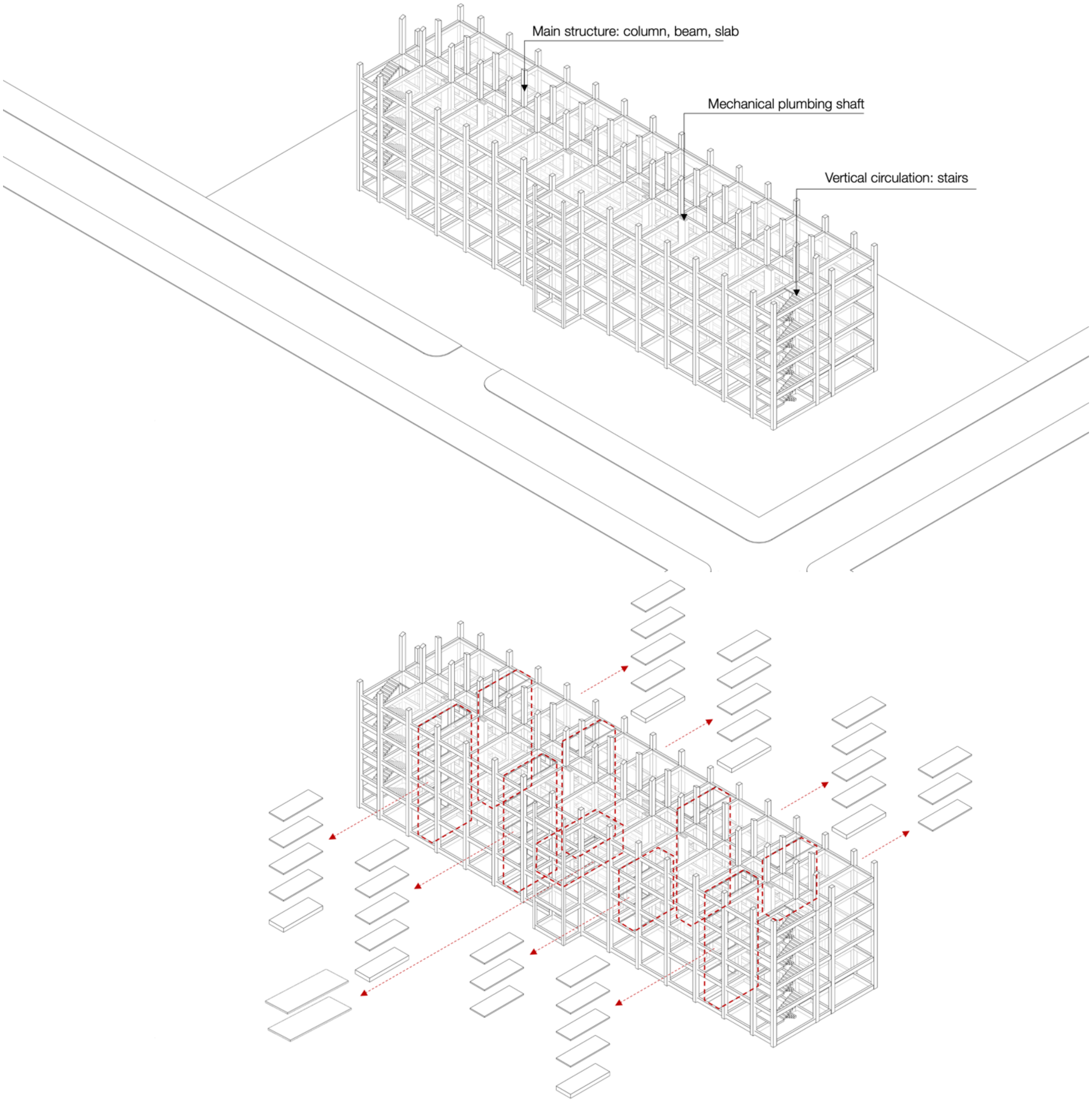


Figure 27. Building Frame Transformation: (a) Main Frame; (b) Cutting Frame to Creating Voids

The transformation of the dwelling unit starts by keeping most of the room's configuration inside the units similar but eliminating the service area. The façade has also been changed by additional balconies that extend the units' space. Most windows will be repositioned and reused, but the glass window's solar heat gain coefficient (SHGC) will be lower, per the energy simulation results. The entrance door of each dwelling unit is replaced with a folding door, which allows the families to extend their space to the corridor. The folding door can be opened fully, half, or closed entirely. This way, the residents can hold an event that requires a bigger space. They can also open a local shop in their own homes. This dwelling unit transformation also accommodates the need for more space if the number of family members increases. Two attached dwelling units can be connected by replacing the solid wall with a folding door.

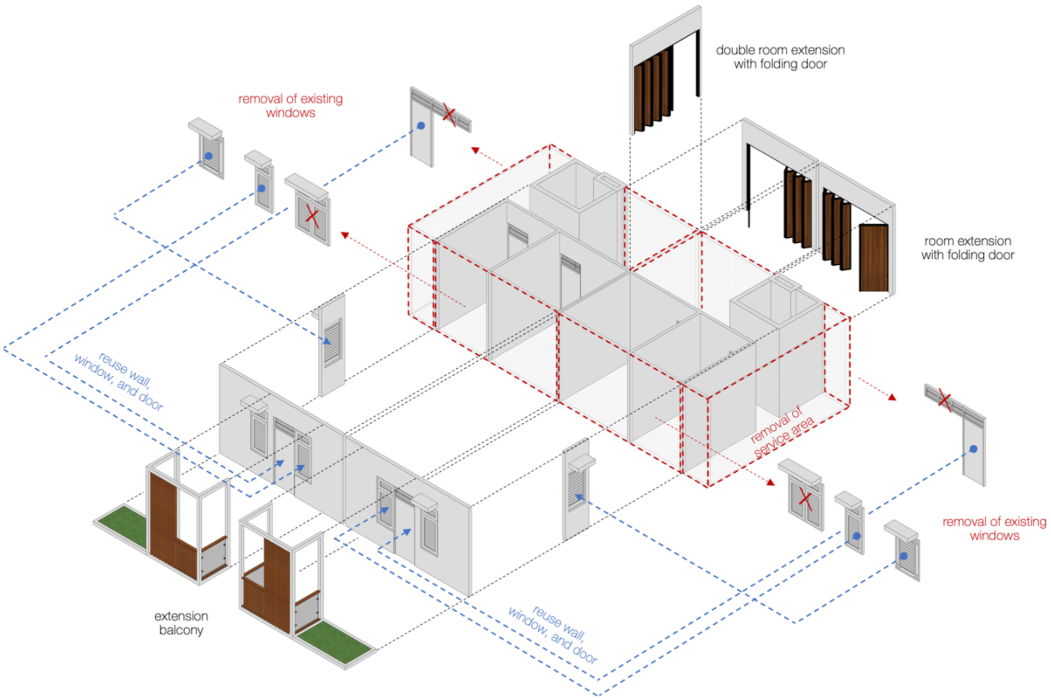


Figure 28. Dwelling Unit Transformation

The stairs on both sides are transformed to be more open, allowing fresh air to come inside and helping to cool the building. It uses a perforated metal screen with green walls. Many windows, glass boxes, and roasters will be reused as urbanite materials. Additional rooms function as shared laundry rooms where the residents can do the laundry and dry their clothes outside on the roof. The roof was changed to PV to generate electricity and achieve zero net energy in the building.

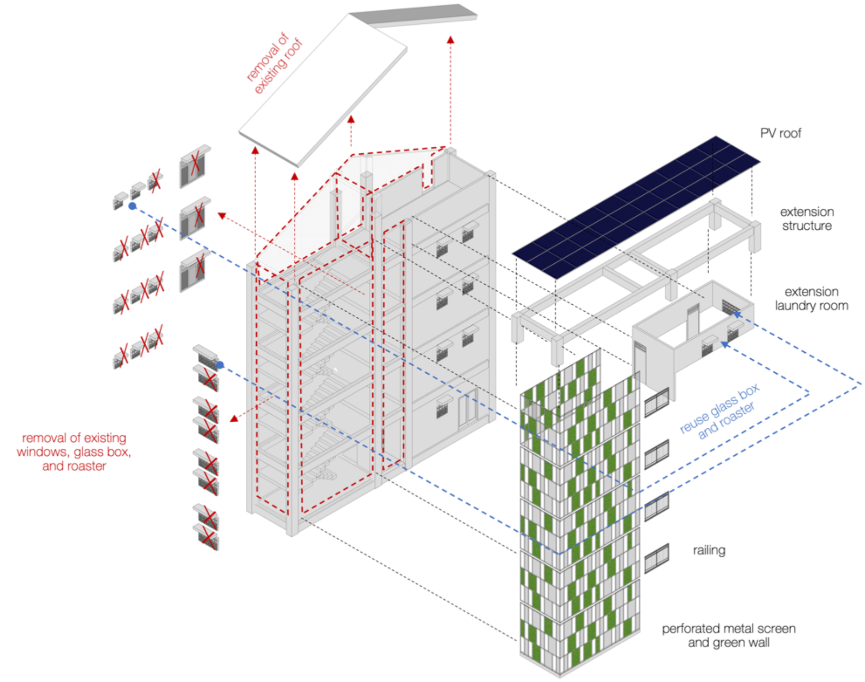


Figure 29. Vertical Circulations Transformation

4.3 Final Design

The transformation of the existing prototype includes the building and the outdoor area. The new prototype offers a better design that achieves thermal comfort, reduces energy consumption to zero net energy, and focuses on accommodating the community's needs.

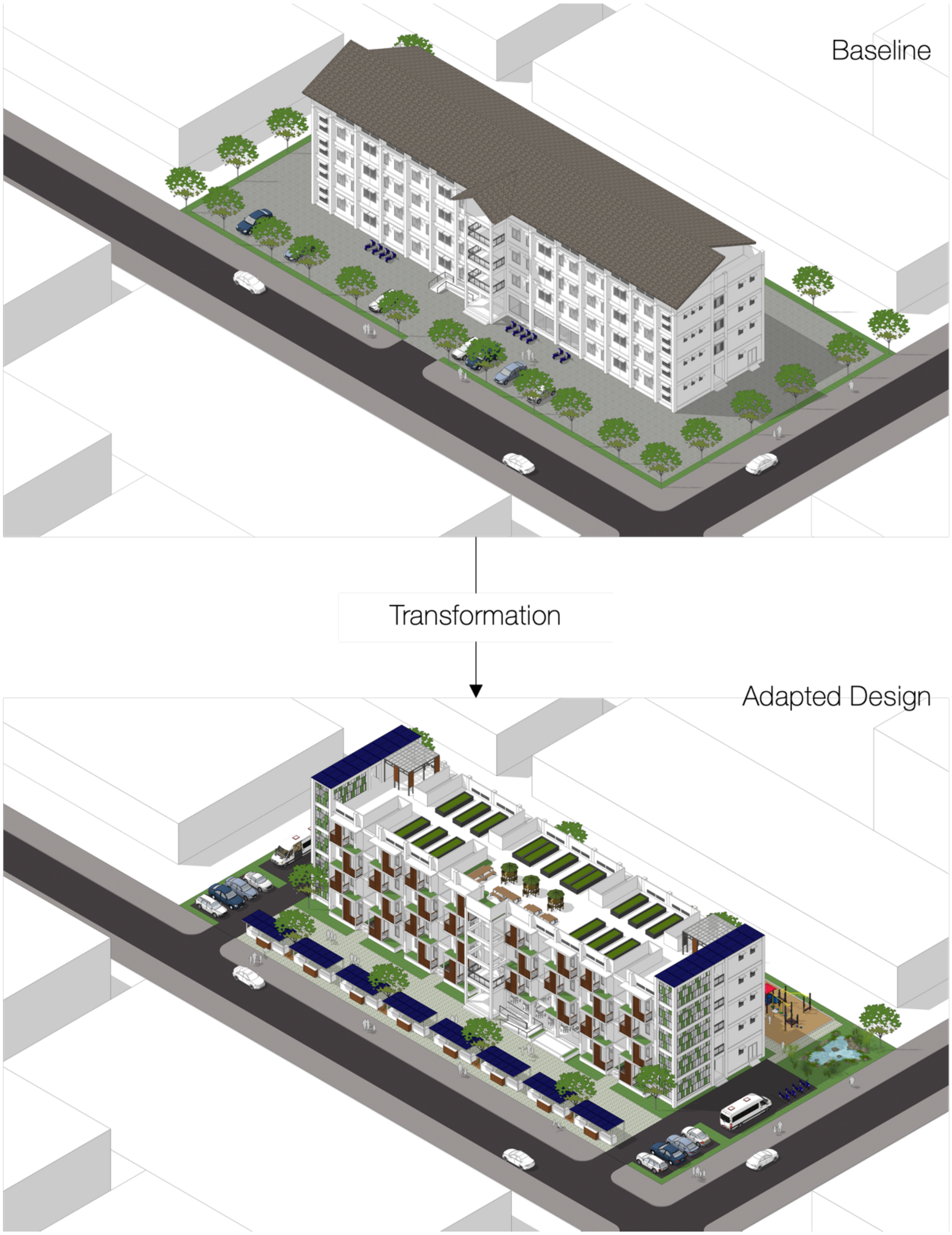


Figure 30. Transformation of Existing Prototype to New Prototype

The new design provides abundant community space, starting by reducing the parking lot and creating smaller community areas that are more productive and well-programmed. There is shared transportation, which the residents can use together with their workplaces, schools, or others. From the street to the front of the buildings is more public, including market stalls, while from the building to the back of the building, they are more private for residents. The common space provided in the new design includes market stalls, a front courtyard, a dining area, a sky terrace or shared balcony, a roof terrace and urban farm, a shared laundry area, pray room, a bioretention, a back courtyard, children's playground, senior playground, and gazebo or pavilion.

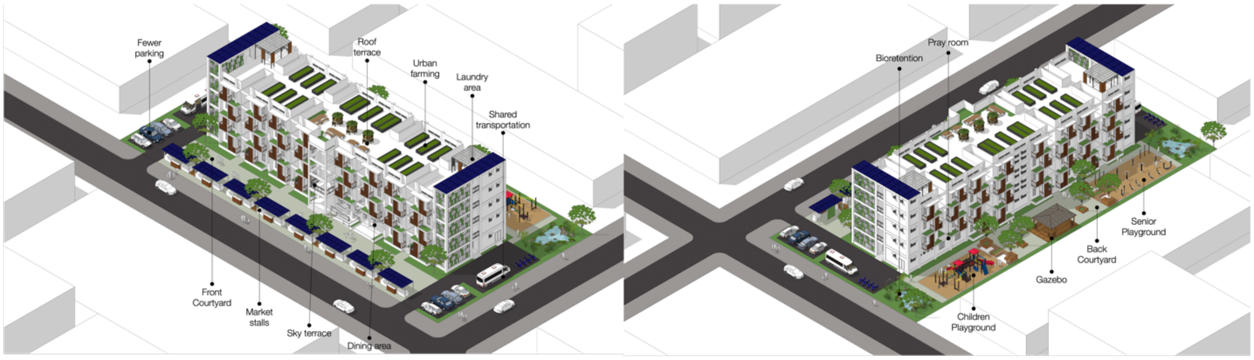


Figure 31. Programming in the Outdoor Area

Block plan drawings show the new design from above and its surroundings. However, these drawings' surroundings are an assumption because affordable housing prototypes can be built in different conditions.

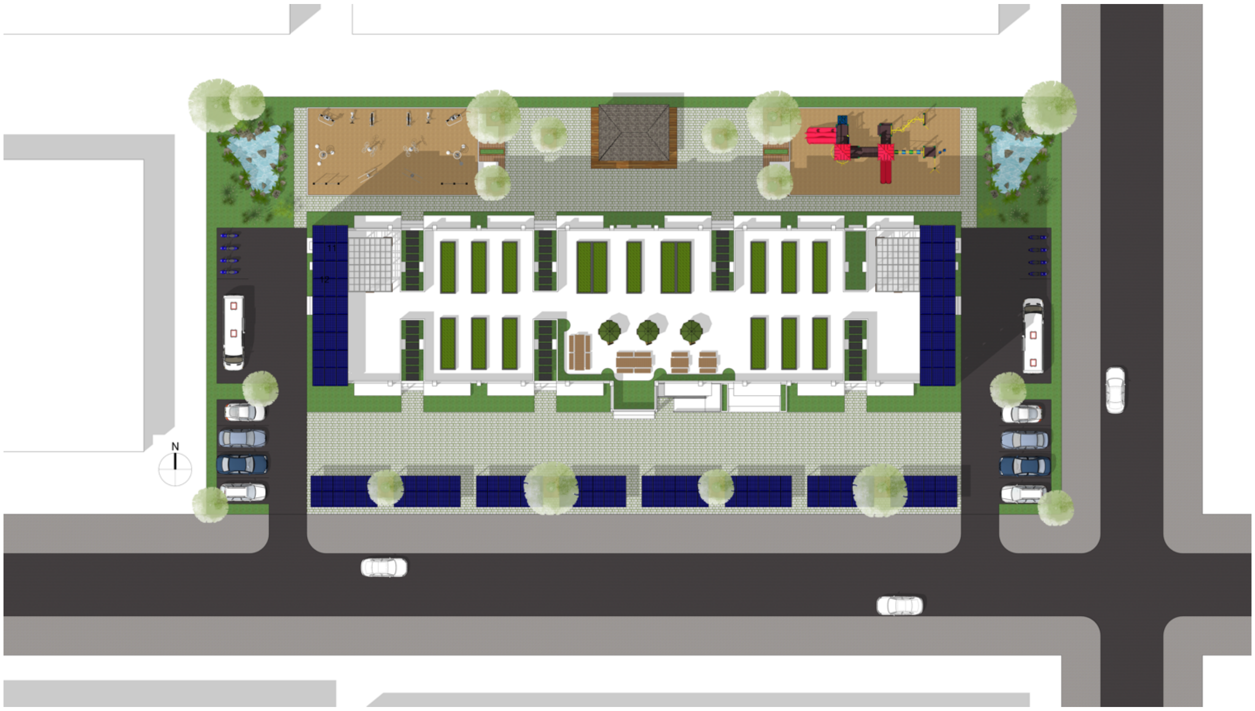


Figure 32. Block Plan

The site plan of the proposed design displays the programming of the ground floor. This drawing also shows this design's openness and accessibility, which connects the front and back of the housing with several smaller entrances. The main entrance in the middle of the building also directly connects to the dining area.

Figure 33. Site Plan

Roof floor plan drawings show the rooftop programming, consisting of a shared laundry area and an urban farm for food cultivation, producing healthy food, and generating income for the residents. The roof terrace is also programmed with an area where people can gather and interact socially. While the other floor plan is quite typical, on the 2nd floor, a shared balcony can be seen from the 3rd and 4th floors. The conditioned areas are only in the bedrooms of each dwelling unit.

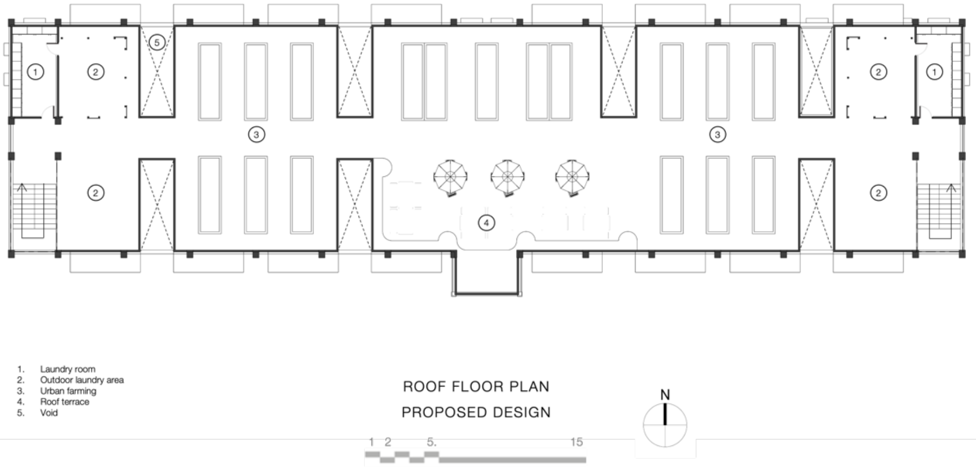


Figure 34. Roof Floor Plan

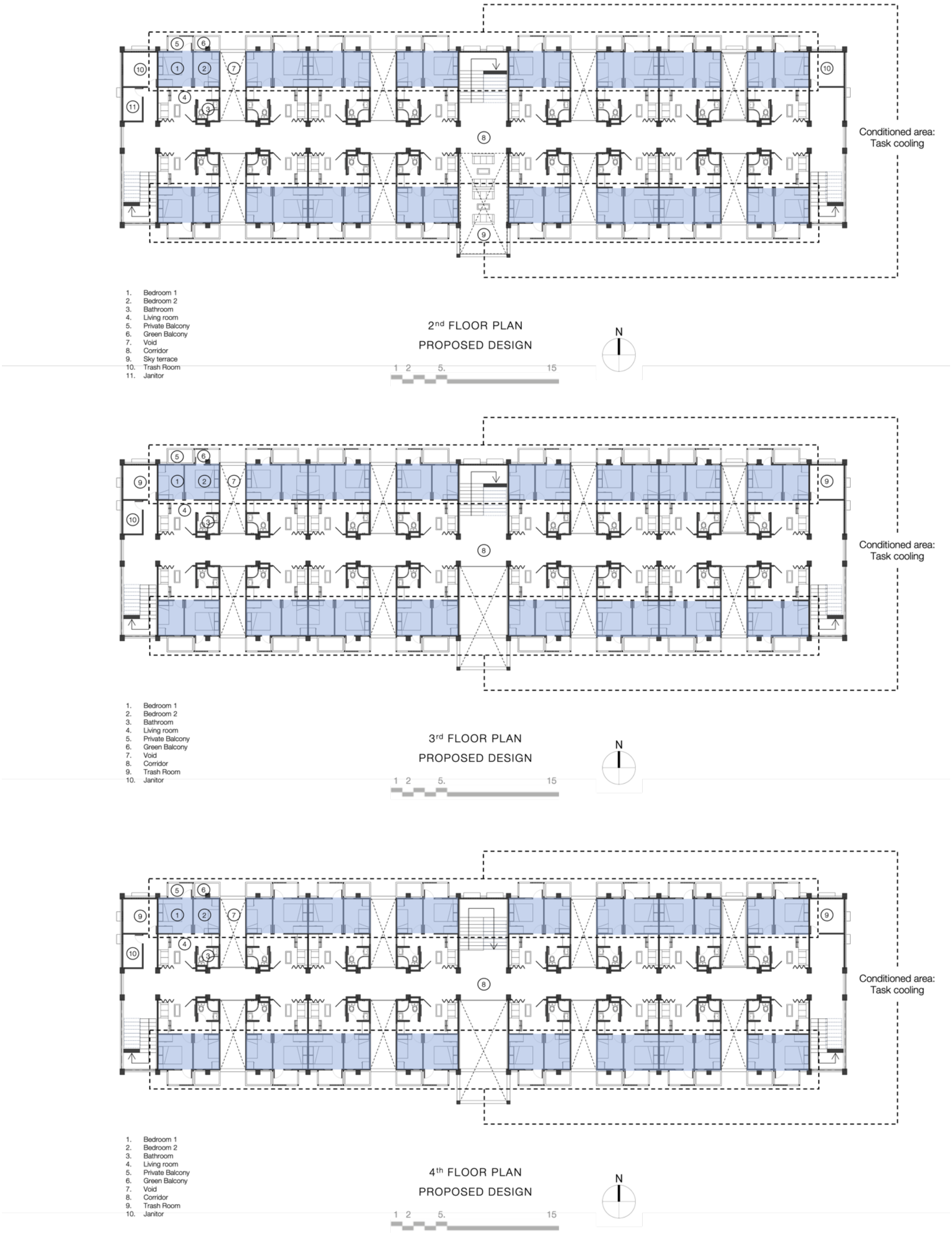


Figure 35. Floor Plan; (a) 2nd Floor; (b) 3rd Floor; (c) 4th Floor

Figure 36. Elevation. (a) South Elevation; (b) North Elevation; (c) East Elevation

Section drawings show how porous the building form of the adapted design is. Section A is cut in the corridor, section B in the dwelling unit, and sections C-C in the dining area and above. From these drawings, this study wants to show the cross ventilation and stack ventilation inside the building, which are the passive design strategies used.

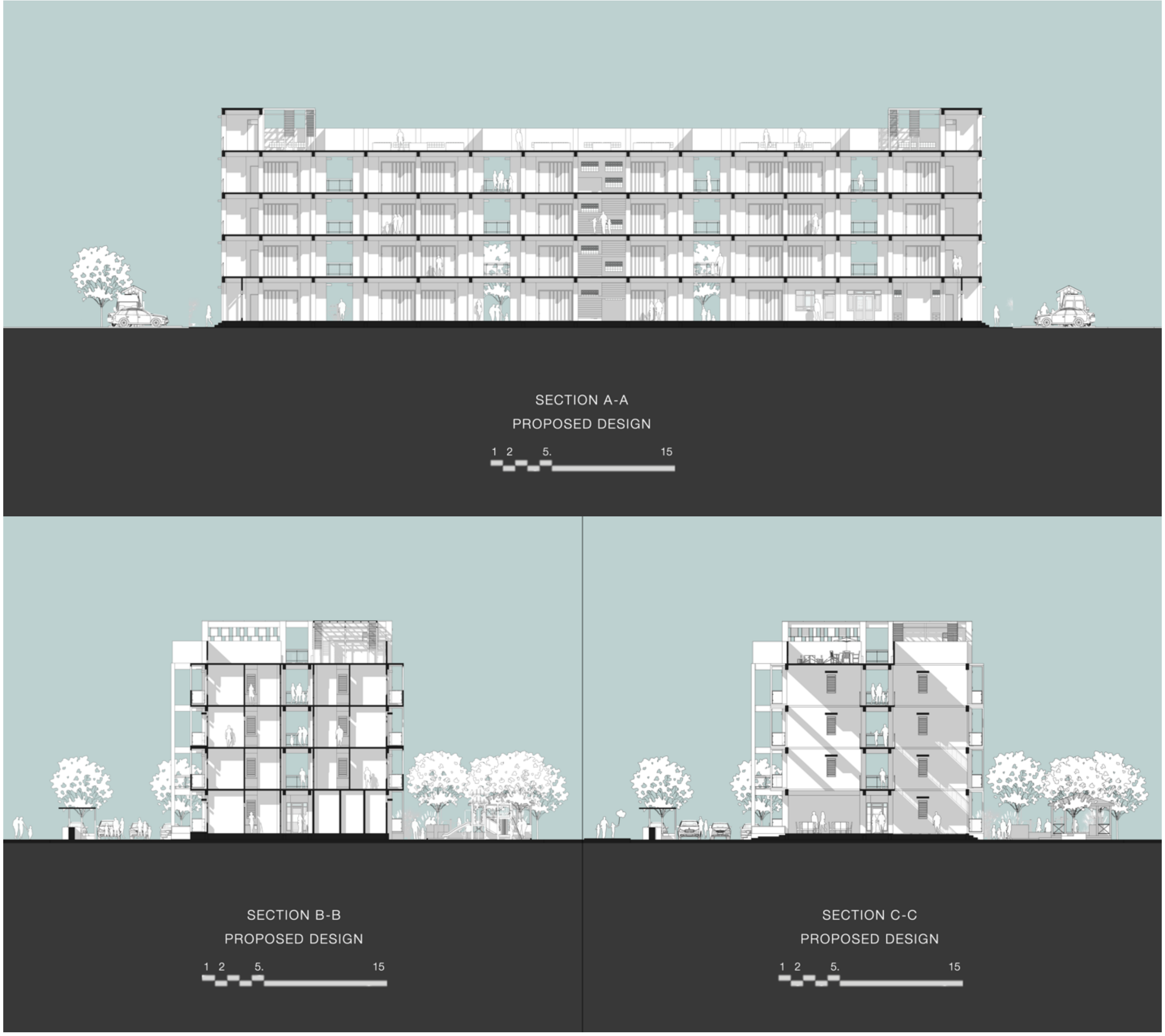


Figure 37. Section: (a) Section A-A; (b) Section B-B; (c) Section C-C

Some mechanical strategies applied in the proposed design come from the energy simulation result. The projected balcony helps with self-shading so the dwelling unit does not get direct sunlight, which can increase the temperature inside. The dwelling units also have an operable window that the residents can manually operate. These windows allow cross ventilation and morning flushing. Only the bedrooms are mechanically conditioned and employ a high-performance heat pump with COP 3 to use energy effectively. The energy simulation also recommends adding an energy recovery ventilator (ERV), which exchanges hot air with cooler air for ventilation and for dehumidification. Lastly, the ceiling fan also helps circulate the air in the room and improves comfort.

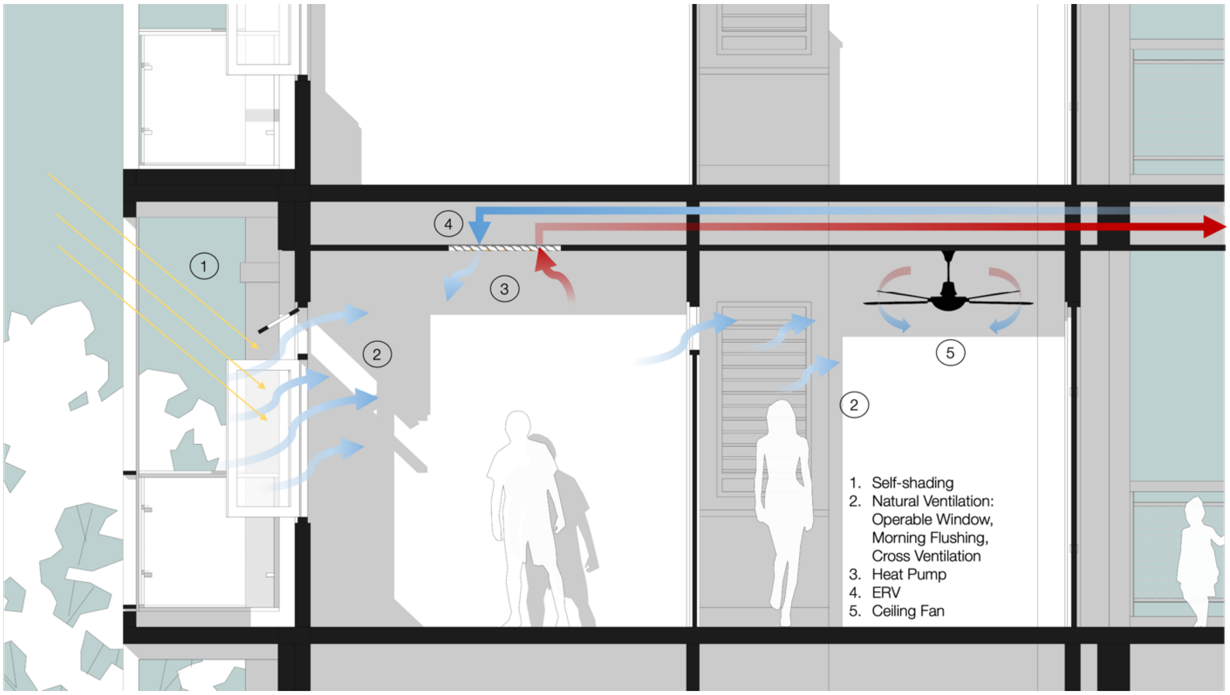


Figure 38. Combination of Passive and Mechanical Strategies

This perspective section displays three types of stack ventilation in the new design. It helps to cool the building and improve thermal comfort passively. From the community standpoint, people can interact on each level. They can see the activities below and above them, which can encourage them to socialize.

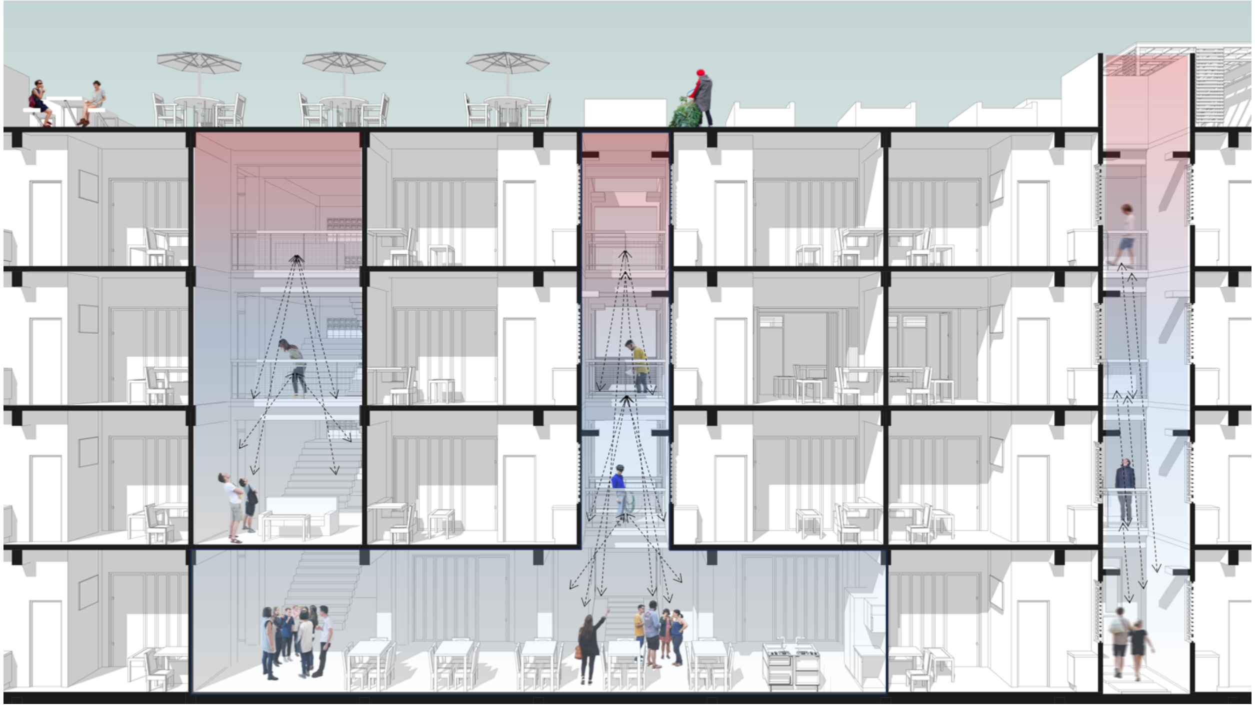


Figure 39. Perspective Sections - Voids

The transversal perspective section aims to show how the community can use the different settings of the folding door. If they open the door completely, they can have a bigger event. They can also have an option to open it or close it entirely.

Figure 40. Perspective Section - Folding Doors

Perspective images of the proposed design demonstrate the community's lives inside the affordable design. The presence of local shops where the people usually do their economic activities in kampung is accommodated in the design. A guard post, which they use as a space to gather, is transformed into a pavilion where the community can hold any events, such as workshops, training, or social gatherings. The new design also accommodated a big dining area where the residents could cook and dine together like they did in their previous settlement. They will always feel connected with their neighborhood because of the openness of the new prototype, which they can experience from their private balconies, voids in the corridor, and common areas. Lastly, they can have opportunities to be self-sufficient and resilient with the presence of an urban farm where they can produce fresh and healthy food while socializing on the roof terrace.

Figure 41. Exterior Perspective

Figure 42. Market Stalls

Figure 43. Gazebo in Back Courtyard

Figure 44. Dining Area

Figure 45. Voids and Projected Balconies

Figure 46. Roof Terrace and Urban Farm

Chapter 5 Conclusions

The affordable housing program built by the Indonesian government has ample opportunities to contribute to reducing energy consumption and carbon emissions. This massive development can significantly impact the environment and community, creating a better quality of life for low-income people. Through this proposed design using adaptive reuse as a design approach, this study aims to offer a better solution that uses the three dimensions of sustainable development and accountability to improve the existing prototype.

5.1.1 Environmental, Social, and Economic Dimensions

- **Environmental and Economic**

The transformation of existing buildings preserves embodied energy and should yield cost savings. Task cooling, 'morning flushing' cooling, and stack ventilation can lower energy use and energy costs and improve thermal comfort. From the comparison between *kampung* and the existing prototype, we also learn that affordable housing has a higher density, so with the adapted design, it can deliver high-quality housing at a much smaller cost to the environment.

- **Economic and Social**

The proposed design transforms not only the building but also the landscape area of the housing. Outdoor spaces can be used for community gatherings, children's play, and informal commerce to accommodate the economic activities usually found in *kampung*. Informal enterprises can generate income through market stalls and food cultivation on the roof. The community activities can also be programmed to improve the economic condition of the residents.

- **Social and Environmental**

The adapted design offers abundant common spaces for social gatherings among families and the community. There are everyday play and activity areas. Moreover, this new design also has adaptable space organization to accommodate change and growth among families.

5.1.2 Design Improvement

The proposed design needs to answer three questions: occupants' comfort, energy consumption reduction, and the community. Compared to the baseline, the adapted design can achieve 100 percent thermal comfort, with temperatures between 65 to 83 °F (18.3 to 28.3 °C) which was previously only 32.1 percent. The new design's energy use that combines mechanical and passive strategies can reduce around 70.33 percent of energy use from 128.686 kBtu/sf/year to 38.192 kBtu/sf/year. It can achieve zero net energy by using a PV panels. Finally, this adapted design can provide 12 productive and programmed community areas that previously had 4 formal common spaces.

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