The Intergration of Net Zero Designs and Vernacular Vietnamese Architecture

Senior Thesis

Linh Mai

ACKNOWLEDGEMENT

My thesis is dedicated to my grandfather and grandmother. Thank you for being my biggest supporter and inspiration every day.

I would like to express my gratitude to Naomi. Without your encouragement and wisdom, this thesis would not have been possible. Thank you for giving me the opportunity to work with you and allowing me to explore my architectural capabilities beyond my wildest imagination.

Thank you to my parents as you have always been there for me through my hardships and my accomplishments. I want to shout out to my brothers, as they never fail to annoy and light up my days.

Shout out to my studio friends. You guys are the greatest rockstars for cracking jokes and sharing stories, and I will miss our late-night snack-sharing and work sessions at Fimbel very much.

I would also like to thank my mentors for guiding me through the early stage of my professional career and adulthood. Your support means the world to me.

THE INTEGRATION OF NET ZERO DESIGNS AND VERNACULAR VIETNAMESE ARCHITECTURE

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Architectural Studies Thesis 2023

ABSTRACT

Rapid urbanization and globalization have brought about cultural erosion in Vietnam as reflected in the International Style buildings that dominate today's skyline. On top of that, global warming and the negative consequences of human dependence on fossil fuels have aggravated rising sea levels and air and water pollution, which heavily affect the South of Vietnam, particularly Ho Chi Minh City, the economic center of Vietnam.

Recently, in COP 27, Vietnam reaffirmed its commitment to net zero by 2050, as initially declared in COP 26, making great strides and investments in the green building sectors. However, Vietnam has no pilot net zero building projects, specifically in the residential area. Buildings are responsible for over 30% of the city's total energy use and associated greenhouse gas emissions. Furthermore, new-built buildings are high in embodied energy and embodied carbon. Net zero designs, which produce as much energy as they consume, can reduce fossil fuel-reliant energy and promote the implementation of renewable energy. Regarding materials, building methods, and passive design strategies, Vietnamese vernacular architecture is an excellent example of low embodied energy building. Thus, the widespread implementation of net zero designs with vernacular architecture attributes will reduce the energy consumption of the building sector and the embodied carbon within the projects.

My thesis focuses on the revitalization of Vietnamese traditional culture and the incorporation of the environmental principles developed by our ancestors in combination with modern net-zero design strategies to optimize the sustainability of building designs. The product of my thesis is a mid-rise, mixed-use net-zero residential development located in Thu Duc City, a municipal city under the administration of Ho Chi Minh City. Thu Duc City is currently under development to become the city's new financial and technological center.

This thesis is a design guide to how Vietnam can move forward with its net zero goal by 2050 and minimize the environmental impacts caused by the building sector while prioritizing the health of Vietnamese people.

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INTRODUCTION

Figure: Turtle Lake. Credit to: iVIVU

INTRODUCTION

This part discusses Saigon from my point of view and the structure of this thesis.

Introduction

Coming from Ho Chi Minh City, the largest metropolis in Vietnam, I have been at the forefront of experiencing the rapid transformation of my city and Vietnam.

Saigon, as I like to call it, is a kaleidoscopic city with multiple colors, shapes, and forms. The energetic city hosts booming businesses and people looking for life-changing opportunities to make a name for themselves. Yet, Saigon is home to the friendliest locals who never fail to help you find directions or offer a hand carrying your heavy market groceries.

As a born and raised local, I cannot help but feel prideful as a Saigonese. My love for Saigon stems from my love for exploration. Endless boulevards, alleys, nooks, and crannies are waiting for you to come and discover the new crunchiest banh mi or the hippest vintage store. Visitors can hear myriads of stories, ranging from history to ghosts to dramas, from a local in any corner.

Thinking back, I am fond of my memories of wandering from the courtyard of Tran Dai Nghia School, past the Notre Dame, past the Children's Hospital, through the Intercontinental Hotel, and back to my mom's old office near the American Embassy. The image of the sun-dappled, interlacing contemporary architecture and 20th-century French-Vietnamese-styled buildings with the friendly locals will linger in the back of my mind for years to come. Perhaps, that was when I unconsciously developed an appreciation for Saigon's unique architectural identity and curiosity for architecture. Although now the city has demolished many of the beloved historical buildings to make place for soulless office and commercial buildings, the spirit of the city remains unwavering through the memory of its people and the continuing preservation efforts.

This city is where my parents migrated to, met, and settled down at my age. Here, my brothers and I, along with our dear friends, were born and raised.

Figure: Tran Dai Nghia School for the Gifted. Credit to Historic Vietnam

However, the impacts of flooding in the city are already quite evident and terrifying. In July 2020, a heavy evening thunderstorm immobilized the streets and traffic by flooding the passages and stranding me along with thousands of people from commuting home. At the time, the water reached my knee level, and I had no choice but to wade through the dark, murky water for 30 minutes to get back to my home. Most buildings are not equipped to accommodate the water level rise as I witnessed many people salvaging their possessions, vehicles, and draining buckets of water out of their houses.

I experienced only a mild case in comparison to current projections. It is heartbreaking to imagine that sea level rise can wipe half or even more of Ho Chi Minh City off the map, reducing what I and my fellow Saigonese know and love to ruin.

As the world is way past the time to reverse climate change, what options do my people have to protect our city? According to The United Nations Framework Convention on Climate Change, we can “mitigate climate change by reducing greenhouse gas emissions and adapt to the impacts of climate change. (UNFCC)”. Then, Vietnam ought to mitigate and adapt. From my experience learning about net zero actions during my Boston internship and at Mount Holyoke, I also believe that we can convert and build net zero buildings that are or will be equipped to adapt to the projected sea level rise. Hence, this design thesis comes into existence as it is the culmination of the lessons I learned as an architectural studies and economics student these past 4 years.

Figure: Flooding in Saigon. Credit to Saigoneer


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The following is the outline of my thesis:

Part I is the Context.

Background Chapter introduces the readers to Vietnam, Ho Chi Minh City, and Thu Duc City. After a brief overview, the readers briefly learn about the history and climate of the land as well as the climate change challenges that the design proposal will address.

Net Zero Chapter allows the readers to dive more deeply into net zero designs, and Vietnam's Net Zero commitment, and net zero strategies.

Vernacular Architecture Chapter discusses vernacular architecture, its history, and the climatic responses of the pre-modern built environment.

Intergration Chapter concludes Part I with a discussion of the integration of net zero designs and vernacular architecture and the reasons behind the author's choice of the mid-rise mixed-use residential and commercial project as the design proposal.

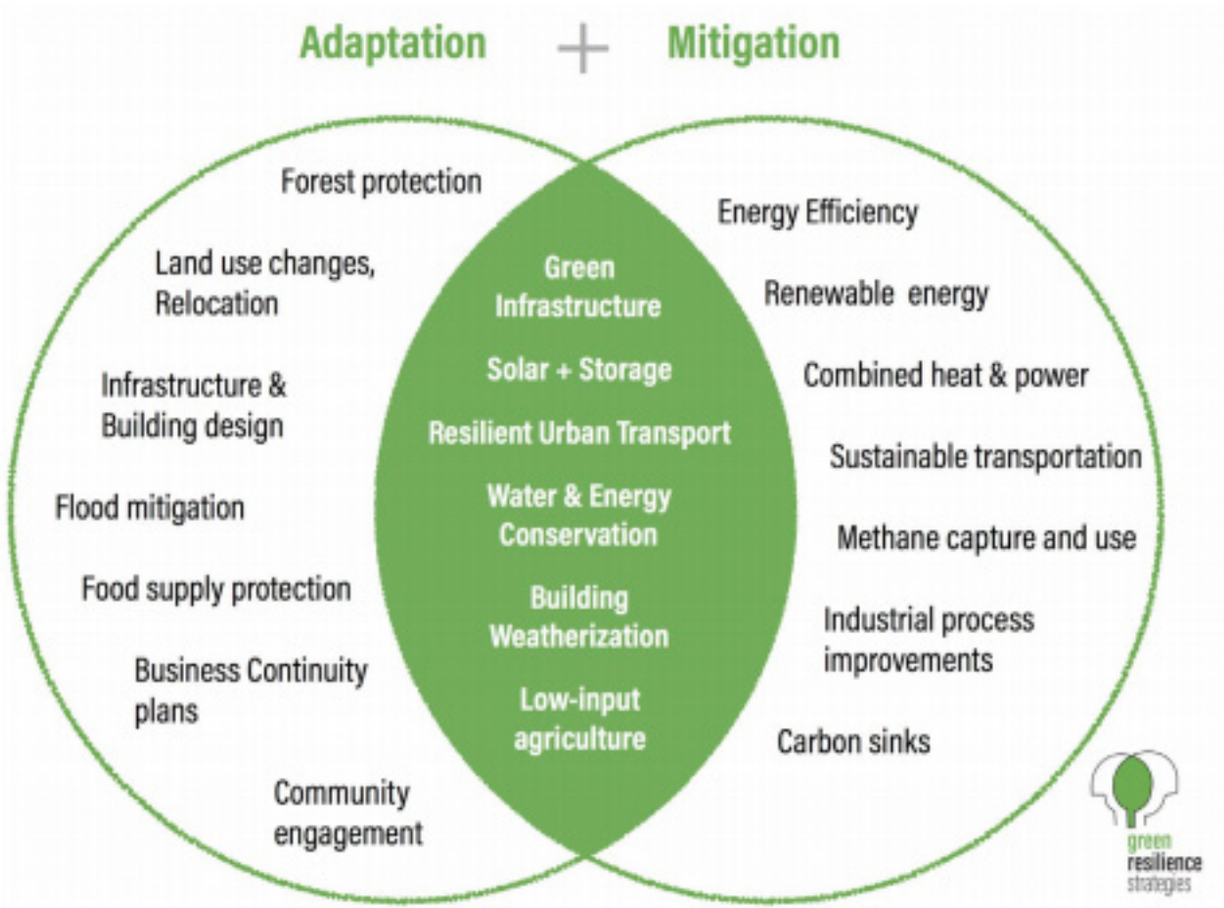
Part II is the Design Proposal.

The Design Proposal will focus on the integration of net zero designs and vernacular architecture strategies on to an mixed-use mid-rise apartment complex design.

Part III is the Conclusion.

The conclusion will discuss the study's limitations and moving forward.

Figure: Flooding in Saigon. Credit to Energy Shrink


Adaptation + Mitigation
Forest protection
Land use changes, Relocation
Infrastructure & Building design
Flood mitigation
Food supply protection
Business Continuity plans
Community engagement
Green Infrastructure
Solar + Storage
Resilient Urban Transport
Water & Energy Conservation
Building Weatherization
Low-input agriculture
Energy Efficiency
Renewable energy
Combined heat & power
Sustainable transportation
Methane capture and use
Industrial process improvements
Carbon sinks
green resilience strategies

PART I:
CONTEXT

Figure : 1969 Saigon. Credit to Saigoneer

BACKGROUND CHAPTER

This Chapter will provide an overview of Vietnam, Ho Chi Minh City, and Thu Duc City, mainly the Thu Duc District area before the city's establishment.

Vietnam started out as a collection of tribes, and is one of the earliest civilizations to practice wet rice farming and experience the stone and metallurgical revolution. The first tribal leaders of Vietnam united and established the Van Lang State, the first state of Vietnam, in a collaborative effort to combat foreign invasion and natural disasters.

After the Han Dynasty's invasion in 111 BC, Vietnam became a colony of multiple Chinese feudal dynasties over the span of 1000 years. During this period, Vietnam absorbed much of the Chinese culture, language, religion, and literature.

In 938 AD, the Bach Dang victory gave Vietnam its long-awaited independence and opened up a new era of a centralized, independent feudal state with its own court, national construction, and defense. After a series of early dynasties (Ngo, Dinh, Early Le), Vietnam entered its renaissance and development period (11th to 16th) under the Ly, Ho, and Le dynasties. Dai Viet

The name of the country during this era, was known as a wealthy nation in Asia. Economic-wise, this period saw the development of agriculture and irrigation with the construction of the Red River Dike and the formation of specialized craft villages. In religious terms, traditional beliefs, Buddhism and Confucianism were considered the three coexisting official religions. Vietnam also developed the Nom scripts, which was the Vietnamization of the Chinese Han script. During this time, Vietnam expanded southward, conquering a portion of the Khmer Empire.

From the 16th century, the country's cultural and economic growth stagnated and declined with a series of civil wars and divisions. Ports and trade cities soon appeared, introducing Vietnam to domestic and international trade with Eastern and Western powers. Through missionary activity, trade, and military power, the French gradually turned Vietnam into its dominant French Indochina colony in the 19th century. As a result of imperialism, Vietnam soon adopted French culture, transportation, architecture, and the Latin script.

The rise of the Vietnamese Communist party defeated the French rule in 1954. However, the country soon divided into Communist North Vietnam and Democratic South Vietnam backed by the United States. The Communist victory in 1975 brought the Vietnam War to an end, uniting the country after years of division, established the Socialist Republic of Vietnam, and shaped what we know as modern Vietnam after the implementation of Doi Moi economic and social reforms. (Pham 2022)

Figure : 1910 French Indochina. Credit to Saigoneer

INDO-CHINE FRANÇAISE

E. Fouré géographe Paris

Touring-Club de France

TOURING-CLUB de FRANCE

Reconnu d'utilité publique

Siège social : 65, avenue de la Grande-Armée, PARIS

COMITÉ DE TOURISME COLONIAL

INDO-CHINE

Overview: Vietnam

Vietnam lies in the eastern part of the mainland of Southeast Asia. With its long coastline, Vietnam stretches across two dominant climate regions: temperate and tropical. In 2021, Vietnam's population reached 98.1 million, with one-third living in urban areas (World Bank, 2021). Most of the urban population concentrates in Hanoi and Ho Chi Minh City. In terms of economic sectors, the agricultural sector gives way to the industry and service sectors. Rice production is a vital link to the country's "food security, rural employment, and foreign exchange" (World Bank, 2021). The geographical location, varied topography, and climate regions make Vietnam one of the most hazard-vulnerable countries in Asia and the Pacific Region.

Ho Chi Minh City, also known as Saigon to locals, has a rich historical background. The southern region, which was previously under the control of the Khmer Empire, came under Vietnamese rule as the Nguyen Lords waged a series of wars and gradually took over Khmer Empire land to expand their territory southward. With its strategic location along the Saigon River, north of the Mekong Delta, and 50 miles from the South China Sea, the city also served as the capital of the French protectorate of Cochinchina and of South Vietnam.

In the 17th century, the Vietnamese first gained entry to the Khmer fishing village, which is the site of modern Saigon. To mark the entry to the conquered land, the explorers founded Saigon in 1698. The Nguyen Dynasty oversaw Saigon as one of its administrative units. With promises of land and opportunities, people migrated to Saigon.

In 1859, the land came under French control, and Emperor Tu Duc of the Nguyen dynasty ceded the land to France in the Treaty of Saigon. As the capital of Cochinchina, Saigon rose to prominence as a major port city and a metropolitan center. Looking for business opportunities, global merchants hailing from China, India, and Europe migrated to and transformed Saigon into a trading hub and a cultural melting pot.

During World War I, the Japanese captured Saigon in 1940. After the Allied Victory, the French briefly gained control of its Indochina colony before engaging in the First Indochina War with the Democratic Republic of Vietnam led by Ho Chi Minh. Started out as the Second Indochine War, The Vietnam War turned Saigon into the headquarters of the United States military operations. In 1975, the North Vietnamese seized Saigon and ended the Vietnam War after the Northern troops' tank crashed through the Independence Palace's gates. Subsequently, Ho Chi Minh City adopted a new name: Ho Chi Minh City.

Figure: 1910 French Indochina. Credit to Saigoneer

Under Communist rule, Ho Chi Minh City was no longer the administrative and political center. The Socialist Republic of Vietnam made efforts to reduce the city's population, curtail reliance on foreign imports, and nationalize its commercial enterprises.

Currently, Ho Chi Minh City experiences a resurgence as the epicenter of commerce and culture in Vietnam, characterized by rapid economic growth and the presence of rapidly rising skyscrapers. Nevertheless, the city continues to exude a distinctive charm through its faded aesthetic, reminiscent of the Indochina era, and an abundance of French-influenced architecture that still remains standing.

Ho Chi Minh City, once named the "Pearl of the Orient" by the French due to its diverse culture, bustling commerce activities, and proximity to the neighboring Southeast Asian countries, upholds its role as Vietnam's most essential financial and cultural center. Home to 8.9 million people, Ho Chi Minh City is the largest city in Vietnam. At the macro scale, the city acts as the center of the Ho Chi Minh Metropolitan Area with a population of 20 million which includes 16 million people inhabiting the urban area. Currently, the city generates 23 percent of Vietnam's gross domestic product (GDP) and receives 20 percent of direct foreign investment.

Ho Chi Minh City retains the "essential French colonial character" as reflected in wide avenues, colonial villas, administrative buildings, and a lively cafe society. Furthermore, the modern buildings, especially tube houses, which is a narrow and vertically-oriented building that is common in Vietnam, and newly built skyscrapers, in different colors and forms, interlace and make up the fabric of the city (Global Future Cities Programme).

Figure: District 1. Credit to The Executive Centre

Before becoming a part of Thu Duc City, Thu Duc District was a town situated in the northeastern corner of Ho Chi Minh City founded by Ta Duong Minh, a Chinese merchant who escaped from the political upheaval in China during the mid-19th century and established the original Thu Duc market. Soon after, the French renovated and built their colonial style market. Before the industrialization in 1970s, Thu Duc was the suburban getaway for city dwellers with many parks and pools for recreational activities. By 1997, in one of the city's expansion efforts, Ho Chi Minh City usurped Thu Duc Town as one of the districts within the ciy. Then, the district soon adopted the role as the city's educational hub with many universities and colleges soon establishing and building their campuses in the affordable area. Fast forward to 2021, Thu Duc District merged with District 2 and District 9 and turned into the latest innovation hub that carries the expectation of producing 30 percent of the city's GDP (Stephenson 2019).

On January 1, 2021, the Vietnamese National Assembly passed Decree 1111 that established Thu Duc City as a municipal city under the administration of Ho Chi Minh City. Thu Duc City is a merge between District 2, District 9, and Thu Duc District, encompassing 211 square kilometers and currently housing 1 million inhabitants. The objective behind this decree is to create an innovative hub that facilitates productivity and creativity through agglomeration effects. The decision aims at boosting investors' confidence and encouraging economic growth on the city level. This strategy takes inspiration from Shanghai and Gangnam.

- District 9 carries the role of a new technology center with urban planning decisions in 2017 that shifts the land use for technology companies, medical facilities, service industries, commercial complexes, and warehouses.
- District 2 will transform into a mixed-use central business district that will host 130,000 inhabitants over the course of 20 years.
- Thu Duc District is the high education center of the city with 12 universities that includes the Vietnam National University and its 70,000 students. As a part of the Thu Duc City, this district will train and educate the future workforce of the area.

Figure: Thu Duc Market. Credit to Foody


CHỢ
THỦ ĐỨC
CÁN BỘ - CÔNG NHÂN VIÊN VÀ TIỂU THƯƠNG CHỢ THỦ ĐỨC
QUYẾT TÂM GIỮ VỮNG CHỢ VĂN MINH - THƯƠNG NGHIỆP
CO.OP
ĐIỂM GIAO HÀNG
BÌNH ỔN THỊ TRƯỜNG
CO.OP

These districts were once underdeveloped and neglected suburban districts. Now, the city has ambitious goals to offer the “infrastructure and human capital capacity” to these three complementary districts and propel the municipal city into an ‘innovation district’. Thus, these plans will come with generous investments, new developments, and incoming talents that turn these concepts into reality.

However, these plans also pose a gentrification threat to the existing communities and aging buildings. In order to actualize Thu Duc City’s vision of becoming a technology, education, and business hub, the city will issue land-use changes that affect low-income and middle-income housing in order to fit the new urban plan. The resulting change in land-use will lead to the cheap acquisition of existing housing, which will force thousands of households to lose their current homes and relocates.

The government relocated the locals who lost their lands and homes to resettlements with shoddy construction work resulting in lower living standards for the residents. The city unjustly compensated the Thu Duc City residents at a lower market rate, forcing many to engage in long periods of legal battles. For insntance, Thu Thiem project at the old District 2 displaced 15,000 residents to government-funded resettlements and removed their rights to their family lands. Although news outlet boasted 99% of the Thu Thiem locals accepted the relocation terms, the actual percentage is lower, considering 3,000 unsettled legal cases that the city has yet to resolved. Unfortunately, the situation at Thu Thiem is among many unfair cases in Thu Duc City.

Figure: Thu Duc City. Credit to Vietnam Insider

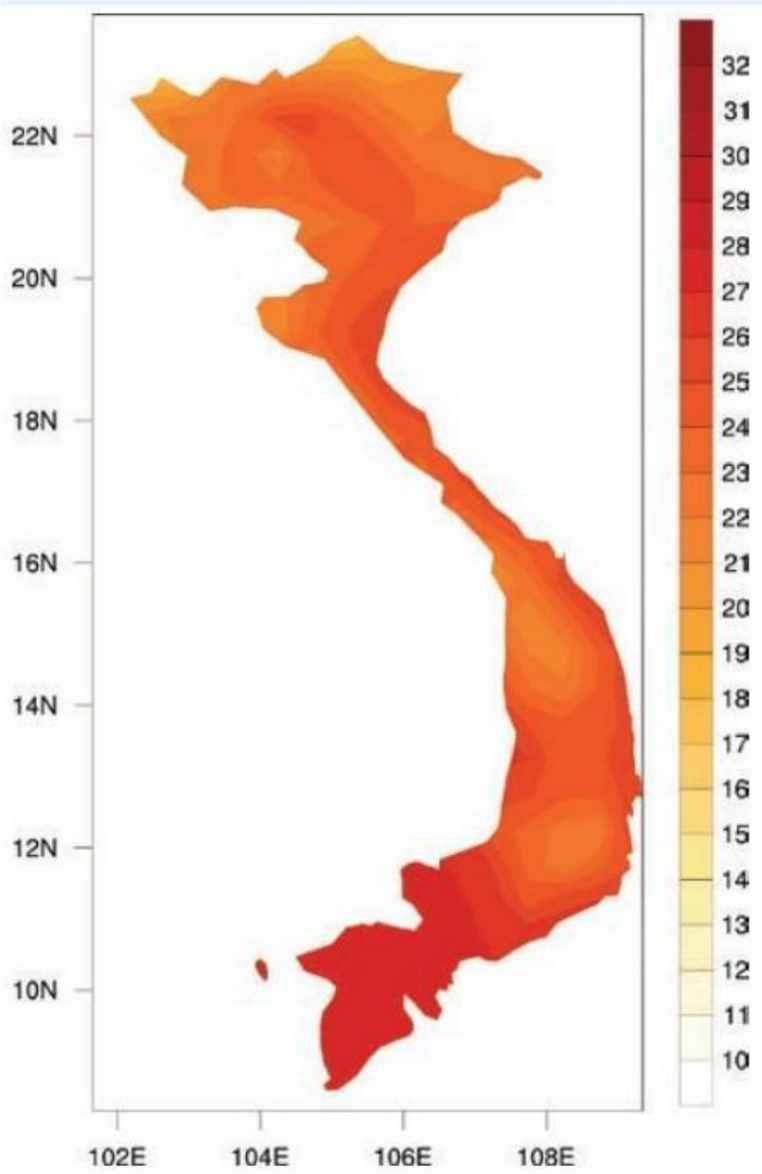

Củ Chi
BÌNH DƯƠNG
Hóc Môn
Quận 12
Thủ Đức
ĐỒNG NAI
Gò Vấp
Quận 9
Tân Bình
Bình Thạnh
Tân Phú
Quận 2
Quận 3
Quận 10
Quận 1
Bình Tân
Quận 11
Quận 4
Quận 5
Quận 6
Quận 8
Quận 7
Bình Chánh
Nhà Bè

Climate: Vietnam

The long geographic span of Vietnam enables the country to have a tropical and temperate climate zone with annual monsoon effects. Rainfall correlates to the monsoon cycles, resulting in heavy rain from May to October in the north and from September to January in the central regions. Less affected by the monsoon circulations, the rainy season in South Vietnam runs from June to November. On average, the temperate north experiences 22°C–27.5°C in the summer and 15°C–20°C in the winter. The Central's temperature ranges 23°C–35°C in the dry season, 25°C–36°C in the storm season, and 18°C–28°C in the rainy season. The tropical south has a more stable warm temperature that averages around 27°C throughout the year. Furthermore, El Niño influences Vietnam through monsoonal circulation, abnormal rainfall levels, and complex temperature patterns that differ across sub-regions (World Bank 2021).

Figure (right): Annual mean rainfall (mm) in Vietnam over the period 1901-2019. Credit to WBG Climate Change Knowledge Portal (CCKP, 2019)

Figure (left): Annual mean temperature (°C) in Vietnam over the period 1901-2019. Credit to WBG Climate Change Knowledge Portal (CCKP, 2019)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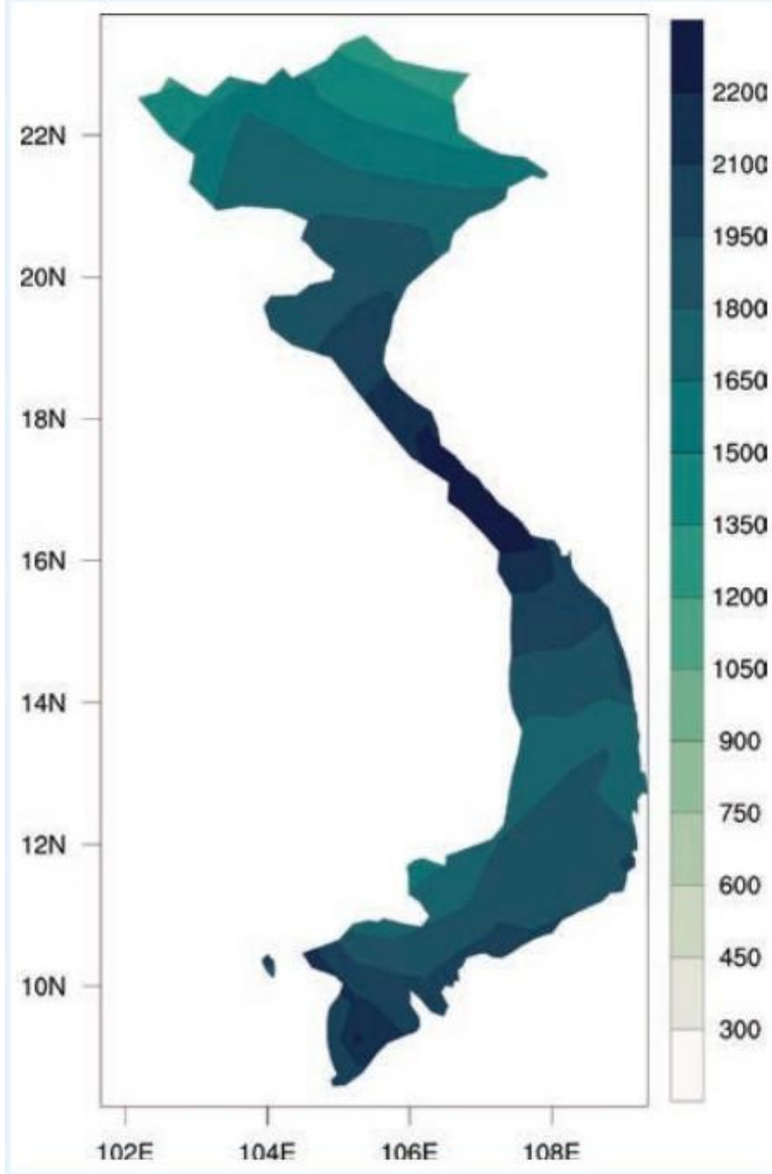
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1200
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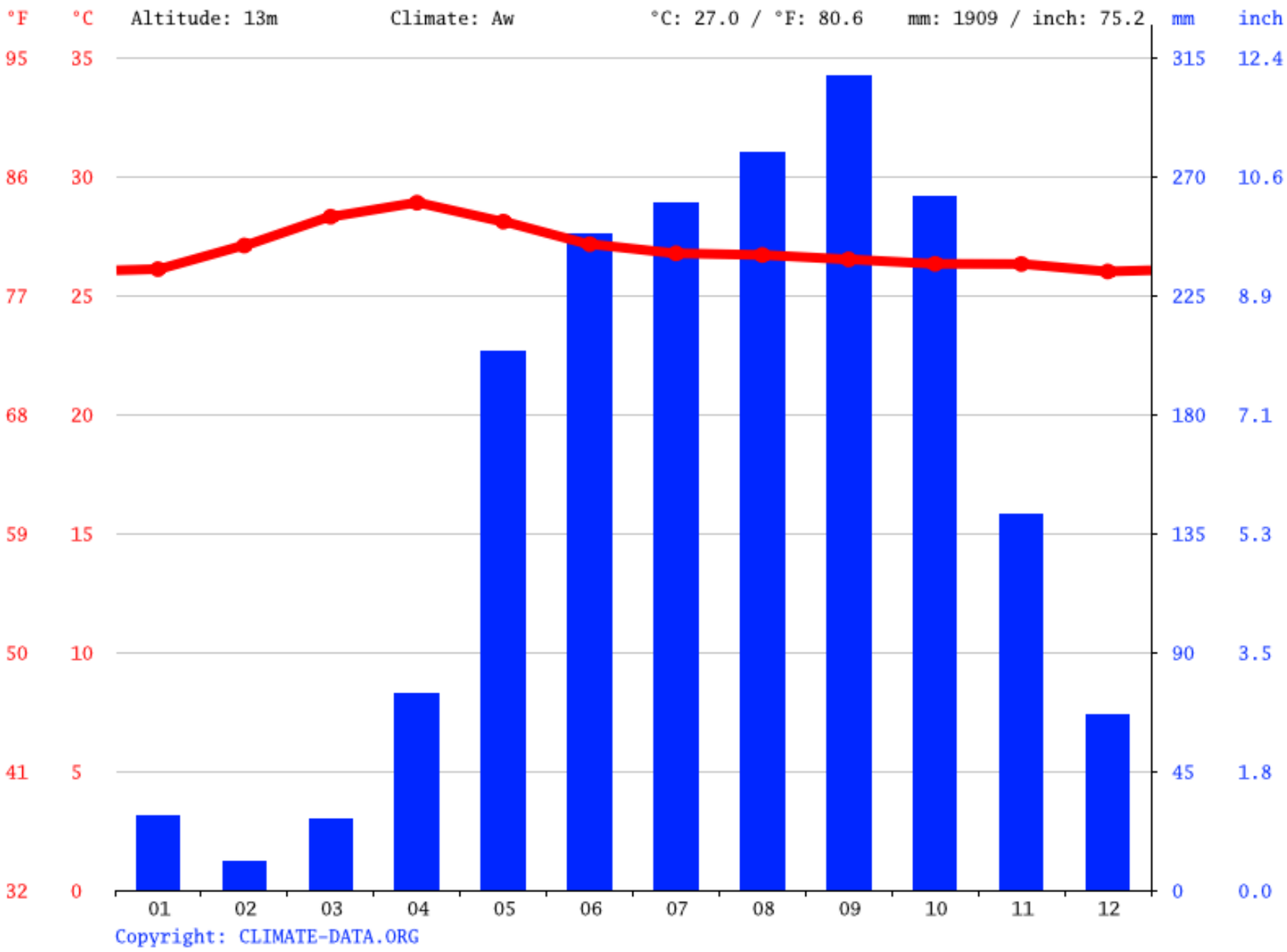
750
600
450
300

At the latitude of 10.8231 N and longitude of 106.6297, Ho Chi Minh City is situated in the tropical monsoon climate area with closer proximity to the Equator. With consistent high tropical temperatures, the city has two main seasons: the rainy season and the dry season. The dry season spans from December to April while the rainy season lasts from May to November. The hottest months start from March to May while the coolest months are around December to January.

The weather in the rainy season has high rainfall and humidity brought by tropical storms. The city experiences intermittent showers in the afternoon during this season. Ho Chi Minh City receives the heaviest rainfall between mid-August and mid-September. The rain often floods the streets and overwhelms the city's stormwater sewage infrastructure.

Figure: Ho Chi Minh City Temperature and Rainfall by month. Credit: Climate-Data.org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°C
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mm
inch
95
35
315
12.4
86
30
270
10.6
77
25
225
8.9
68
20
180
7.1
59
15
135
5.3
50
10
90
3.5
41
5
45
1.8
32
0
0
0.0
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05
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11
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Copyright: CLIMATE-DATA.ORG

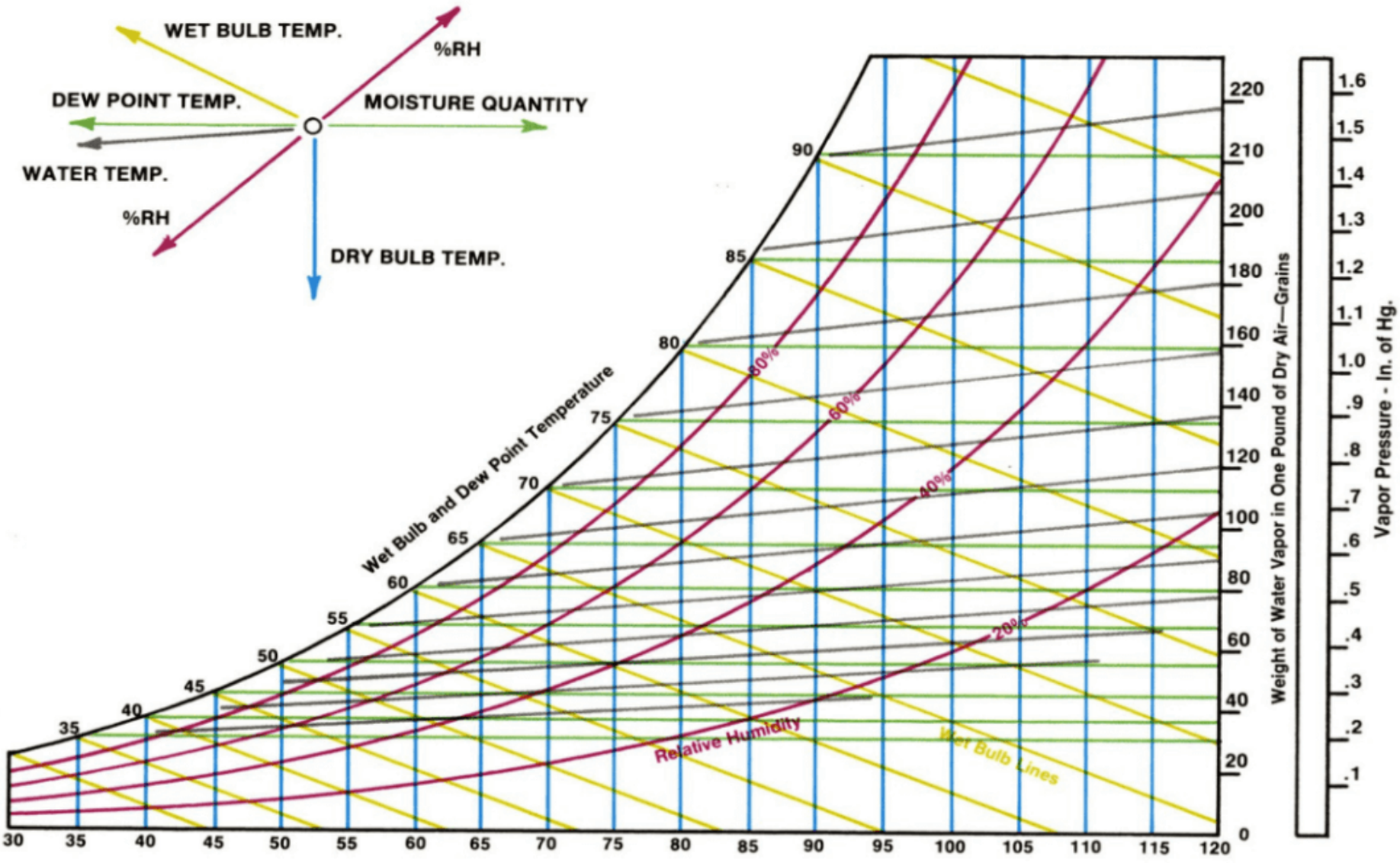
Psychrometric Chart: Definition

To gain insights into the impact of Ho Chi Minh City's climate on human comfort, it is necessary to explore the psychrometric chart. A psychrometric chart is a graphical tool that portrays the thermodynamic properties of air, including temperature, humidity, dew point, and enthalpy that aids architects in making design decisions for how to achieve thermal comfort including air conditioning, heating, and ventilation. These charts lay out the properties as lines and curves on a grid that visualize how the change of one property impacts the other. The psychometric charts allow architects to design the built environment that ensures optimal thermal comfort and indoor air quality for the occupants (ASHRAE).

The comfort zone of the psychrometric chart is the area that depicts the combination of temperature and humidity levels that are comfortable for the majority of occupants. The comfort zone encompasses a range of varying temperature and humidity levels that rely on a person's personal preferences, clothing, and activity level. A normal occupant can find their comfort zone falls between the lines of 30% to 60% relative humidity and 68F to 80F (20C to 27C) dry bulb temperature. Outside of the comfort zone, the conditions might be too hot, too cold, or too humid for the residents. Based on the psychrometric charts, architects can devise humidity and temperature tempering strategies, such as air conditioning, natural ventilation, or dehumidification, that allow the inner temperature to fall back into the comfort zone for the users' health.

Some of the psychrometric chart standards include ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), CIBSE (Chartered Institution of Building Services Engineers) psychrometric chart, and Giovanni Bioclimatic Chart. The ASHRAE and CIBSE Standards focus on the thermodynamics properties of air and are commonly used in the United States and Great Britain respectively. The Giovanni Bioclimatic Chart portrays indoor and outdoor environments in relation to human's comfort.

Figure: Understanding Psychrometric Chart Credit: Parameter Generation and Control


WET BULB TEMP.
%RH
DEW POINT TEMP.
MOISTURE QUANTITY
WATER TEMP.
%RH
DRY BULB TEMP.
Wet Bulb and Dew Point Temperature
80%
60%
40%
20%
Relative Humidity
Wet Bulb Lines
Weight of Water Vapor in One Pound of Dry Air—Grains
Vapor Pressure - In. of Hg.
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
35 40 45 50 55 60 65 70 75 80 85 90
0 20 40 60 80 100 120 140 160 180 200 210 220
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6

According to Fanger's study, ASHRAE stated that under steady-state conditions "people cannot physiologically adapt to preferring warmer or colder environments, and therefore the same comfort conditions can likely be applied throughout the world". However, in the study by Nguyen and Reiter, the Vietnamese have adapted and built a tolerance for its hot humid climate over time. Therefore, the ASHRAE's comfort zone standard might not be accurate when applied to Vietnam (Nguyen, Reiter).

Based on the Climate Consulant Software with the comfort model of ASHRAE standard 55, 4.9% of the total time of the year is comfortable, which is lower than the reality. The study further investigates the comfort zone in a different weather tool that implements Szokolay's method. The psychrometric chart predicts 2.5% of the total time of the year is comfortable.

Utilizing the steady-state thermal comfort model, the study offers a thermal comfort zone for the Vietnamese. The comfort zone designed for an average Vietnamese with a height of 1.65 m and weight of 60kg "in sedentary work (60W/m2 – 1 met) and in still air condition (0.15 m/s), is established for 90% occupant acceptability." The value for clothing insulation ranges from 0.5 clo (summer) to 1 clo (winter), which takes into account seasonal clothing changes.

Figure (upper): Incorrect prediction of comfort zone for Hanoi by weather tool. Credit to:Nguyen, Reiter

Figure (lower): Comfort zone proposed for Vietnam and its enlarge. Credit to: Nguyen, Reiter

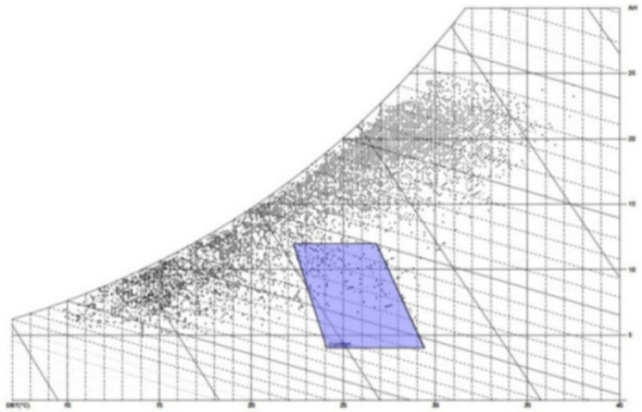


Figure 1: Incorrect prediction of comfort zone for Hanoi by weather tool [4]

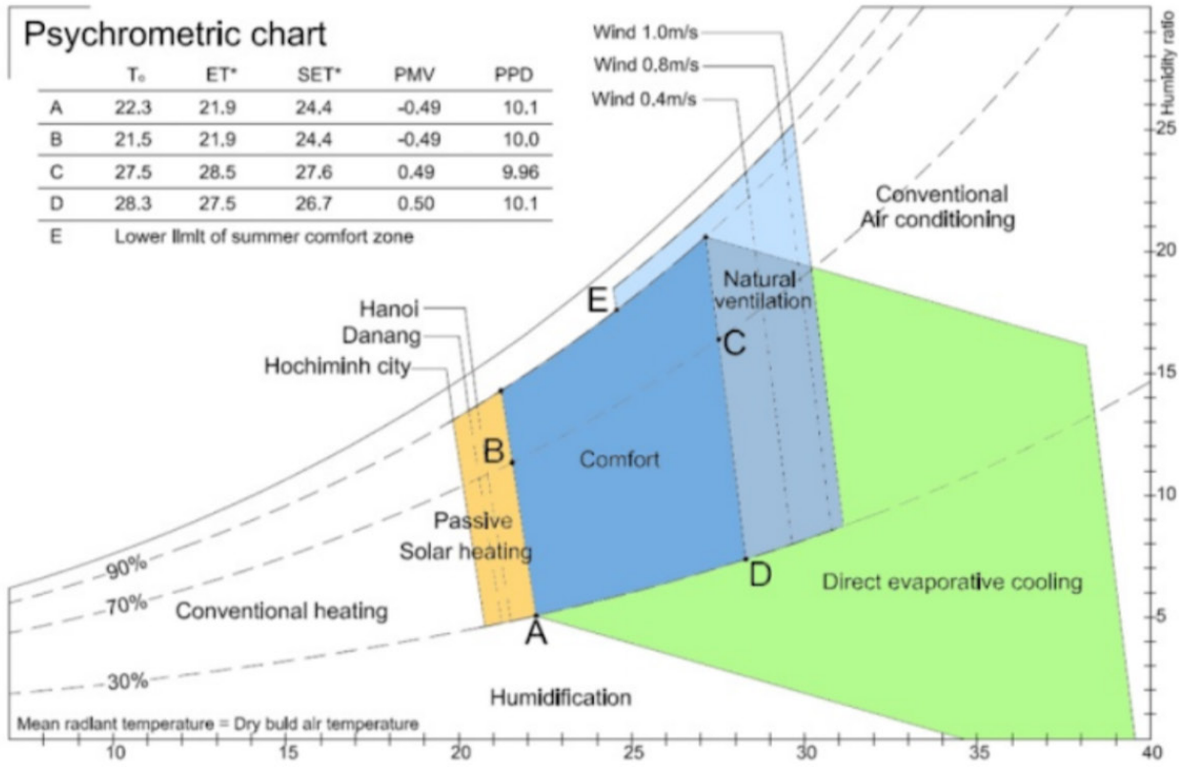


Figure 2: Comfort zone proposed for Vietnamese and its enlarge

Psychrometric Chart: Ho Chi Minh City

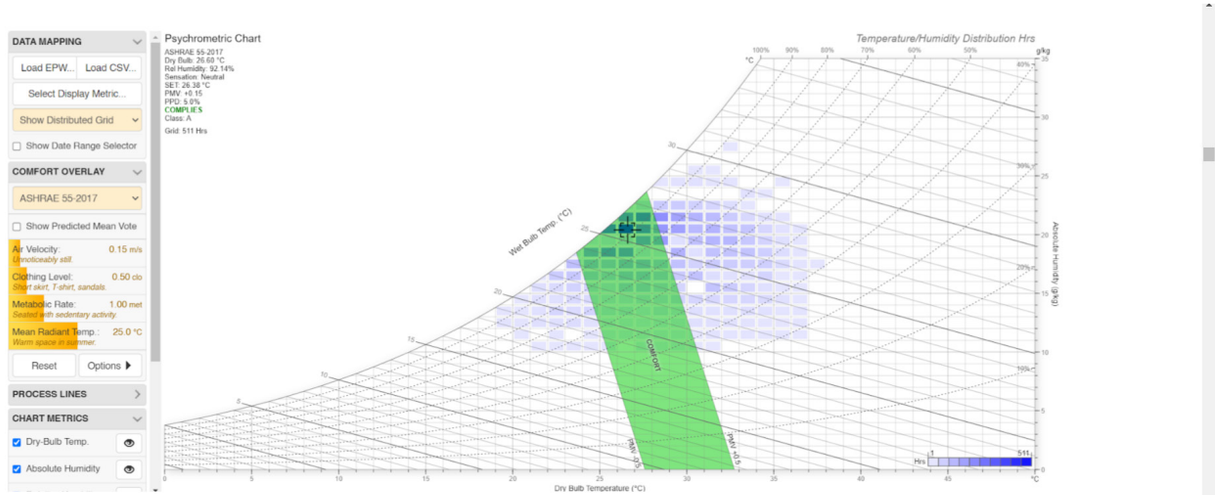
Based on Andrew Marsh's psychometric chart and climate one building climate data of Ho Chi Minh City, the days mostly fall out of the comfort zone by Giovanni Bioclimatic Comfort Overlay. However, with natural ventilation, most days fall into the comfort zone. Therefore, natural ventilation will facilitate thermal comfort for the building occupants. The thermal comfort improvement of natural ventilation strategy raises up to 31.4% in Ho Chi Minh City. Plus, the implementation of all passive strategies will improve the thermal comfort by 47.6% Ho Chi Minh City (Nguyen, Reiter).

By the ASHRAE 55 2017 standard, substantial temperature and humidity occurrences in Ho Chi Minh City fall into the comfort zone.

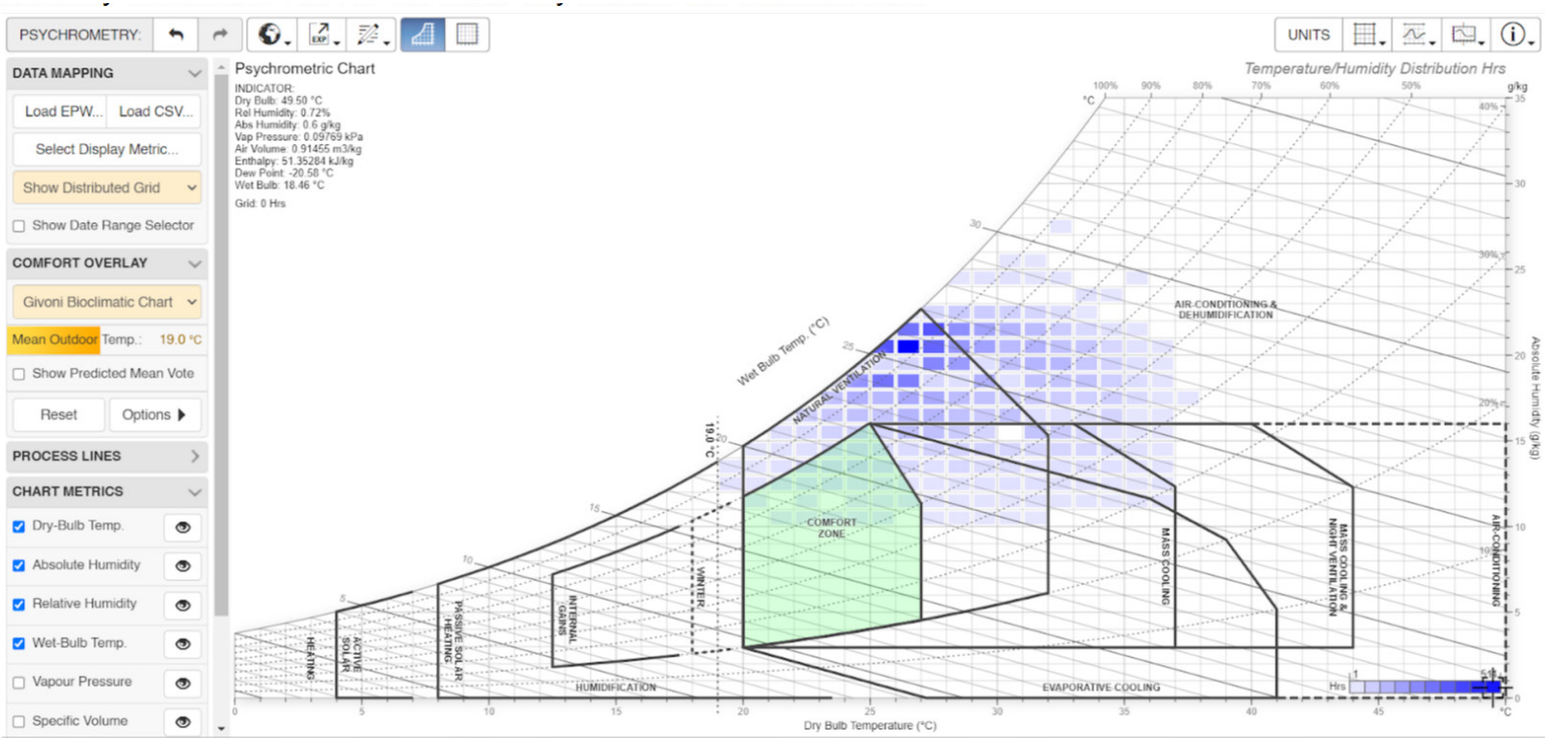
As a Ho Chi Minh native, I believe that the temperature is often comfortable for me as the temperature is relatively stable long all year round. However, the heat at noon in scorching, so it is best to stay indoor during the time and schedule your outdoor activities for the early morning or the afternoon. Additionally, I grew up without access to air conditioning due to high electricity bills. My family, as well as many other Vietnamese households, has built a tolerance for the heat with the assistance of our reliable electric fans. Electric fans create a cooling sensation through the wind-chill effect that occurs when sweat evaporates from your skin and eliminate body heat.

Figure (upper): ASHRAE 55-2017 Comfort Overlay. Credit: Andrew Marsh

Figure (lower): Giovanni Bioclimatic Chart Comfort Overlay of Ho Chi Minh City. Credit: Andrew Marsh



ASHRAE 55-2017 Comfort Overlay



Giovani Bioclimatic Chart Comfort Overlay

Vietnam

Vietnam has experienced an increase of 0.5°C–0.7°C average temperatures since 1960, with higher increases in southern Vietnam and the Central Highlands. From 1971 to 2010, the rate of warming was recorded at 0.26°C per decade, nearly twice the rate of global warming in the same period. The number translates to over 1.0°C over the past 50 years. Trends show higher warming in winter months than in summer months (World Bank 2021).

What are RCPs?

RCP stands for 'Representative Concentration Pathway'. Representative Concentration Pathways (RCPs) are models used to depict the possible outcomes of carbon dioxide emissions and atmospheric concentration reductions in the current century. These pathways are designed based on future predictions of different carbon dioxide emission scenarios that range from best-case to worst-case scenarios, covering various sectors that could be affected by these emissions.

Among many scenarios, this thesis will focus on RCP 4.5 and RCP 8.5. According to the Intergovernmental Panel on Climate Change (IPCC), RCP 4.5 is a moderate scenario in which emissions peak in 2040 and decline afterwards. RCP 8.5 is a scenario that assumes the highest level of baseline greenhouse gas emissions in which emissions are expected to increase continuously throughout the twenty-first century.

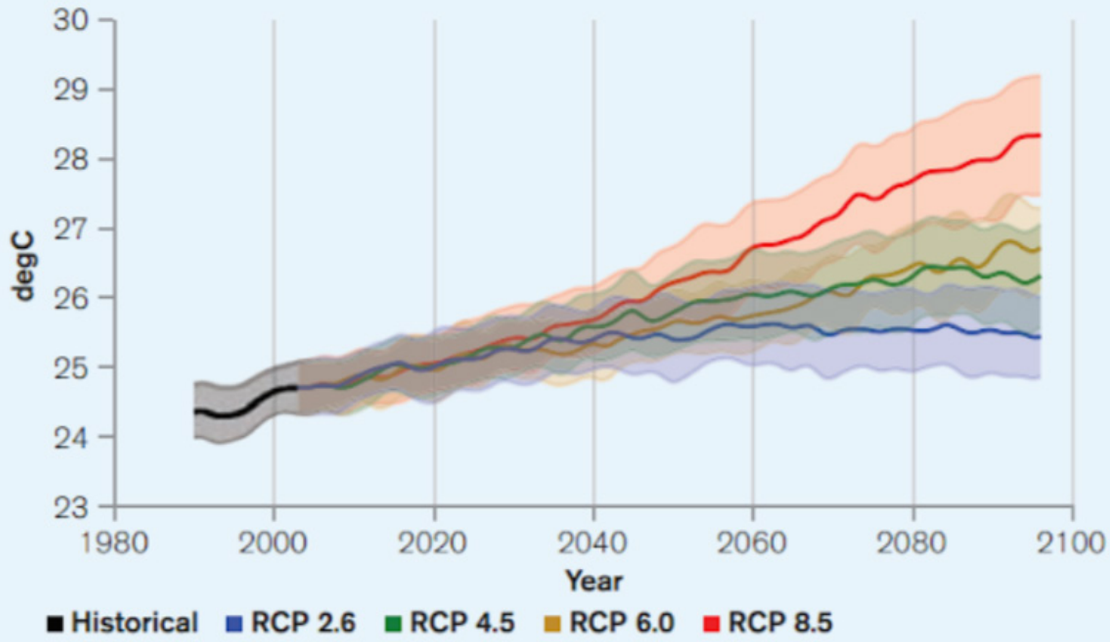
Unfortunately, current estimates suggest that the Earth is currently tracking toward a future that is more consistent with the high emissions RCPs, such as RCP 8.5, rather than the lower emissions scenarios with the assumption of high emissions throughout 21st century.

Ho Chi Minh City

Based on the RCP 8.5 scenario, Ho Chi Minh's citizens already experience a temperature increase from 0.92°C to 0.98°C in comparison to RCP 4.5. By 2050, the temperature will rise from 1.55°C to 1.68°C. By 2100, the temperature will go up from 3.2°C to 3.55C in comparison to 2021 (Le 2022). By 2050 and 2100, the comfort zone in the psychrometric chart will shrink significantly, increasing the people of Ho Chi Minh City's reliance on air conditioning and natural ventilating for enhanced thermal comfort.

Figure: Historic and projected averageanuual temperature in Vietnam under RCP2.6 (blue) and RCP8.5 (red). Source : World Bank

FIGURE 5. Historic and projected average annual temperature in Vietnam under RCP2.6 (blue) and RCP8.5 (red). The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10th–90th percentiles.[14]



Precipitation in Vietnam

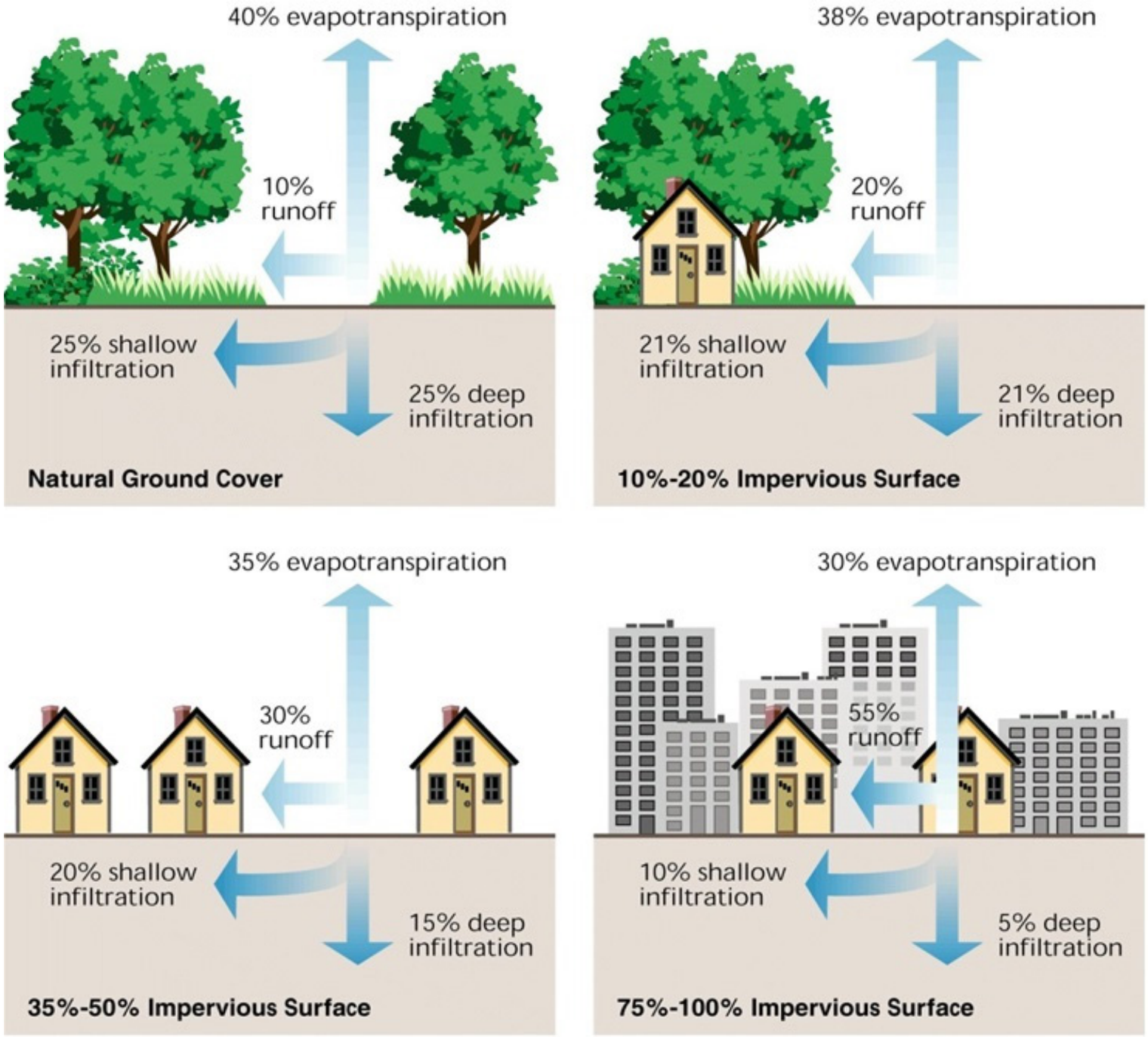
Annual rainfall has not fluctuated much in Vietnam since 1960. However, on a sub-region level, south and north Vietnam receives less rainfall while the central region has higher rainfall trends. El Niño plays an important role in determining the precipitation level in Vietnam (World Bank 2021).

Precipitation in Ho Chi Minh City

In terms of rainfall, the city's average rainfall will go up by 12 to 21% in the RCP 4.5 Scenario and by 12 to 17% in the RCP 8.5 Scenario. By 2050, the average rainfall is projected to increase 13 to 15% in the RCP 4.5 Scenario and 15 to 17% in the RCP 8.5 Scenario. The rainfall increase projection by 2100 ranges from 18 to 22% in RCP 4.5 Scenario and 20 to 21% in RCP 8.5 Scenario (Le 2022).

Since Ho Chi Minh City is mainly a concrete jungle, 55% of the stormwater runoff will flood the city (see Massachusetts Clean Water Toolkit), disrupting businesses, causing water-borne diseases, and stalling traffic. Despite the storm sewer system upgrade under the framework of the Japanese International Cooperation Agency, the pluvial flood continues to rampage the city due to inefficient management of the storm sewage system (Scussolini 2017).

Figure: Urban Runoff. Source: Massachusetts Clean Water Toolkit


40% evapotranspiration
10% runoff
25% shallow infiltration
25% deep infiltration
Natural Ground Cover
38% evapotranspiration
20% runoff
21% shallow infiltration
21% deep infiltration
10%-20% Impervious Surface
35% evapotranspiration
30% runoff
20% shallow infiltration
15% deep infiltration
35%-50% Impervious Surface
30% evapotranspiration
55% runoff
10% shallow infiltration
5% deep infiltration
75%-100% Impervious Surface

Vietnam is one of the most vulnerable regions in the upcoming years due to climate change impacts and sea levels rising. The New York Times reports that most of the low land in southern Vietnam, including Saigon, will be below the high tide line by 2050. Notably, the average floodeddepth will rise from 0.1 meters today to 0.9 meters in the 180 cm sea-level rise scenario. The flooded area will increase from 23% today to 66% in the 180 cm sea-level rise scenario. In other words, the lowland region of Saigon alone will disappear by mid-century, displacing 20 million people (Flavelle, 2019).

The Mekong Delta region of Vietnam will cease to exist by 2050 with the current rate of sea level rise triggered by global warming. The projection is alarming because the Mekong Delta is home to 17 million people, supports a rich biodiversity system, and produces more than half of the country's rice (Espange, 2022). If we can not reverse the sea level rise, the drowning of the Mekong Delta region will be one of the biggest ecological, humanitarian, economic, and food crises in the history of Vietnam and Southeast Asia.

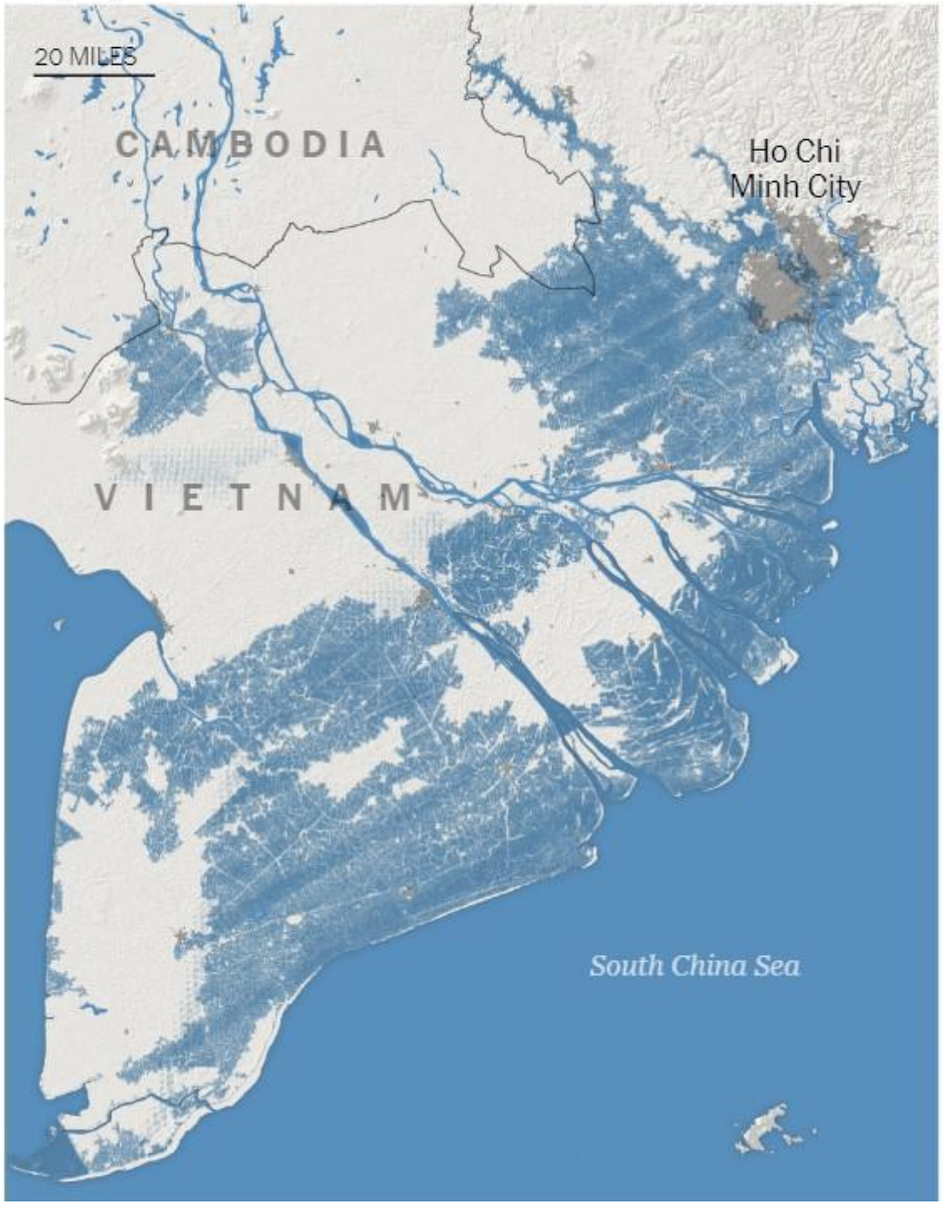
The old projection of the following sea rise map is based on RCP (Representative Concentration Pathway) 2.6 scenario where the Earth will warm up by 0.9°C to 2.3 °C . The current projection is based on the RCP 8.5 scenario where the Earth warms up from 3.2°C to 5.4°C.

RCP 2.6 scenario predicts that the greenhouse gas emissions will peak in the near future and rapidly decline afterward. This scenario is highly dependent on the effectiveness of carbon sequestration policies and the rapid deploymennt of low-carbon technologies. On the other hand, RCP. 8.5 is a "business-as-usual" pathway with greenhouse gas emissions rate incresasing until the end of the century. RCP 8.5 is not inevitable with its dependency on a great carbon emission increase and a lack of effective carbon sequestration measures. However, the Sixth IPCC places the effectiveness of the implemented policies that fall into the RCP 8.5 scenario. Therefore, RCP 8.5 is currently more likely than RCP 2.6.

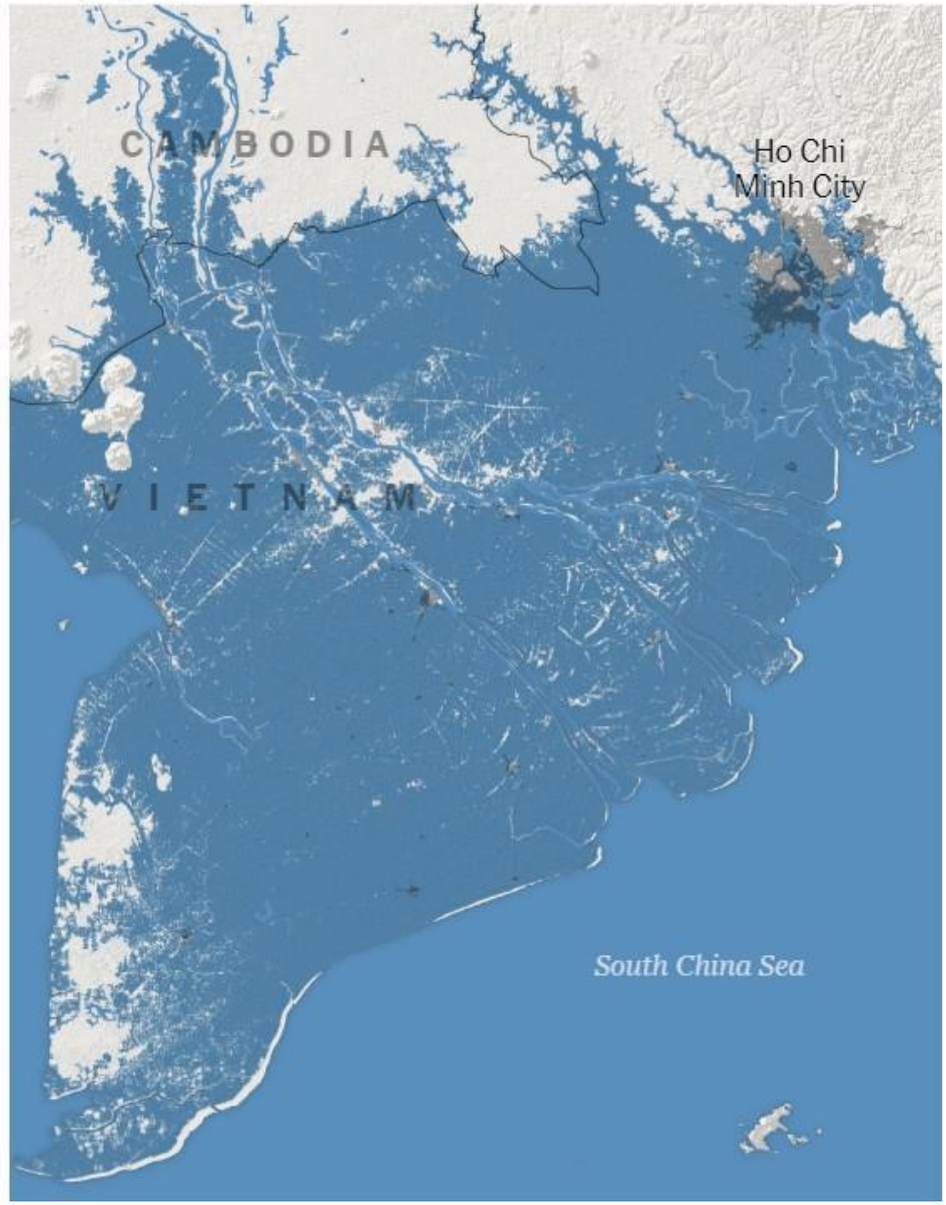
Figure: Stimulation of 2050 sea level rise scenarios in Southern Vietnam. Source: The New York Times

Land underwater at high tide Populated area

Old projection for 2050



New projection for 2050



Ho Chi Minh City is susceptible to flooding. Forty to Forty-five percent of the city stands less than a meter above sea level. The combination of low altitude, an overwhelmed drainage valve system, heavy rainfall, the discharge from upstream reservoirs, extensive groundwater extraction, and storm surges overlapping with high tides exacerbates the city's flooding. Record high tides that go up to 1.77 metres become more frequent because the tide-draining swamps have been covered for new development projects.

A paper by Kulp and Strauss calculates the 1m to 2m sea level rise will place a large part of the city underwater without flooding occurrences. The city will suffer from $7.8 billion in infrastructure damage and $18 billion real estate costs. The ripple effect of the city's shutdown will cost Vietnam $45 billion, which is a fifth of the country's GDP (Kulp & Strauss).

Unlike the temporary flooding effects of the wet season in Ho Chi Minh City, the changes brought by sea level rise are permanent. Seven million of the city's residents, which makes up 78% of the population, will lose their homes forever. In addition to the displacement of 7.8 million people, sea level rise can put human health at risk through water-borne illnesses resulting from the contamination of freshwater sources. Some of these water-borne illnesses include cholera, typhoid fever, and dysentery A (National Institute of Health). Increased flooding will create stagnant puddles that provide breeding grounds for mosquitoes that can further spread Zika, dengue fever, and malaria.

As Ho Chi Minh City is home to many historical buildings in the lowlands, the city will struggle to maintain and preserve these built environments during sea level surges. The destruction or damage of these beloved buildings results in the loss of architectural identity for the city and its people. Furthermore, the citizens also practice many traditions at cultural sites tied to the lowlands, such as the Ben Duoc Temple in the Cu Chi District. Displaced communities will also lose their existing social networks and cultural celebrations established for generations at specific sites.

To mitigate the effects of sea level rise, Ho Chi Minh City plans to construct sea walls, upgrade drainage systems, and create green infrastructure such as parks or wetlands. In order to protect the population's health, the city should also upgrade its water management and sanitation infrastructure. As for the cultural impacts, Saigon can work with local communities to develop adaptation strategies that preserve cultural heritage and traditions. These practices can range from protecting cultural and historical sites to maintaining closely-knit communities in times of relocation to protect regional identity. However, currently, the city has not made any relocation plans for the people in response to the RCP 8.5 Scenario of a 180 cm flood in 2100.

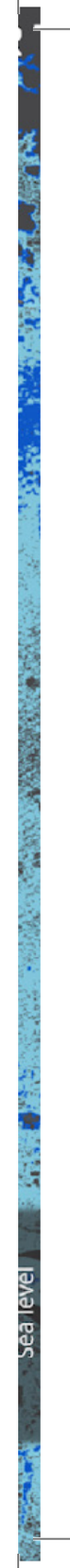
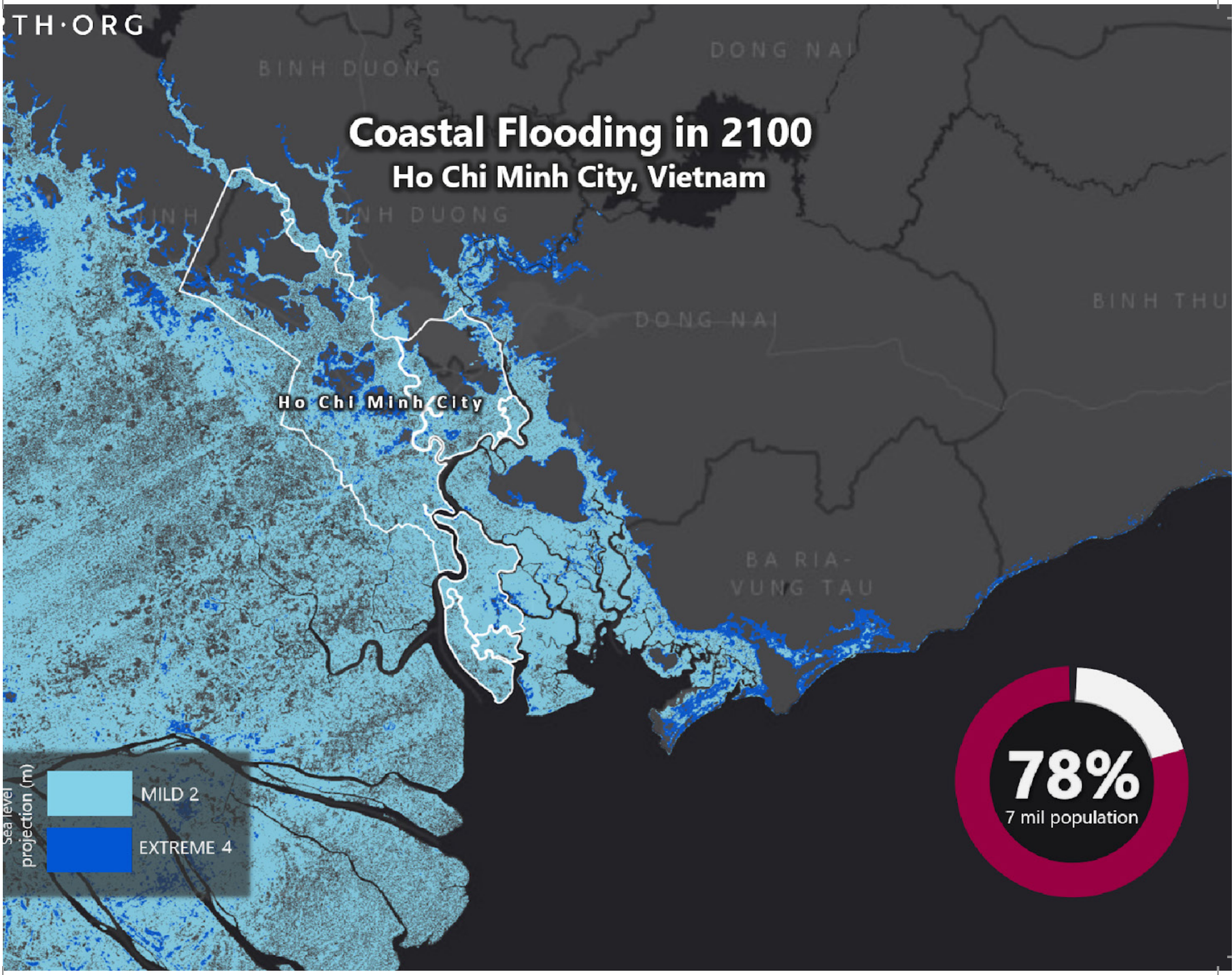


Figure: Coastal Flooding in 2100, Ho Chi Minh City. Source: Earth.org


TH·ORG
BINH DUONG
DONG NAI
Coastal Flooding in 2100
Ho Chi Minh City, Vietnam
INH DUONG
DONG NAI
BINH THU
Ho Chi Minh City
BA RIA-
VUNG TAU
Sea level projection (m)
MILD 2
EXTREME 4
78%
7 mil population

On top of the devastating impact of sea level rise, Ho Chi Minh City is also sinking. A group of international scientists from Nanyang Technological University in Singapore conducted a study based on satellite images and concluded that the Southeast Asian region is sinking at a faster rate than the rest of the world. Ho Chi Minh City also shares the same sinking crisis as the city is currently sinking at the rate of 16.2 mm/year. The cause behind the land subsidence lies in excessive groundwater extraction (Tran 2022).

Another study conducted by the Japan International Cooperation Agency (JICA) reports that Ho Chi Minh City has been sinking at an annual rate of 2 to 5 cm every year since 1990. Thu Duc City is among the most affected area. Aside from groundwater extraction, clusters of skyscrapers, such as Landmark 81, are speeding up the sinking process. Therefore, in the long run, it is not sustainable to provide housing by building vertically. The city should not support more skyscraper cluster developments and should instead expand to the neighboring areas (Anh 2022).

As a result of the sinking of the city, many streets collapsed and created dangerous, deadly potholes. Plus, many buildings are sitting on top of unstable ground that can cave in at any time.

Figure: Street Collapse in Ho Chi Minh City. Source: TTXVN


PHONG VŨ
SỮA CHỮA TỐT

Ho Chi Minh City is a moderately polluted city in Southeast Asia. In the 2017 to 2018 period, the PM2.5 level went up from 23.6 to 26.9 micrograms per cubic meter (μg/m³), which more than doubled the acceptable level proposed by WHO (United States Embassy in Vietnam).

The air quality is dynamic throughout the year as it worsens during dry season, starting from November to January. The absence of rain allows fine particulates to linger and build up in the air. Therefore, you often find people wearing masks around Ho Chi Minh City to avoid respiratory issues.

The causes of air pollution are the overburdened transportation system with millions of cars and motorbikes causing traffic on a daily basis. The majority of Saigonese relies on personal vehicles as the public transporation relies mainly on an overburdened bus system and an incoming metro that won't operate until 2024. Furthermore, the buildings in construction and demolition projects further pollute the air with dust.

Saigon General Hospital recorded a 5 to 10 percent rise in respiratory cases in September 2019. These cases have higher levels of PM2.5 particulates which establish a connection between air pollution and public health. In 2016, air pollution accounts for 60,000 deaths.

What is PM?

PM is an abbreviation for Particulate Matter, which is a mixture of solid particles and liquid droplets in the air. The sizes of PM vary from nanometer-sized particles to visible ones. PM level stands for the concentration of these particles in the air. The size of particles determine the health impact. Particles with diameter of 2.5 micrometers or less (PM 2.5) can penetrate deep into the lungs and bloodstream, causing respiratory and cardiovascular diseases. Particles with diameter of 10 micrometers or less cause less harm since our nose and throat can filter these out (EPA).

Figure: Smog in Ho Chi Minh City. Source: VnExpress International

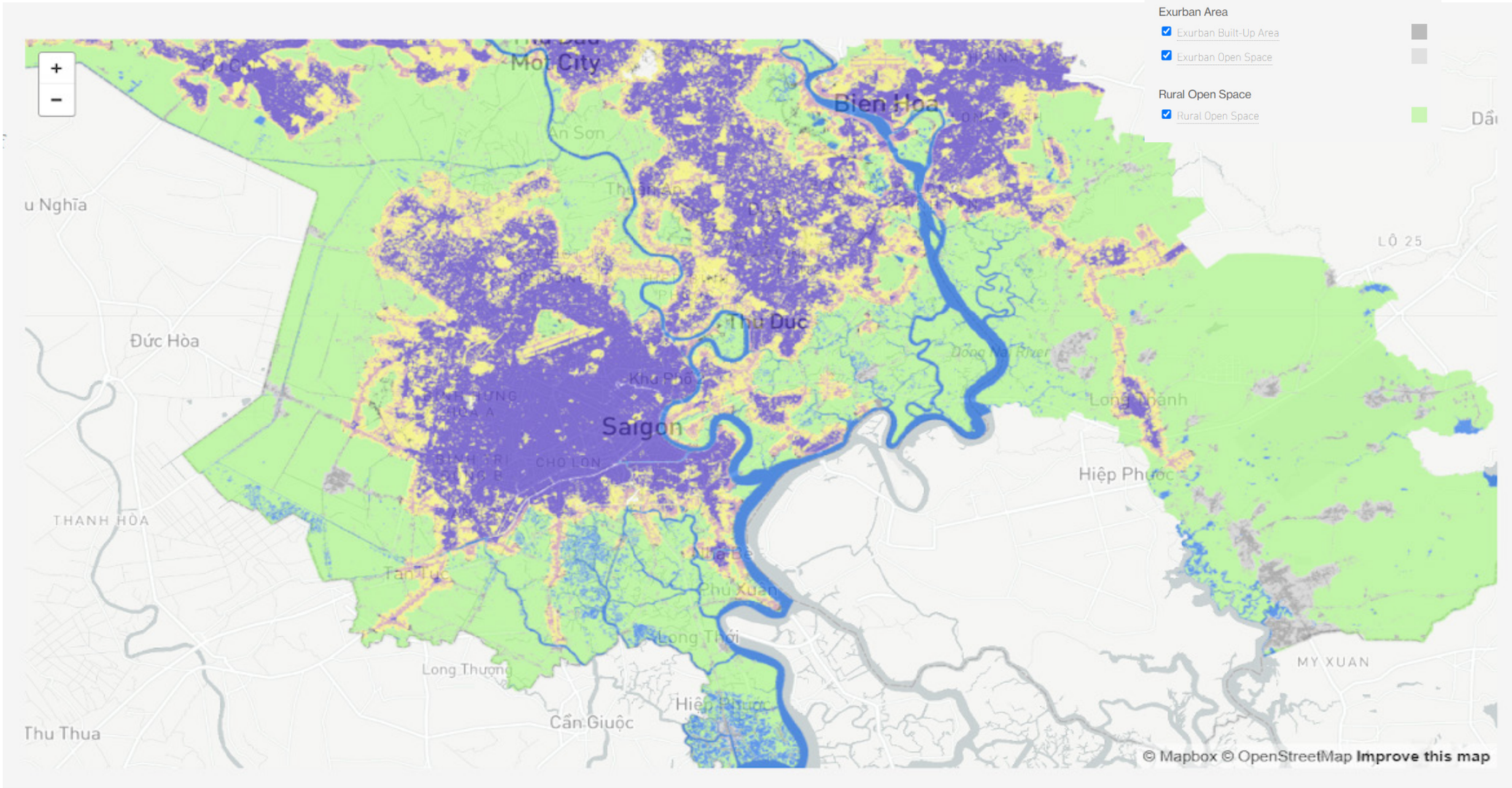

Keppel
MERIDIEN

Housing inequity in Ho Chi Minh City is a pressing issue. Despite leading the country in the highest salary at the minimum annual average of $5472, most people won't be able to afford the average-priced apartments that cost up to $149,059, which equates to 27 years of their annual income. Compared to the neighboring metropolitan regions, in Ho Chi Minh City it takes a family 7 years longer than in Bangkok and 10 years longer than in Malaysia to be able to buy their home. The median house price to income ratio in Vietnam comes in second only to Singapore. However, with the current housing prices increasing, Vietnam will soon surpass Singapore in the median house price-to-income ratio.

Houses and villas in Thu Duc City now go up from $12,932 to $17,200 per square meter. To put into perspective, a middle-class net zero house in the United States cost about $3230 per square meter to build. According to Huynh Tuan Kiet, the director of housing project marketing at CBRE Vietnam, affordable and mid-end apartments are rare and only can be found in the suburban areas. Housing prices are highly inflated, which furthers the class division and exacerbates the financial stress the average-income household faces.

As depicted in the map, urban density in Saigon is heavily concentrated in the central district, driving the city's vertical expansion through numerous high-rise projects. However, the city should also pursue sensible horizontal expansion into suburban districts, taking into account the potential effects of sea-level rise, sinking soil, and gentrification in those areas.

Figure: Urban Built-up concentration in Ho Chi Minh City. Credit to:Atlas of Urban Expansion


Urban Extent
Urban Built-up
Suburban Built-up
Rural Built-up
Urbanized Open Space
Exurban Area
Exurban Built-Up Area
Exurban Open Space
Rural Open Space
Rural Open Space
Mới City
Biên Hòa
Thủ Đức
Đức Hòa
Saigon
Hiệp Phước
LỘ 25
THANH HÓA
Long Thượng
Cần Giuộc
Thu Thua
MY XUAN
© Mapbox © OpenStreetMap Improve this map

Median House Price to Income Ratio Table

Countries	Median House Price to Income Ratio
Vietnam	20.85
Thailand	14.88
Malaysia	8.89
Singapore	22.54
Developed Countries	5.1
Developing Countries	3.6

Figure: Median House Price to Income Ratio Bar Chart. Credit: Multiple Sources

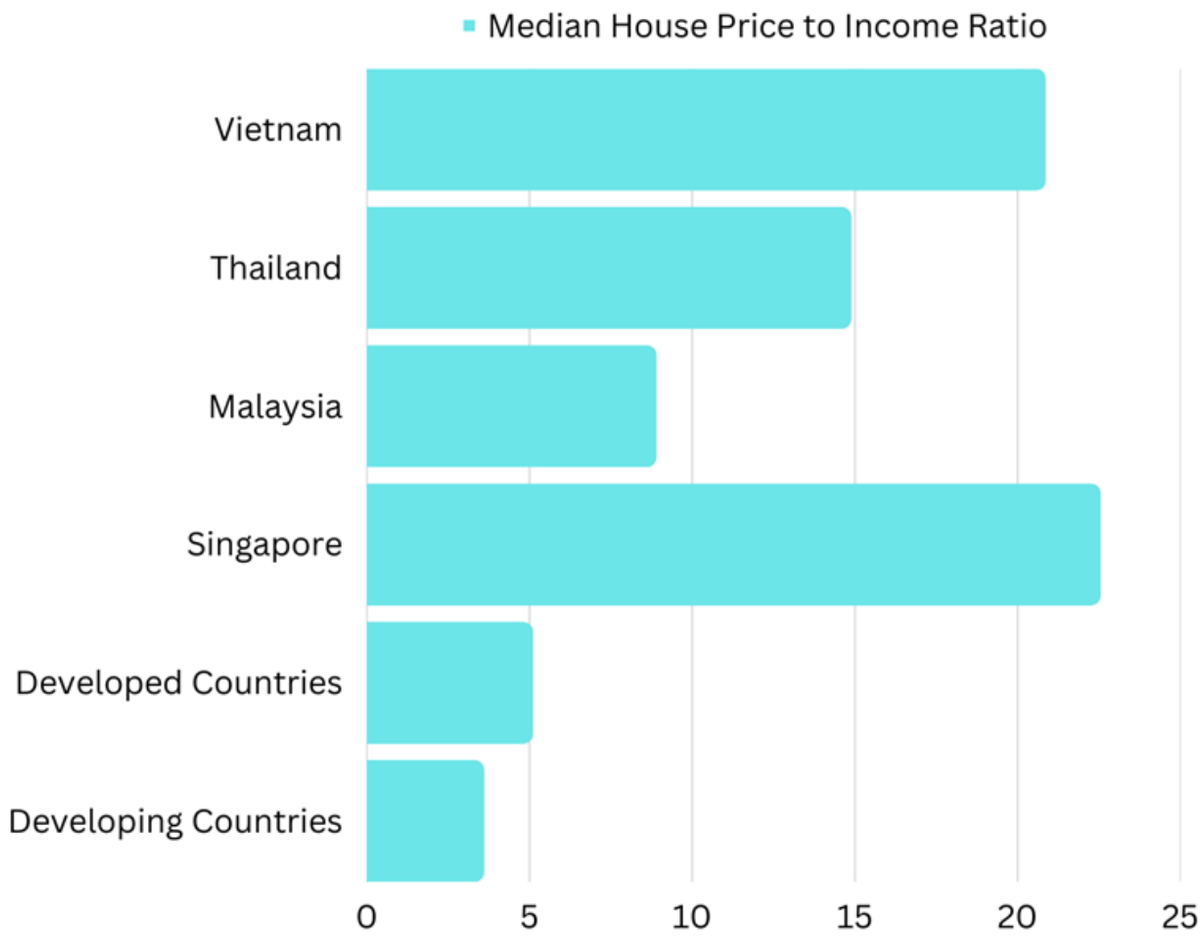

Median House Price to Income Ratio
Vietnam
Thailand
Malaysia
Singapore
Developed Countries
Developing Countries
0
5
10
15
20
25

Figure : A wind farm in Vietnam. Credit to: Vietnam Insider

NET ZERO CHAPTER

This Chapter will explore the inequity of Carbon Impacts, Vietnam's commitment to Net Zero, and Net Zero Design Strategies

Although Vietnam ranks 29th in global carbon emissions, the country suffers significantly more from the impacts of climate change in comparison to the top-emitting countries. Among those countries, China, the United States, India, Russia, and Japan are the top five carbon emitters, contributing to 56% of global carbon emissions (Worldometer). Developed countries are responsible for the majority of carbon emissions as the by-product of their unrestricted and unchecked capitalist pursuit. Therefore, this raises the question of inequity and unequal distribution of climate change impacts among developing and developed countries. Developed countries should be held accountable for their carbon emissions impact on climate change and the spillover impacts on countries like Vietnam.

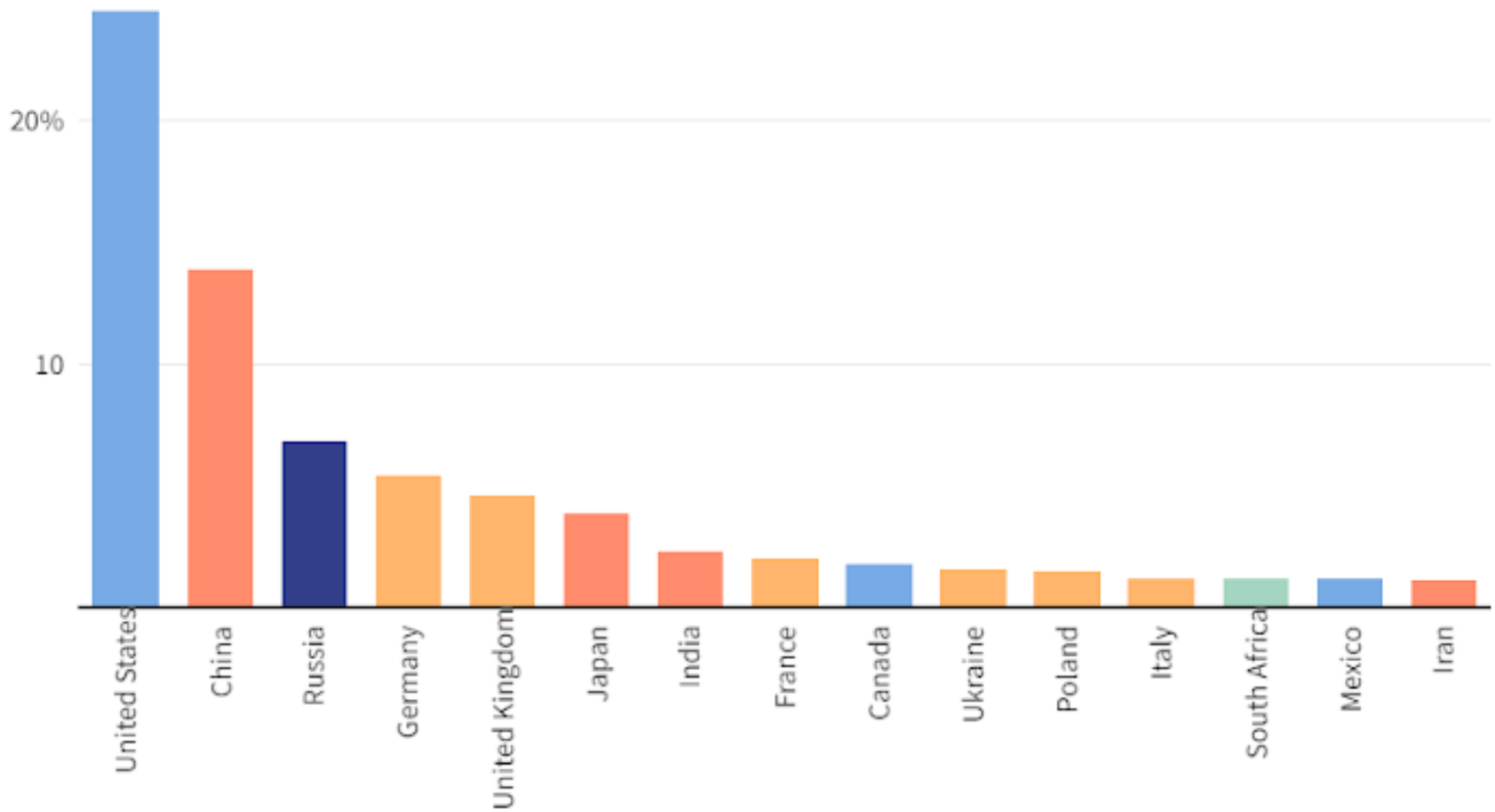
At COP27 in Egypt, discussions regarding climate accountability led to the establishment of "loss and damage funding" for countries that take the biggest climate disaster hits (United Nations Climate Change). This is a significant development towards giving equity to low-income and mid-income countries that suffer from the consequences of first-world nations' massive energy consumption and carbon-emitting activities. However, the 'loss and damage funding' only amounts to USD 230 million. This is not enough to compensate for the economic, social, and people losses due to climate change disasters that have lasted for decades. Top emitting countries such as the United States should step up and take responsibility for the irreversible damages suffered by the developing countries by holding the top carbon emitters, mainly the oil companies, in their countries accountable through carbon tax, carbon permits, or compensation for the environmental damages with their profits.

Vietnam should consider more sustainable development in the economy that focuses not only on economic growth but also on the equal distribution of wealth among the people. As the fastest-developing economy in South East Asia, Vietnam has the potential to change its development route from early on and incorporate a circular economy model that does not sacrifice human and environmental health (Strangio 2022). Furthermore, the sustainable route will also allow the development of preparation and strategies against climate change impacts.

Figure : Top CO2 Emitting Countries from 1750 to 2020. Credit to: Investopedia

Top CO2 Emitting Countries, 1750–2020

Percentage of total (1.7 trillion tons).



Like many capitalist countries, Vietnam's current dominant economic model is based on a linear economy, which translates to the "take-make-dispose" model. In a linear economy, the use of collected raw materials is optimized during the production process, which results in the disposal of unusable resources. Many of the unused materials end up in landfills or water streams, contaminating the local environment further. The unutilized waste that has upcycling and reusing potential in other production processes also exacerbates the scarcity of raw materials. An estimation shows 85% of waste in Vietnam ended up in landfills.

Recognizing the unsustainable linear economic model, the Vietnamese government initiated a shift towards a circular economy that circles around the "make-use-recycle" model. This model allows waste reduction, and lowers resource extraction through recycling, reducing, and reusing.

The Vietnamese government shows its commitment in tackling sustainable development and climate change at the Conference of the Parties (COP26) by declaring net-zero carbon emissions by 2050 goal. To further demonstrate the commitment, Le Minh Khai, the Deputy Prime Minister, authorized Decision 687 which passed the national development plan for a circular economy.

Decision 687 targets sequestering greenhouse gas emissions per GDP by at least 15 percent compared to 2014 levels.

By 2025, this model is expected to "recover renewable energy, reduce energy consumption, and increase the rate of renewable energy, rate of forest coverage and waste recycling" (Nguyen 2022).

By 2030, the model should increase the rate of urban solid waste collection and treatment to 50 percent with 100 percent of recycled organic waste in urban areas and 70 percent of recycled organic waste in rural areas.

In between COP26 and COP 27, Vietnam passed Decree 06 which defines Vietnam's net zero commitment by detailing each ministry's carbon reduction target. The government initiated the development of a carbon market and delivered clear guidelines for energy market development planning (Barnes 2022).

Figure : Table of Vietnam's Greenhouse Gas Reduction Targets by Ministry by 2030. Credit to: Vietnam Briefing

Ministry	Field	CO2 million tons
Ministry of Industry and Trade	• Energy production • Energy consumption in industry	268.5
The Ministry of Transportation	• Energy consumption in transportation	37.5
Ministry of Agriculture and Rural Development	• Energy consumption in agriculture • Agricultural production • Forestry	129.8
Ministry of Construction	• Industrial processes • Energy consumption in cement production • Building	74.3
Ministry of Natural Resources and Environment	• Waste treatment	53.7
Total by 2030		**563.8**

Terminology

Net Zero Building

A Net Zero energy building is a building that produces as much energy as it consumes on an annual basis. These buildings can implement energy-efficient design, on-site renewable energy generation, and energy storage technologies to attain net zero.

Net Zero buildings can still connect to the electric grid, utilizing electricity from traditional sources as backup power when on-site energy generation cannot meet the building's energy demand.

Embodied Carbon and Operational Carbon

Embodied Carbon and Operational Carbon both play an essential role in reaching carbon-neutral architecture. However, they are different in the building's lifecycle stages.

Embodied Carbon is the carbon emissions released during building construction, including extracting, transporting, and manufacturing materials. Built environments that attain net zero embodied carbon utilize low-embodied carbon materials, minimize waste, and optimize the construction process.

Operational carbon is the carbon emitted when a building is in use on a daily basis. The operational carbon can come from heating, cooling, lighting, powering the building's systems and appliances. The net zero operational carbon projects usually have energy-efficient technologies, renewable energy utilization, and site (solar, wind, etc) optimization.

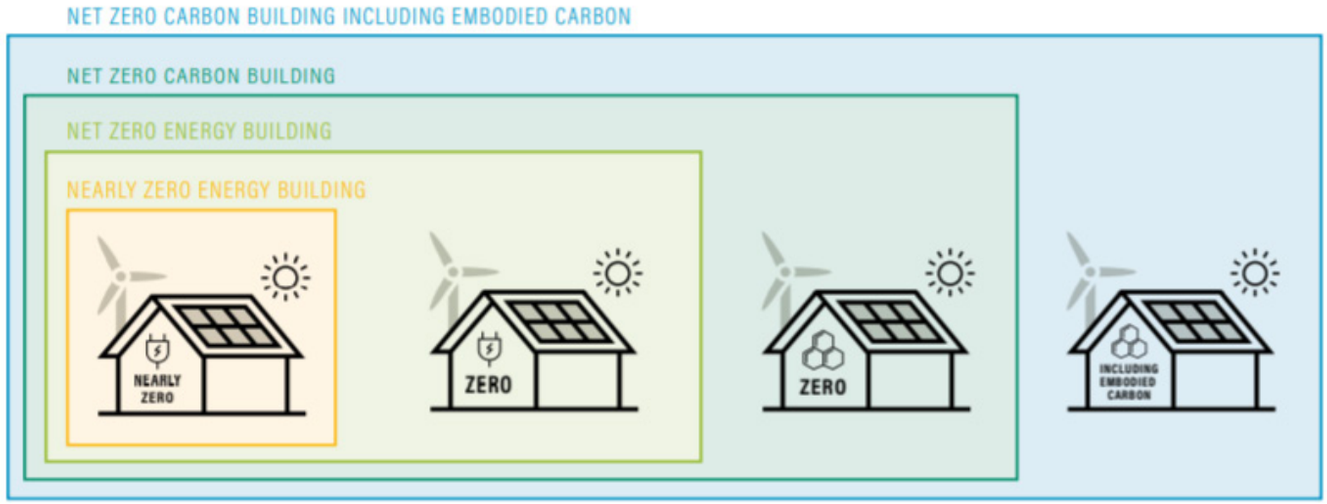
Net Zero Carbon Building

Net Zero Carbon Buildings refers to buildings that produces net zero carbon emissions on an annual basis.

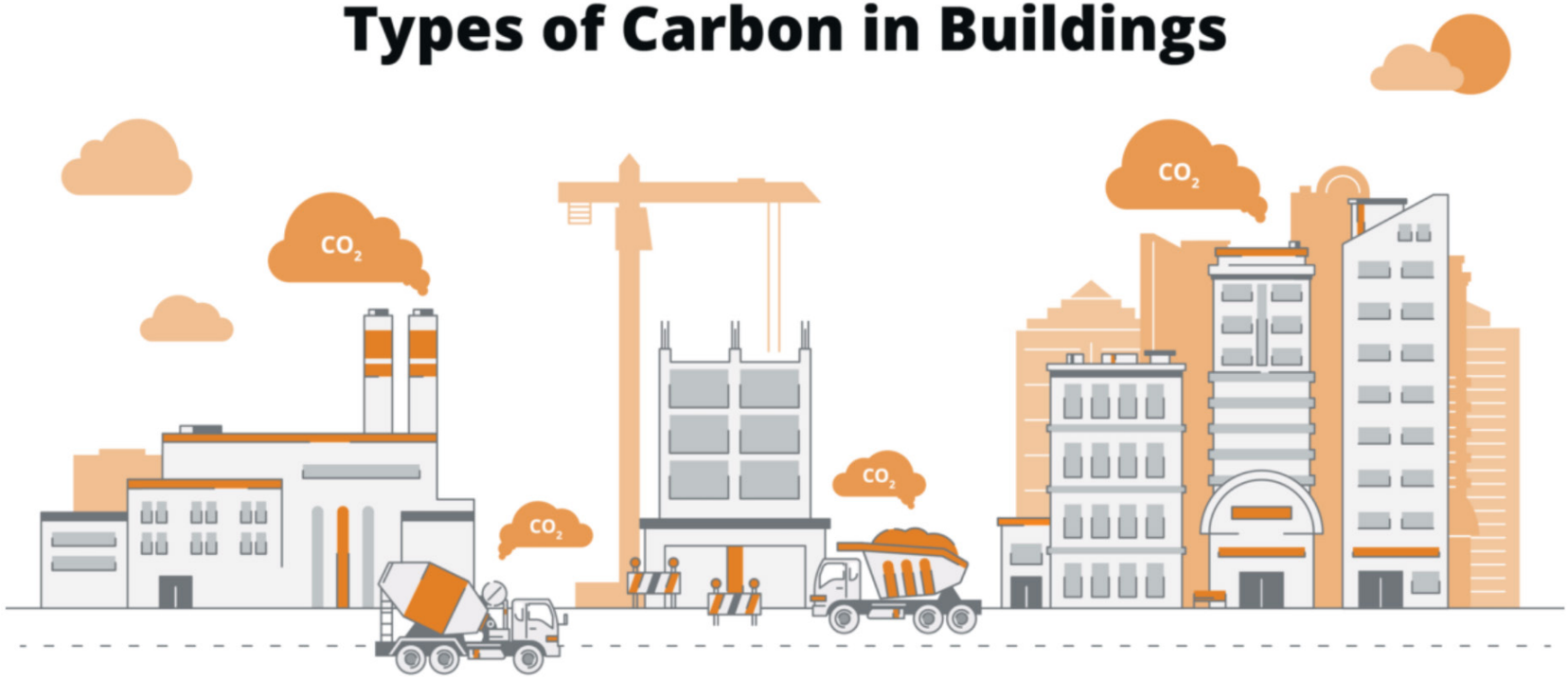
Near Net Zero Building

In comparison to Net Zero Building, near net zero building still relies on some non-renewable energy sources to meet its energy demand, but the grid reliance is less than traditional buildings.

Figure (Upper) : The Different Levels of Net Zero Building. Credit to: GRESB
Figure (Lower) : Types of Carbon in Building. Credit to: CarbonCure



Types of Carbon in Buildings



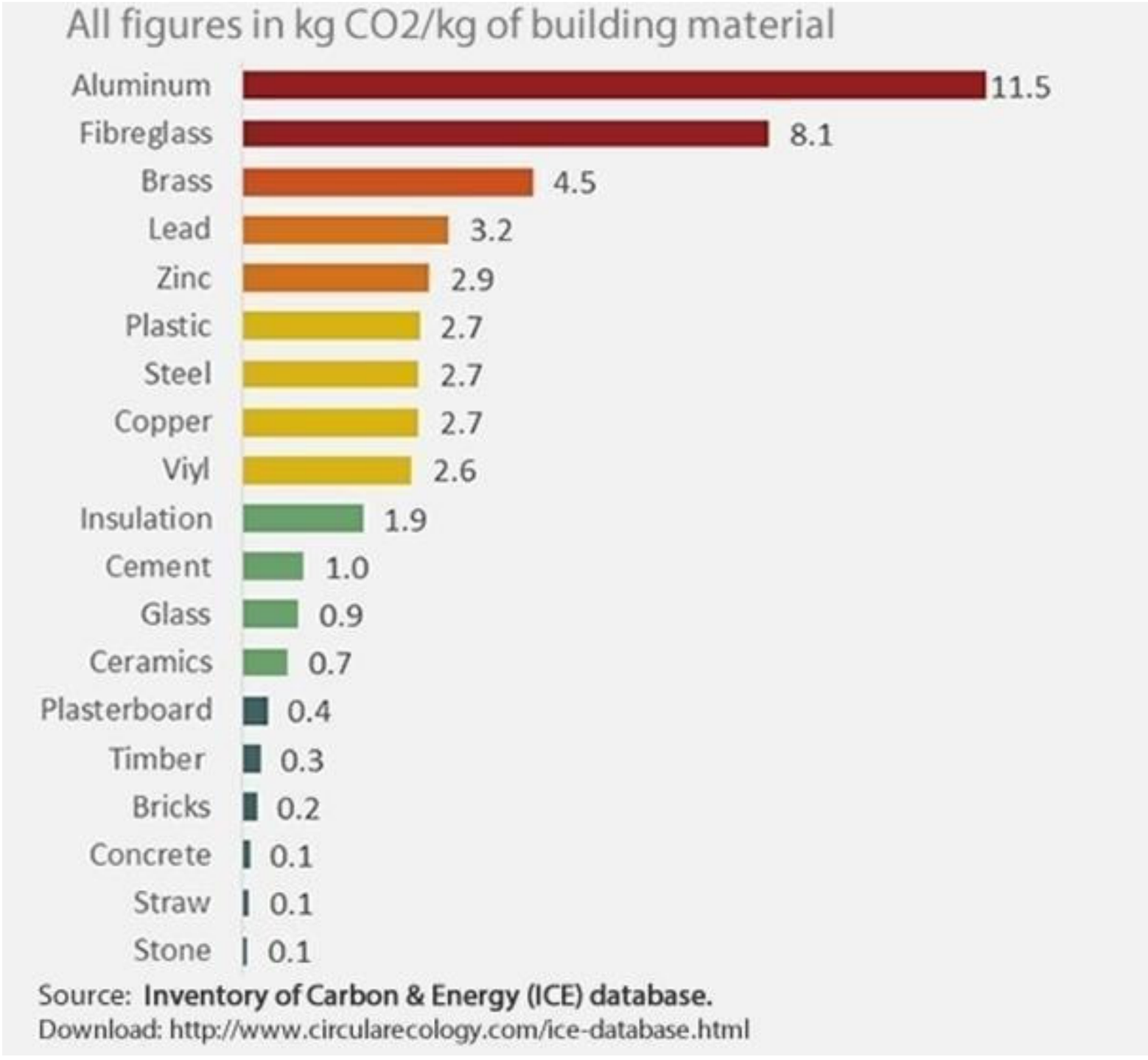
Embodied Carbon
The emissions from manufacturing, transportation, and installation of building materials.

Operational Carbon
The emissions from a building's energy consumption.

Thirty-nine percent of global carbon emissions stem from the built environment and construction activities. The carbon emissions stem from two sources: (1) operational carbon (28%) and (2) embodied carbon (11%). In operational carbon, humans emit carbon dioxide into the atmosphere through heating, lighting, and cooling activities with fossil fuel, coal-based energy. Embodied carbon is the carbon produced through the acquisition, production, transportation, construction, maintenance, and end-of-life of the building materials (Raitzer 2015).

Cement and steel are the two building materials with the highest embodied carbon due to their used quantities and carbon-intensive production processes. Currently, cement is responsible for 65% of all carbon emissions. Therefore, there is a recent movement towards low embodied carbon natural materials such as bamboo, timber, and straw (Moncaster 2021). There is also a movement towards lower embodied carbon versions of high embodied energy materials, such as fly ash concrete made out of coal power plant waste or carbon-negative concrete made out of biochar (charcoal made from organic waste) (Li 2023) .

Figure: Embodied Carbon of Building Materials. Credit to: Inventory of Carbon & Energy (ICE) Database


All figures in kg CO2/kg of building material
Aluminum 11.5
Fibreglass 8.1
Brass 4.5
Lead 3.2
Zinc 2.9
Plastic 2.7
Steel 2.7
Copper 2.7
Viyl 2.6
Insulation 1.9
Cement 1.0
Glass 0.9
Ceramics 0.7
Plasterboard 0.4
Timber 0.3
Bricks 0.2
Concrete 0.1
Straw 0.1
Stone 0.1
Source: Inventory of Carbon & Energy (ICE) database.
Download: http://www.circularecology.com/ice-database.html

The Net Zero Strategies List provides a guide to design and build a Net Zero Building. Collectively, the implementation of these strategies will improve energy efficiency, reduce energy consumption, and create a healthier living environment for the residents.

Net Zero Stratergies List

Orientation
Orients the building to the direction that optimizes natural lighting and ventilation

Passive Design
Utilizes natural resources such as sunlight, natural ventilation, and shading

Renewable Energy
Generate on-site energy with renewable sources, including solar panels, wind turbines, and geothermal systems

Electrification of Appliances
Shifts away from fossil fuels with the electrification of appliances that powers on renewable energy

Water Conservation
Reduces energy consumption through rainwater harvesting

Minimizes water consumption through utilizing low-flow fixtures, which saves energy in the pumping and water treating process

Energy Storage
Stores surplus energy created by on-site renewable energy generation for energy hikes

Efficient HVAC Systems
Employs efficient HVAC systems that cut down on energy consumption and carbon emissions

Efficient Lighting
Installs efficient lighting systems such as LEDs

Low Embodied Energy Materials
Chooses low embodied energy materials to cut down the overall energy consumption of the building over its lifetime

Insulation
Insulates the walls, ceiling, and roof to reduce energy consumption and provide energy efficiency to the building

Hot Water
Selects a highly-efficient hot water system that utilizes renewable energy sources, such as solar

Figure: Net Zero Building Diagram. Credit to: Mead & Hunt

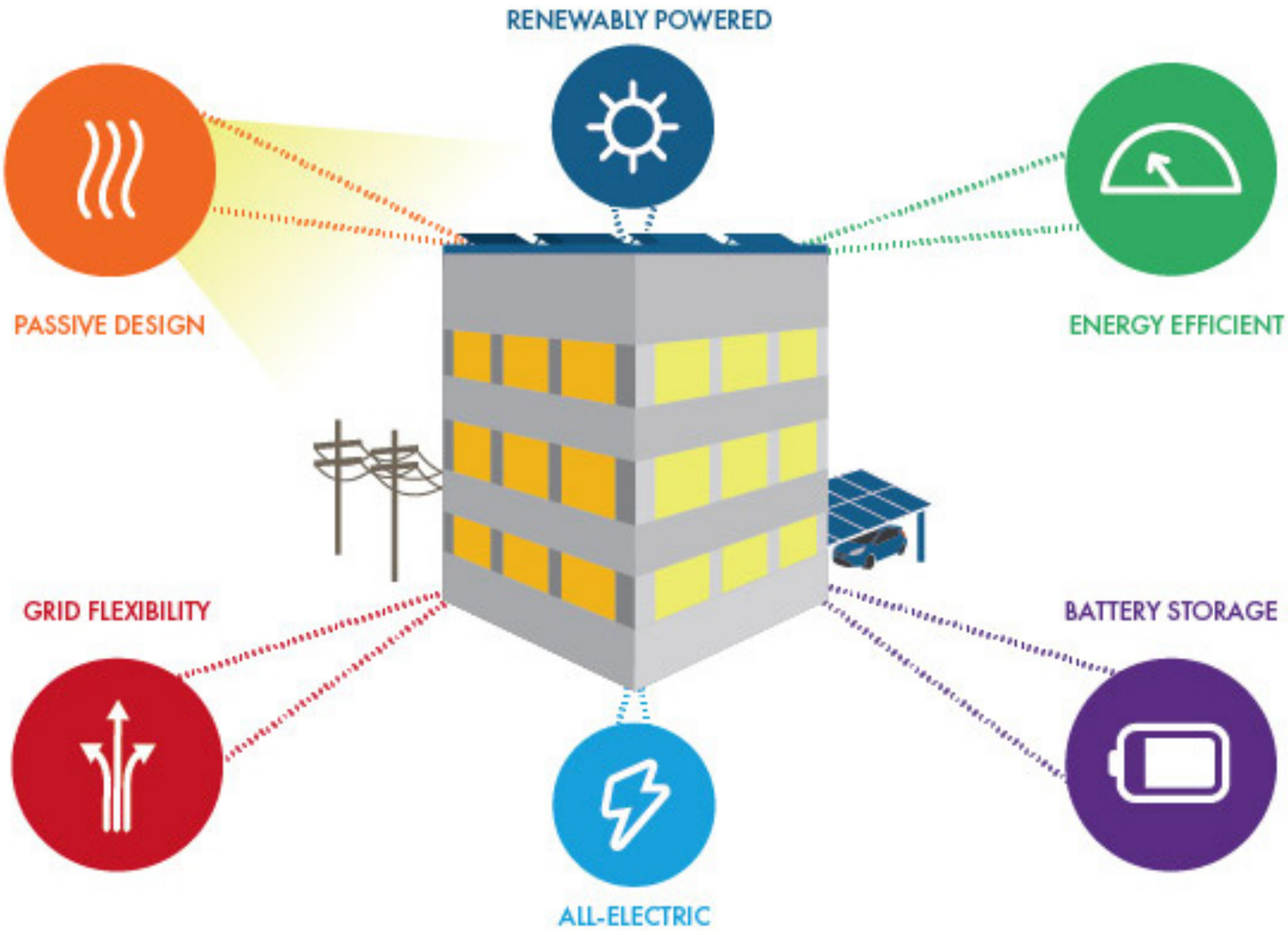

RENEWABLY POWERED
PASSIVE DESIGN
ENERGY EFFICIENT
GRID FLEXIBILITY
BATTERY STORAGE
ALL-ELECTRIC

Figure: Vietnamese Modernist Architecture. Credit: Architecture Vietnam

VERNACULAR ARCHITECTURE

This section will focus on the history of Vietnamese and Ho Chi Minh City Vernacular Architecture, the passive strategies, and the case studies

Before any foreign influences, traditional architecture in Vietnam was mainly stilt houses built from wood and bamboo, which are low embodied materials. After becoming a colony of China, Vietnamese architecture carried the influences of Chinese architecture and Buddhist architecture. The building materials shifted from wood and bamboo to more durable stone and brick. Palaces, mansions, and temples were ornamented with intricate designs of leaves, phoenixes, and dragons to display the status and importance of the owners. Houses typically followed the U-shape organization with 3 blocks that created a partially enclosed garden and work area.

Northern, Central, and Southern Vietnamese share many similarities with their wooden post and lintel systems, sloping roofs, and classic materials such as bricks, wood, and thatch. One difference that can be found is the thickness of the walls. Due to the temperate climate pattern of Northern Vietnam, their walls are thicker to provide better insulation.

In the past, a common building type in each village was a community house that had a courtyard for the village's worshipping and cultural celebrations. These courtyards typically had a water feature and a rectangular-shaped floor plan. The water feature represented the sky, while the rectangle-shaped floor plan represented the Earth (Le 2020).

Figure: Traditional Architecture in Vietnam. Credit to: Eviva Tour

Prior to the French occupation of Saigon, the Chinese migrants from Southeastern China, including the Cantonese, the Teochew, the Hakka, the Hainanese, and the Hokkien, brought traditional Chinese Architecture with them as they settled in the Cho Lon area. Socialization is key to the Chinese community, so they constructed guild houses to connect with their fellow people. Thus, vividly colored and well-adorned Chinese-Buddhist Temples serve as worshipping places. Most of these have open courtyards.

As French Indochina's capital for six decades, Saigon is the cultural and trading hub designed by the French to compete with Hong Kong and Singapore - their British counterparts. Building projects at grand scales ranging from ports, banks, palaces, and churches are the architectural representation of French power on the regional and international stage. Furthermore, the city constructed numerous cafes, restaurants, amusement facilities, and hotels for French officials and military men. Like many colonial territories of imperial powers, Saigon carries the image of French cities and its most architectural phases are seen in the most widely-recognizable buildings (Cooper 2000).

- Saigon Notre Dame Cathedral with the mixture of Neo-Roman and Gothic architectural styles
- City Hall models after Hotel de Ville with the Renaissance Revival
- Ho Chi Minh City Museum of Fine Arts with the Art Deco style
- Ho Chi Minh City State Bank of Vietnam with the Modernist

After an extensive period of French-influenced architecture, the Vietnamese Modernist movement became popular after the unification of the North and the South. The Vietnamese architects developed a local architectural style that responded to the tropical climatic conditions of Saigon. The elaborate brise soleil of the buildings double as a solar screen and a decorative, regionally inspired facade. Independence Palace designed by Ngo Viet Thu, the first Vietnamese Grand Prix de Rome winner, is the most iconic Vietnamese Modernism building in Saigon with intricately desgined brise soleil.

In the 21st century, contemporary buildings with their clean lines and sleek form dominate the skyline. A race for height began with the lotus bulb-inspired Bitexco Tower reaching 262 meters high and followed by Landmark 81 measuring up to 461 meters high.

In response to the ubiquitous International style, many Vietnamese architectural firms embrace vernacular architecture and define the Vietnamese Modern Vernacular movement through their wealth of projects that highlight local materials, construction methods, and cultural practices.

Figure (top left): Saigon Notre Dame. Credit to: Vietnam Discovery Travel
Figure (top right): City Hall. Credit to: Saigoneer
Figure (bottom left): Museum of Fine Arts. Credit to: Silver Kris
Figure (bottom right): State Bank of Vietnam. Credit to: Saigoneer


1419. COC
Cathédrale


THIEN TUNG HOTEL

Figure: Independence Palace. Credit to: VietnamOnline

Figure: Chuon Chuon Kim 2 Kindergarten Credit to: KIENTRUC O

In response to the tropical climate and rainy season, traditional housings have these following characteristics:

Roof
- Sloping roof diverts direct sunlight absorption, which cools down the interior temperature
- The sloping roof also allows rain to flow off the roof
- Deep overhang roof protects the house from rain and sun, especially in summer months

Courtyard
- Courtyards allow for ventilation, which brings in fresh air
- Some vernacular courtyards have ponds that can provide cooling through evaporation.

Chimney Effect
- Chimney effect (Stack Effect) allows hot air to rise and cold air to enter and replace it
- Traditional buildings in Vietnam have high roofs that allow the hot air to rise
- Other natural ventilation effects include single sided ventilation and cross ventilation

Low-Embodied Carbon Materials
- Vernacular architecture utilizes locally sourced, low-embodied carbon materials such as timber, bamboo, straw, stone, bricks, etc.

Building Orientation
- Vernacular houses mainly face south with narrow facades on the East and West sides to avoid extreme heat, resulting in a long rectangular shape
- Facing south will also helps the housing avoid North East winds

Stilt Houses
- Stilt houses enables air to circulate under the house
- The height offers protection from wild animals and other dangerous factors
- Stilt houses are flood-resilient

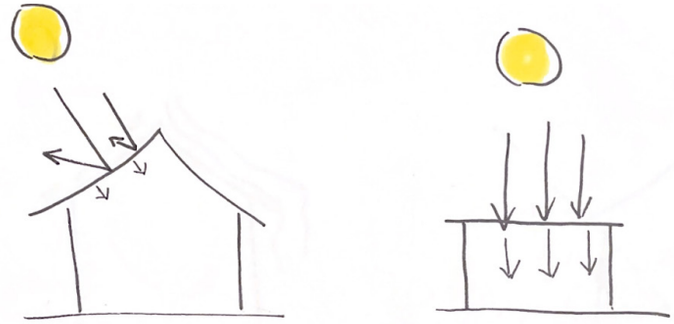
Deep Porches
- Deep porches offer shade and block the living space from the direct sunlight

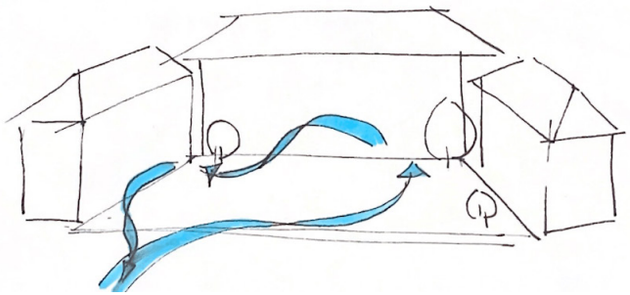
Small Windows
- Small windows limit the amount of sunlight/heat that enters the house

Screen or Brise Soleil
- Functions as a solar control device and allows privacy

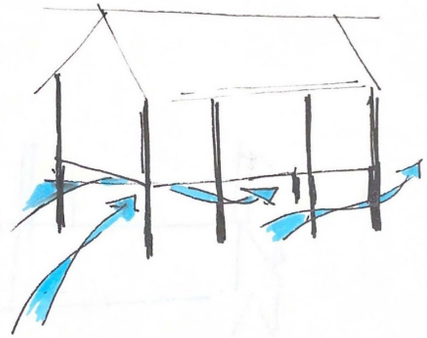
Louvers
- Acts as rain and sun control devices

Roof

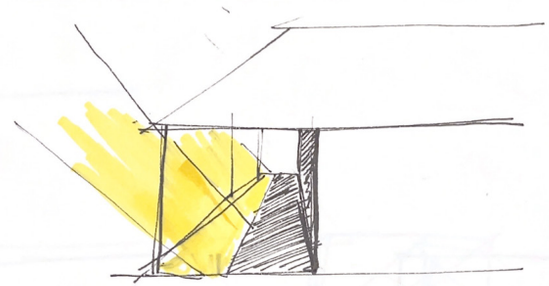




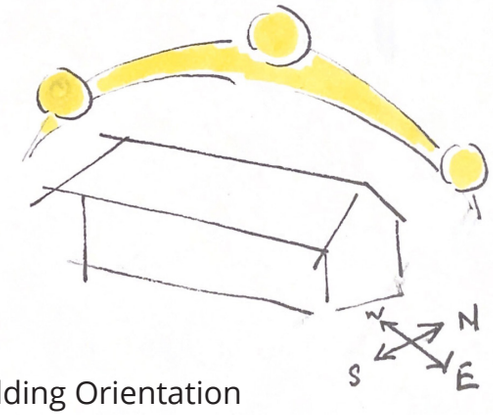
Courtyard



Stilt Houses



Deep Porch



Building Orientation

Unfortunately, the race for the highest-built skyscraper contributes to the sinking of the city with the building dead load. Furthermore, these skyscrapers are energy-intensive with high demand for air conditioning and ventilation. The cultural heritage and architectural wealth of past Saigon architecture is also disappearing, leaving a uniformly looking International style that is prevalent among newer buildings.

New buildings should visually communicate with the surrounding architectural, historical, and cultural context to continue the characteristics and charms of Saigon. The contemporary buildings should allow locals and visitors to distinguish Vietnamese architecture from other ubiquitous glass boxes in the region and on a global scale. Plus, the development of these buildings should sensibly respond to the environment to maintain community and biodiversity health while curbing its energy usage and abating carbon emissions.

Through these bad new-built architectural case studies, we arrive at a better understanding of the current architecture landscape in Vietnam and the potential to design more environmentally responsive and culturally appropriate architecture moving forward.

Case Study 1: Landmark 81

Case Study 2: Three Straw Opera House

Case Study 3: Hai Son General Castle

Collectively, these buildings demonstrate a lack of responsiveness to the predominantly tropical climate, cultural appropriateness, and efficient use of resources. As a result, their high operational carbon and/or embodied carbon exacerbates climate change and contribute to cultural erosion. In addition, the case studies overlook time-tested traditional vernacular architecture strategies that optimize human thermal comfort and mitigate carbon emissions.

Figure: The construction of the long-stalled IFC One Saigon. Credit to: Tuoi Tre News

LANDMARK 81

Landmark 81 is the tallest building in Ho Chi Minh City that is situated among a cluster of glazed apartment complexes named Vinhome Central Park. The apartments here are the most desirable for many Saigon people due to the luxurious branding of the development despite the unsustainable traits.

Unsustainable traits:

- High embodied carbon as the building uses a large amount of glass, concrete, and steel
- High operational carbon as the glass building has a huge cooling demand
- The location among other glazed buildings creates heat islands
- The valley effects generated by the cluster of glass buildings prevents coastal winds from entering or exiting the area, worsening the area's pollution
- The land in this area is sinking at a faster rate than the surrounding area, making the area more prone to flooding

Figure: Landmark 81 and Vinhome Central Park. Credit to: Uncover Vietnam

THREE STRAW HAT OPERA HOUSE

Serving as the architectural attraction in Bac Lieu province, the Three Straw Hat Oper House was built for a music festival. Unfortunately, due to construction complexities, the building fell behind schedule, racked up more costs, and was not completed for the festival.

Unsustainable traits:

- Consumes a lot of operational carbon as there are no operable windows
- While the blue glazing filters some of the heat, it still enables harsh sunlight to pierce through the building envelope and overheats the interior. Therefore, the AC needs to run 24/7 to maintain the indoor temperature
- East-West orientation exacerbates the overheating.

Figure: Three Straw Hat Opera House. Credit to: AG Photography

HAI SON GENERAL CASTLE

Hai Son General Castle was a Rococo-styled castle built for a Vietnamese millionaire.

Unsustainable traits:

- Unbreathable building envelope
- High embodied carbon and operational carbon as the building has high cooling demand
- Using rare timber as a material construction which endangers the wood species and raises extinction threats
- Cultural inappropriateness to the location

Figure: Hai Son General Castle. Credit to: Vietnamnet

These case studies focus on how contemporary architecture firms in Vietnam and Singapore incorporate vernacular design elements into their urban projects and allow the buildings to approach net zero targets through the selective use of architectural strategies that are rooted in vernacular architecture or net zero designs.

Case Study 1: The Vibes Office by Infinitive Architecture

Case Study 2: Long An House by Tropical Space

Case Study 3: Kientruc O Office by Kientruc O

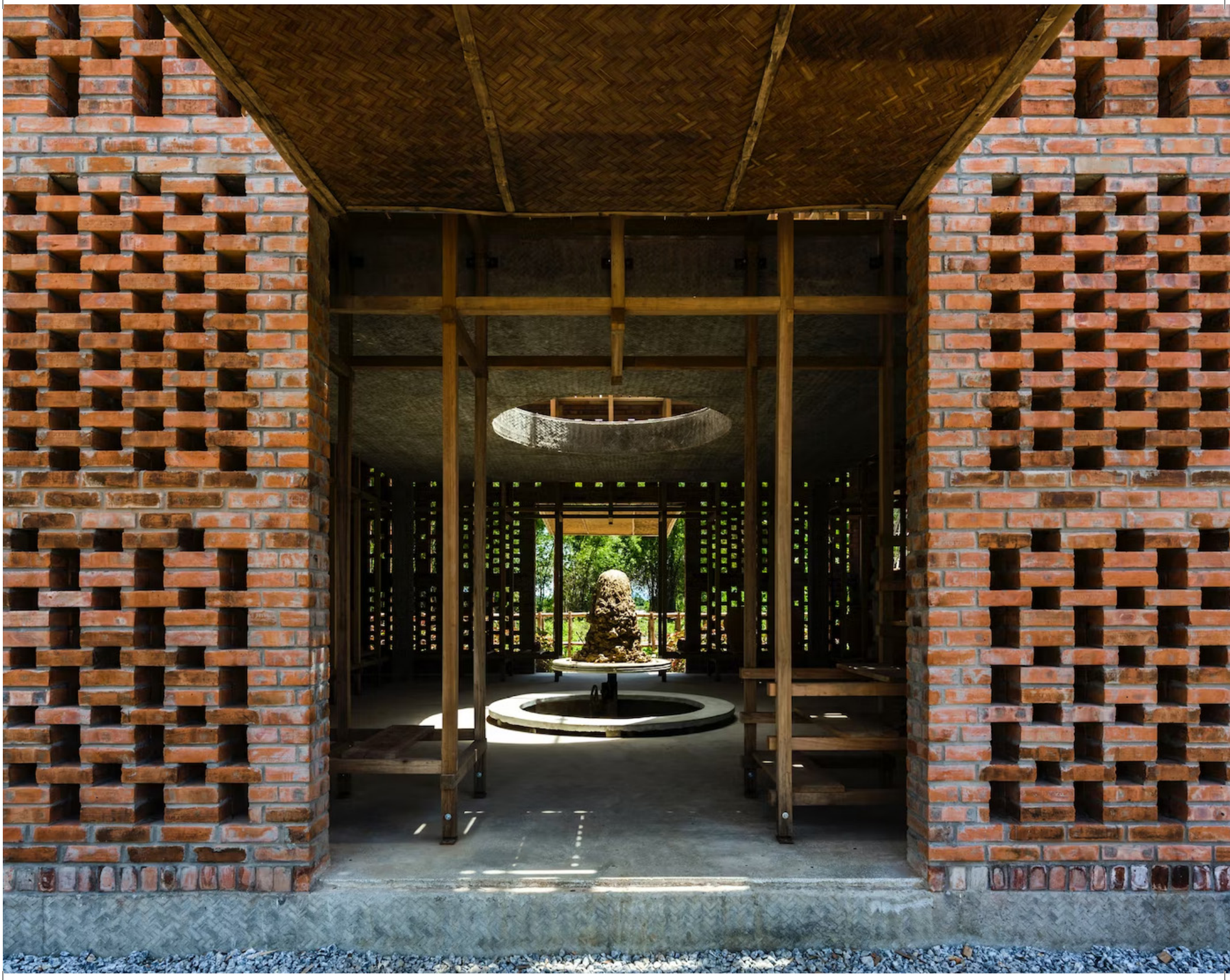
Case Study 4: Atlas Hotel by VTN Architects

Case Study 5: 14 Ton That Dam Street by unknown

Case Study 6: School of Design and Environment 4 (SDE4) by Serie Architects + Surbuna Juron + Multiple Architects

Vietnamese architectural firms are leading the way in adopting and advancing strategies of vernacular architecture to enhance thermal comfort, improve occupants' health, and reduce energy consumption. Diagrams of these projects offer insights into how buildings activate and implement vernacular architecture or net-zero/sustainable strategies. In a sense, these projects are leading the modern vernacular architecture movement in Vietnam and proving that the combination of vernacular architecture and modern sustainable strategies with sensitive cultural and historical considerations is feasible and effective.

Figure: Terra Cotta Studio. Credit to: Tropical Space



THE VIBES OFFICE

The Vibes office building boasts a variety of open spaces and green areas that create a serene and tranquil atmosphere despite being situated in an urban setting. However, due to its location on a narrow residential street, it needs to adapt from a residential neighborhood vibe to a more suitable working environment.

Size: 1555 m2
Location: Ho Chi Minh City
Category: Office

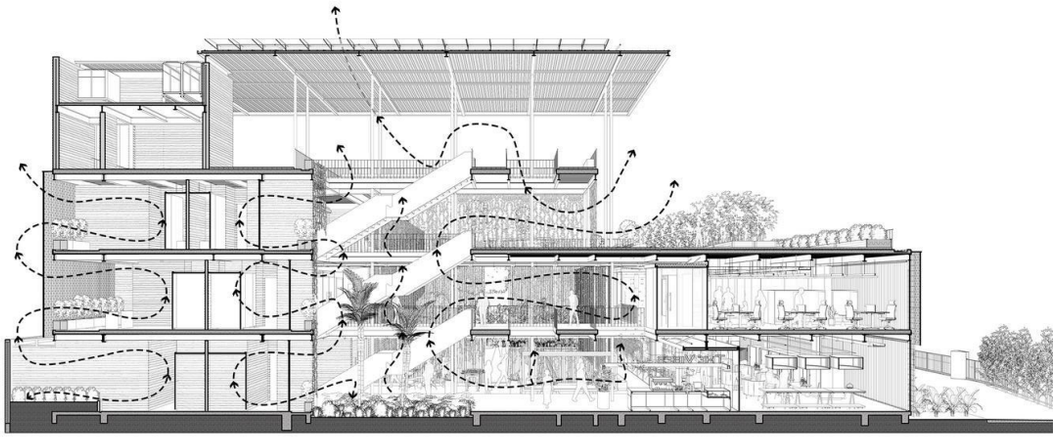
Vernacular Inspired Design Element:

- Natural Ventilation Optimization
- Bamboo Skin
- Open Space/ Courtyard with Water Feature
- Deep Porch

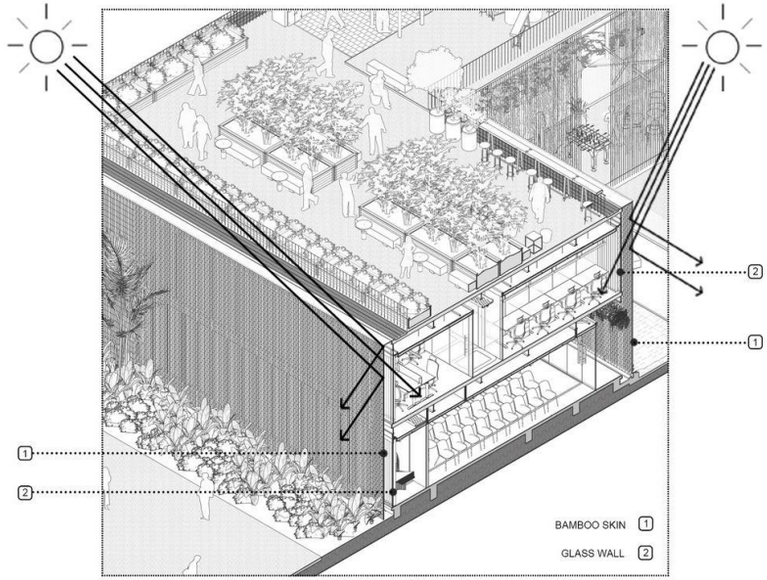
Modern Characteristics:

- On-site renewable energy generation with solar panels
- Green walls

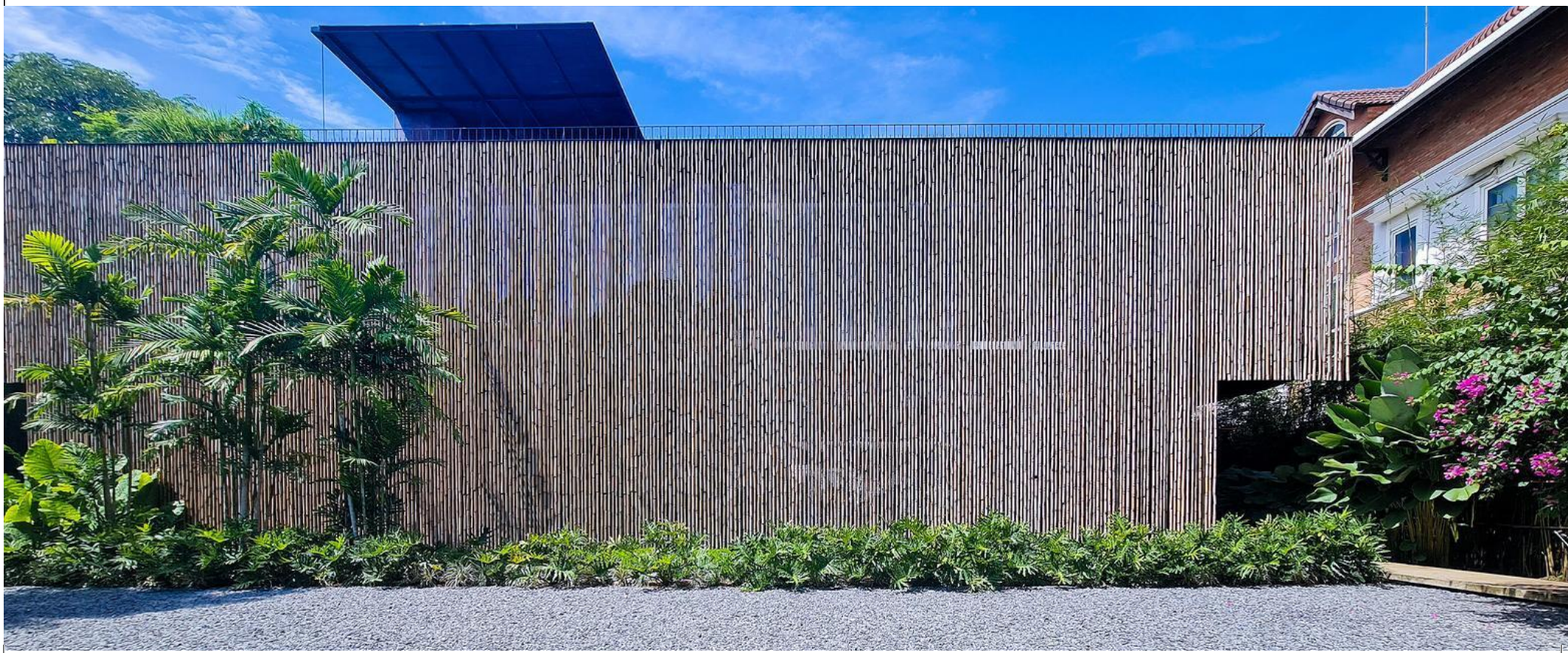
Figure (top left): Stack Effects. Credit to: Infinitive Architecture
Figure (top right): Bamboo Skin. Credit to: Infinitive Architecture
Figure (top left): The Vibes Office. Credit to: Infinitive Architecture



NATURAL VENTILATED PUBLIC SPACES



NATURAL LIGHT AND SECONDARY SKIN FACADE DESIGN



LONG AN HOUSE

Drawing inspiration from vernacular architecture, the architects aimed to create a modern and robust house design that features the traditional structure, along with three separate spaces and a sloping roof.

Size: 750 m2
Location: Long An
Category: Residential

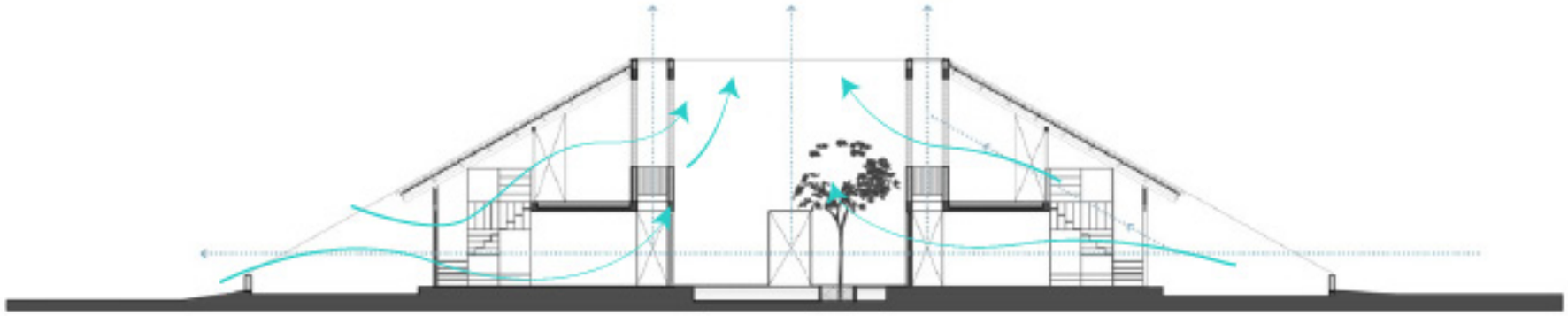
Vernacular Inspired Design Element:

- Natural Ventilation
- Courtyard with Water Feature
- Slope Roof

Modern Characteristics:

- Walls with brick organizational patterns that leaves gaps for air circulation

Figure (upper): Stack Effects. Credit to: Tropical Space
Figure (lower): Long An House Courtyard Credit to: Tropical Space



KIEN TRUC O OFFICE

To mitigate the effects of the tropical climate in Vietnam, the passive cooling methods used employ three criteria: heat prevention, modulation, and dissipation. The office design prioritizes shielding the indoor micro-climate from direct sunlight and selecting an appropriate building orientation. In addition, vegetation is utilized to minimize the impact of the sun on the exterior fabric.

Size: 221 m2
Location: Ho Chi Minh City
Category: Office

Vernacular Inspired Design Element:

- Natural Ventilation
- Open Space/ Courtyard
- Multi-layered Roof

Modern Characteristics:

- Green Wall
- Autoclaved Aerated Block Wall

Figure (upper): Stack Effects. Credit to: Kien Truc O
Figure (lower): Long An House Courtyard Credit to: Kien Truc O

PASSIVE DESIGN

PASSIVE COOLING METHODS

HEAT PREVENTING

Microclimate and site
Landscaping
1 +Vegetation
2 +Water surface
3 Wind direction
Solar access
4 +Multi-layer & sky view roof

Building Orientation
Building layout
5 +Long & thin floor plan
6 +Window/wall ratio
Building form
7 +Buffer zones: close & open
8 +Self-shading: wall &veranda ratio

HEAT MODULATION

Thermal mass
9 Autoclaved aerated - block-wall
10 Slab on ground

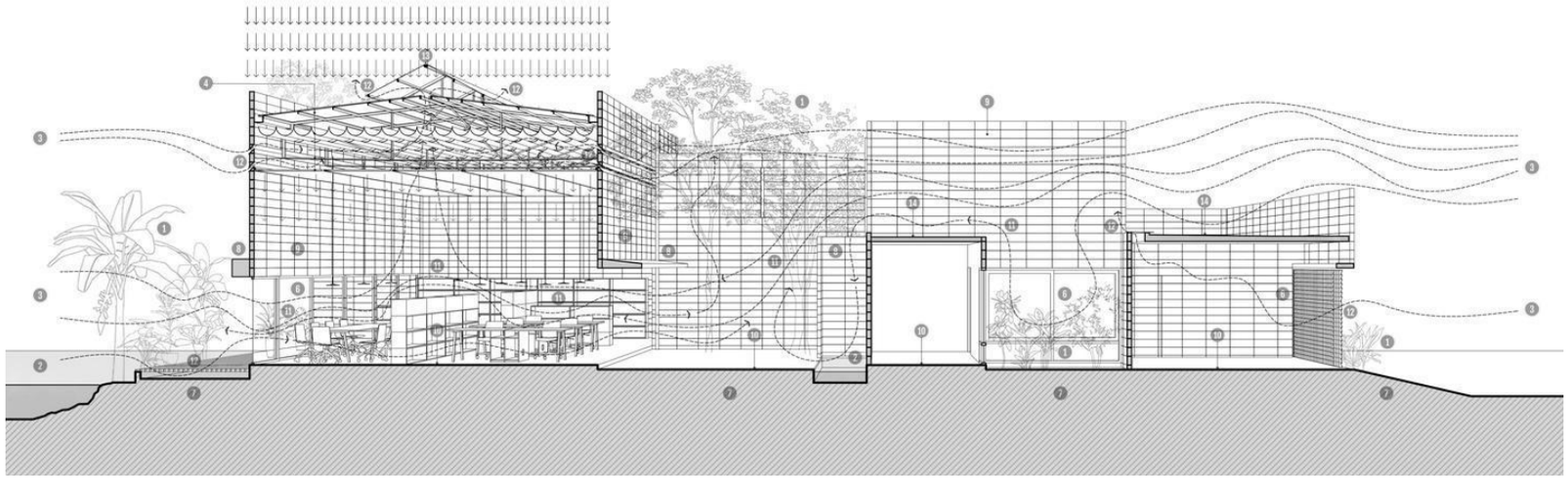
HEAT DISSIPATION

Wind control
11 Cross ventilation
12 Stack ventilation

Water-solar control
Evaporative cooling
13 +Sprinkler sprays roof
Reflective cooling
14 + Roof painting

TYPICAL DETAILS

SHADING and VENTILATION for the office space



ATLAS HOTEL

The design strategy of the Atlas Hotel involves utilizing the irregular shape of its plot of land to its advantage, creating a distinctive character. The building has a linear layout that is separated into multiple internal courtyards, and by elevating the structure above the ground, it allows for an interconnected network of courtyards to be created on the ground floor. This design element not only represents the energy of the modern Hoi An but also preserves the allure of the Old Town.

Size: 3115 m2
Location: Quang Nam
Category: Hotel

Vernacular Inspired Design Element:

- Courtyard with Water Feature
- Oriented for Optimizing Natural Daylight
- Natural Ventilation

Modern Characteristics:

- Walls with brick organizational patterns that leaves gaps for air circulation
- Green Facade

Figure: Atlas Hotel. Credit to: VTN Architects

14 TON THAT DAM STREET

Saigon's downtown District 1, specifically the old apartment block on Ton That Dam Street, has become a hub for trendy cafes, bars, boutiques, and dining establishments. The French colonial-era complex is not only filled with these cool and hip establishments, but also boasts captivating architectural remnants in every corner. Although this is not a modern vernacular example, this apartment exhibits the charming qualties of the disappearing apartment of the old Saigon.

Size: 2400 m2
Location: Ho Chi Minh City
Category: Mixed-Use, Residential

Vernacular Inspired Design Element:

- Balconies with metal frame as balcony expansion
- Screen
- External Staircase
- Courtyards

Modern Characteristics:

- Air-Conditioning

Figure: Interesting Balconies Detail. Credit to: Vietnam Corale

SDE4

NUS Design and Environment collaborated with external consultants, builders, and developers to construct Singapore's first net-zero energy building, known as SDE4. The six-story, 8,588 square meter academic building is designed to provide user comfort and health in the tropical climate while being highly energy efficient. The building incorporates a range of sustainable design elements that have been seamlessly integrated into its architecture in a holistic manner. This net zero building that harmoniously tie vernacular architecture and modern technologies offers great guidance for my project.

Size: 8500 m2
Location: Singapore
Category: Academic

Vernacular Inspired Design Element:

- Overhanging Roof
- Oriented for Optimizing Natural Daylight
- Facade Openness for Natural Ventilation

Modern Characteristics

- Aluminum curtains filtering light on the West and East Facade
- 1200 Photovoltaic Panels on the rooftop
- Hybrid Cooling System in combination with ceiling fans

Figur (upper): Application of different net zero strategies. Credit to: NUS School of Design
Figure (lower): SDE4 facade and courtyard. Credit to: ArchDaily

SDE4

SINGAPORE'S FIRST NEW-BUILD NET-ZERO ENERGY BUILDING

Located within the National University of Singapore's School of Design and Environment, the new six-storey building is a living laboratory to demonstrate and explore human-centric approaches for integrated sustainable development. A suite of strategies are deployed to reduce the building's energy demands and to generate all the energy it requires.

Figure: Looking at Bitexco Tower through the old apartment building Credit to: DreamsTime

INTEGRATION CHAPTER

This Chapter will dive into the integration of Net Zero Design and Vernacular Vietnamese Architecture

The Integration

As Ho Chi Minh City is moving towards the Net Zero goal by 2050, the government crafts favorable laws and regulations that incentivize businesses and design firms to explore and adopt net zero housing. However, the city has yet to produce a pilot net zero-built project nor fund any net zero residential projects. Plus, the housing inequity aggregated with the sea level rise, land subsidence, and architectural erosion calls for a building project that addresses these critical issues. Hence, I propose designing a mid-rise mixed-use residential and commercial project to establish a precedent for the incoming waves of net zero designs and offer a built solution to these problems.

In addition, the net-zero design presents the opportunity to modernize and study the feasibility of net-zero strategies in a tropical climate zone. Furthermore, the overlapping passive design, orientation, and low-embodied energy materials of net zero and vernacular architecture prove that net zero designs are not foreign concepts to the locals. The psychrometric chart provides the affirmation that thermal comfort aided by natural ventilation is enough for most days of the year in Ho Chi Minh City.

Thus, through the integration of Net Zero Designs and Vernacular Vietnamese ardchitecture, the people of Ho Chi Minh City can mitigate, adapt, and preserve. The integration will help mitigate carbon emissions, adapt to the sea level rise, and preserve the city's architectural past that is eroding at an alarming rate.

Credit (left to right) to: International Finance Corporation, Yahoo News Sinngapore, Saigoneer

MITIGATE

Adopt practices that remove or eliminate green house gas emissions to avoid adverse climate change impact

ADAPT

Acclimate to the sea level rise and rising temperature through making preparations for the RCP 8.5 Scenario

PRESERVE

Ensuring the structural and visual integrity of the historical sites and architecture to ensure their long lasting future

As depicted in the diagram, Vernacular Architecture represents the past of Vietnamese architecture, while International Style reflects the current dominant building style. Through this thesis, I hope to promote the adoption of net-zero + vernacular architecture among the next architectural movements in Vietnam. This movement will help to mitigate the carbon excess of the built environment, adapt to the urgency of climate change, and preserve the spirit of Vietnamese traditional architecture.

Past

Vernacular
Architecture

Present

International
Style

Future

Net Zero
+
Vernacular Architecture

PART II: DESIGN PROPOSAL

Figure: South Elevation of the Unity

DESIGN PROPOSAL

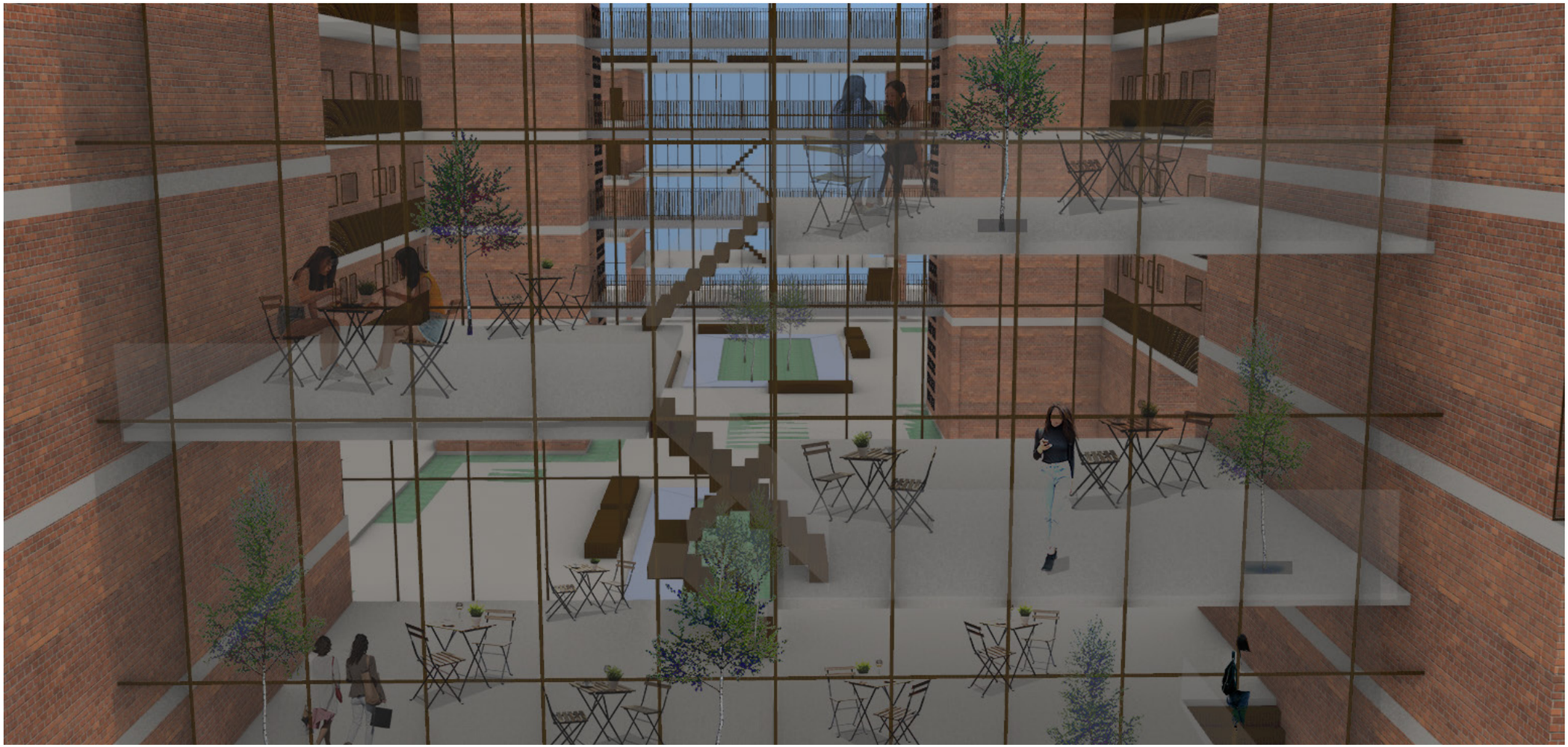
This chapter translates the integration of Net Zero Design and Vernacular Vietnamese Architecture into an mixed-use apartment complex.

Why a Mid-Rise, Mixed Use Apartment Complex?

The housing inequality in Ho Chi Minh City prevents the young generations, including the millenials and generation Z - my generation, and lower-to-middle income families to own housings. Therefore, I think the first net-zero design and vernacular Vietnamese architecture should be a project that is accessible to the majority of the population.

The main clientele for this proposal is middle-income families, who are in need of affordable housing projects that are located near the city center. Plus, as the site I chose is located in the heart of the area, a mixed-use complex can multi-function as a commercial building for restaurants or stores that can meet the entertainment and shopping needs of the residents, the locals, and the visitors. The proposal also has a courtyard that can function as a community courtyard.

Figure: Vertical Commerical Space



Site: Van Phuc, Thu Duc City, Ho Chi Minh City

Site: Van Phuc, Thu Duc City, Ho Chi Minh City
Site Footage: 127,500 square foot

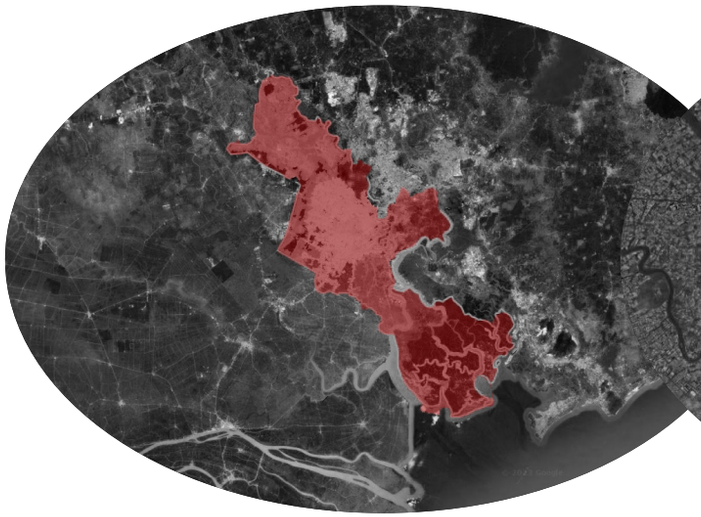
The design project is located in Van Phuc, Thu Duc City, Ho Chi Minh City.

Van Phuc is a development project in Thu Duc City that emerges as one of the future-proof areas that equips the residents with the housing, infrastructure, and facility for the incoming sea level rise. Most built buildings in Van Phuc are damp-proofed and elevated one story off the ground to prepare for the flooding season. Situating the flood-resilient project in this flood adaptive area will allow the project and the area to become the architectural and urban planning models that Ho Chi Minh City and Vietnam need for planning the next steps to move toward the Net Zero by 2050 goal.

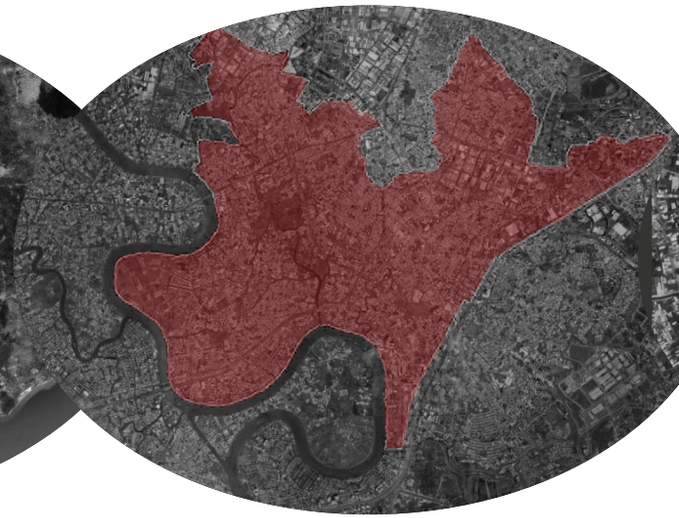
The eastern peninsula is adjacent to the Saigon River with three sides of the peninsula facing out towards the River. According to Vietnamese feng shui, the location will bring in good earth energy from the North that brings in good luck and health. Plus, Van Phuc is 30 a minute drive away from Ben Thanh market and 20 a minute drive away from Tan Son Nhat International Airport.

As for the site location, I chose a 492 feet by 252 feet (124323 square feet) plot of land that directly faces Dai Nhat Lake to take advantage of the lake's natural ventilation and cooling capacities. The Van Phuc development is still in the early stages of construction, so the development can also replicate my proposal in other unbuilt areas of Van Phuc.

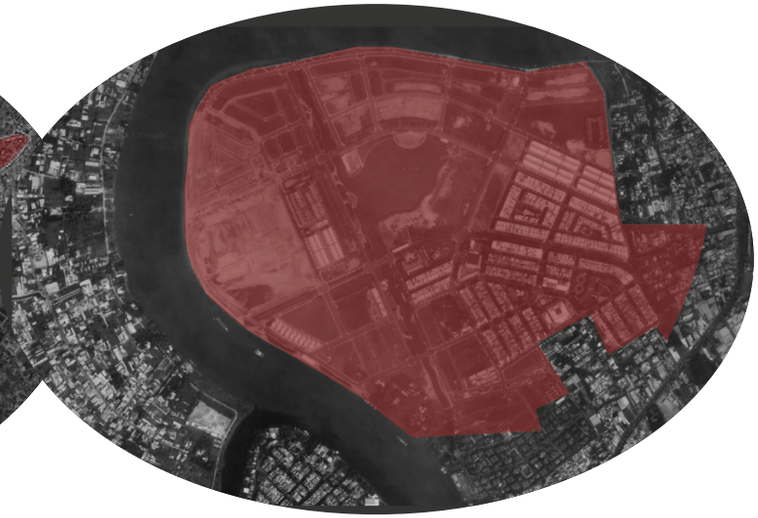
Figure: Maps of Vietnam, Ho Chi Minh City, Thu Duc City, and Van Phuc City.



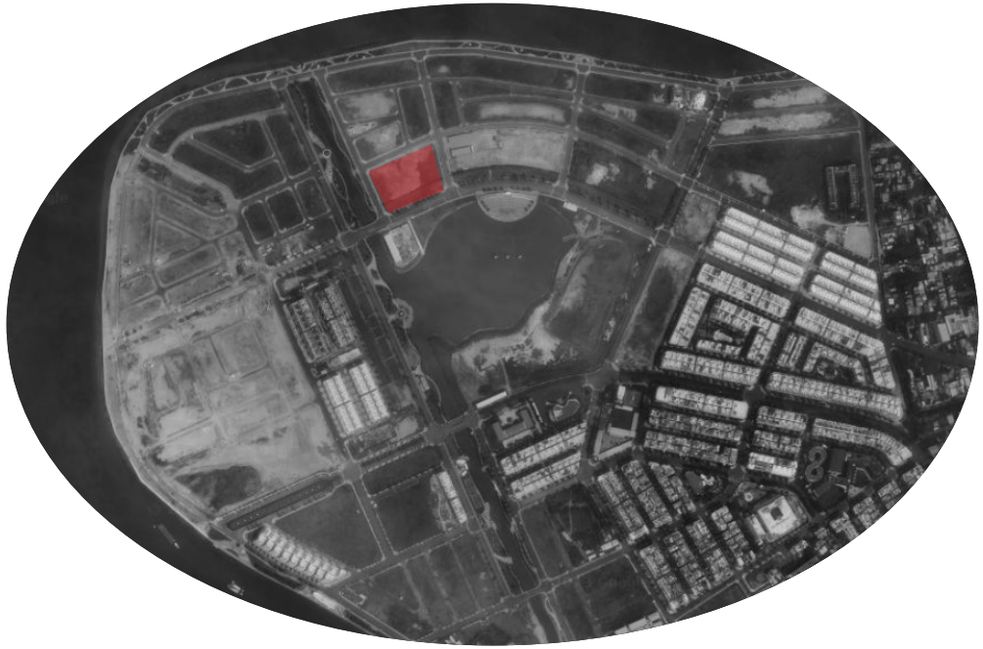
Ho Chi Minh City



Thu Duc City



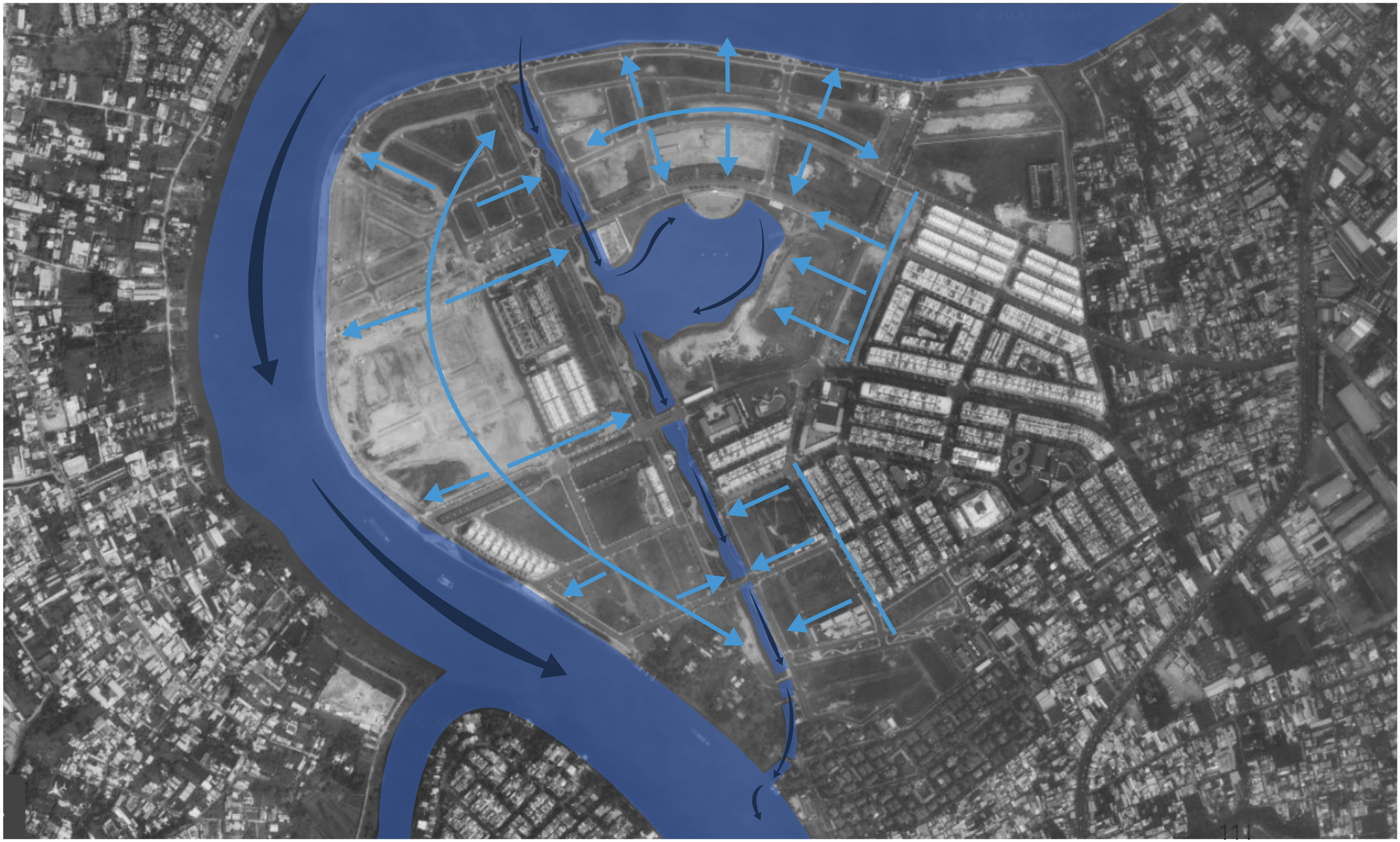
Van Phuc City



The Site

To prepare for the water surge, Van Phuc has Dai Nhat Lake and Trang River Canal System to adjust and maintain the area's water level. Plus, the green landscaping that covers 60% of the Van Phuc area will absorb the incoming rainwater. The runoff water on the street will redirect to Dai Nhat Lake through a modern water drainage system. Plus, 10 flood gates will be ready to pump the rainwater out from the lake to the Saigon River. The floodgates will close when the tides are high to mitigate flooding risk for the community.

Figure: Van Phuc Hydrology



In comparison to the gridlock street patterns typically found in Ho Chi Minh City that organically sprawl over the city and connect each location, the streets that total up to 20km are straight and wide to accommodate the surplus of traffic during rush hour. The development is adjacent to Boulevard 13, which connect Thu Duc City with Binh Thanh District.

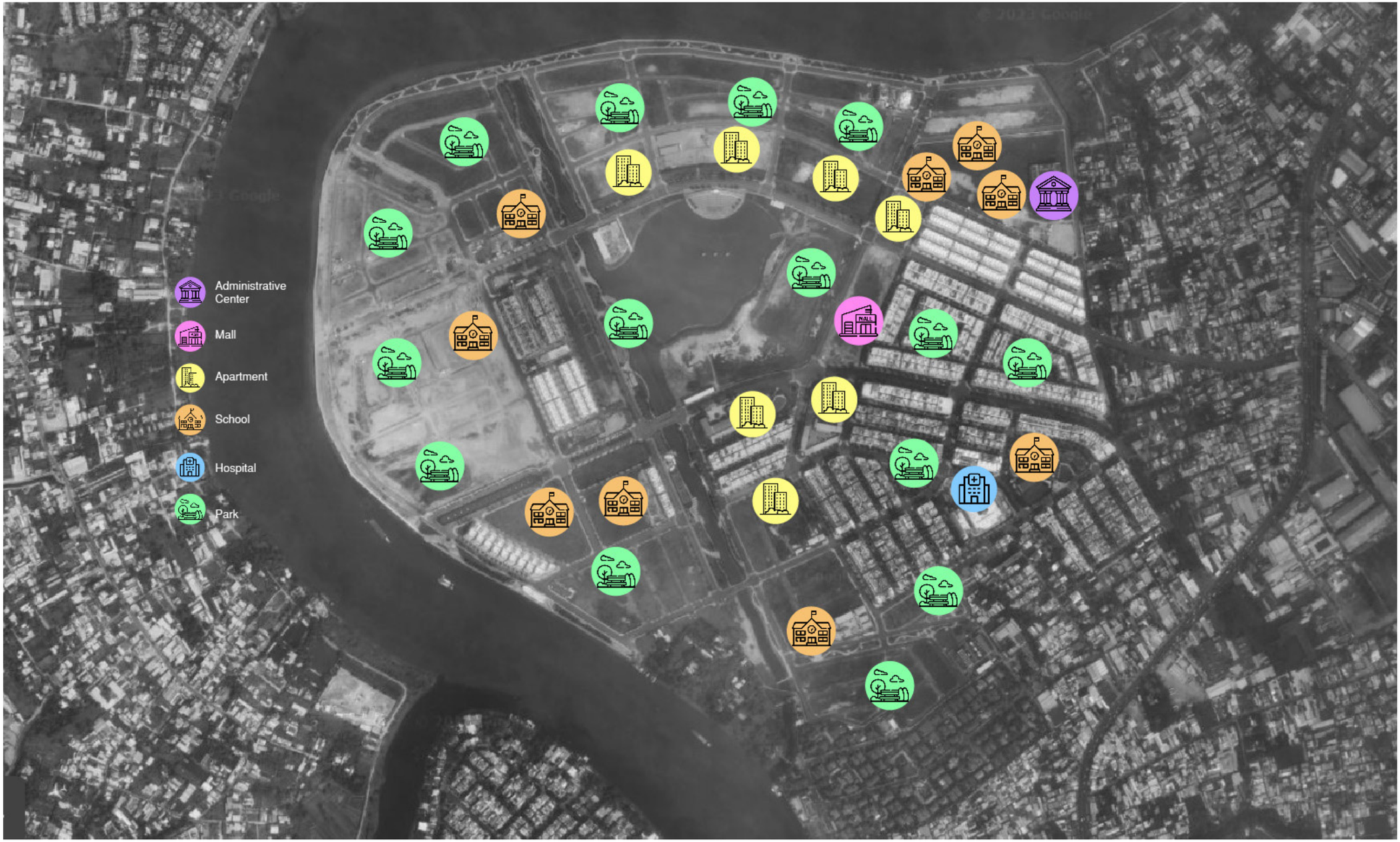
Figure: Van Phuc Street System

Site Analysis: Proximity Amenities and Parks

The site is close to schools, hospitals, and shopping places. The proximity allows convenient and safe access to these amenities that ensure higher quality of life and people's happiness.

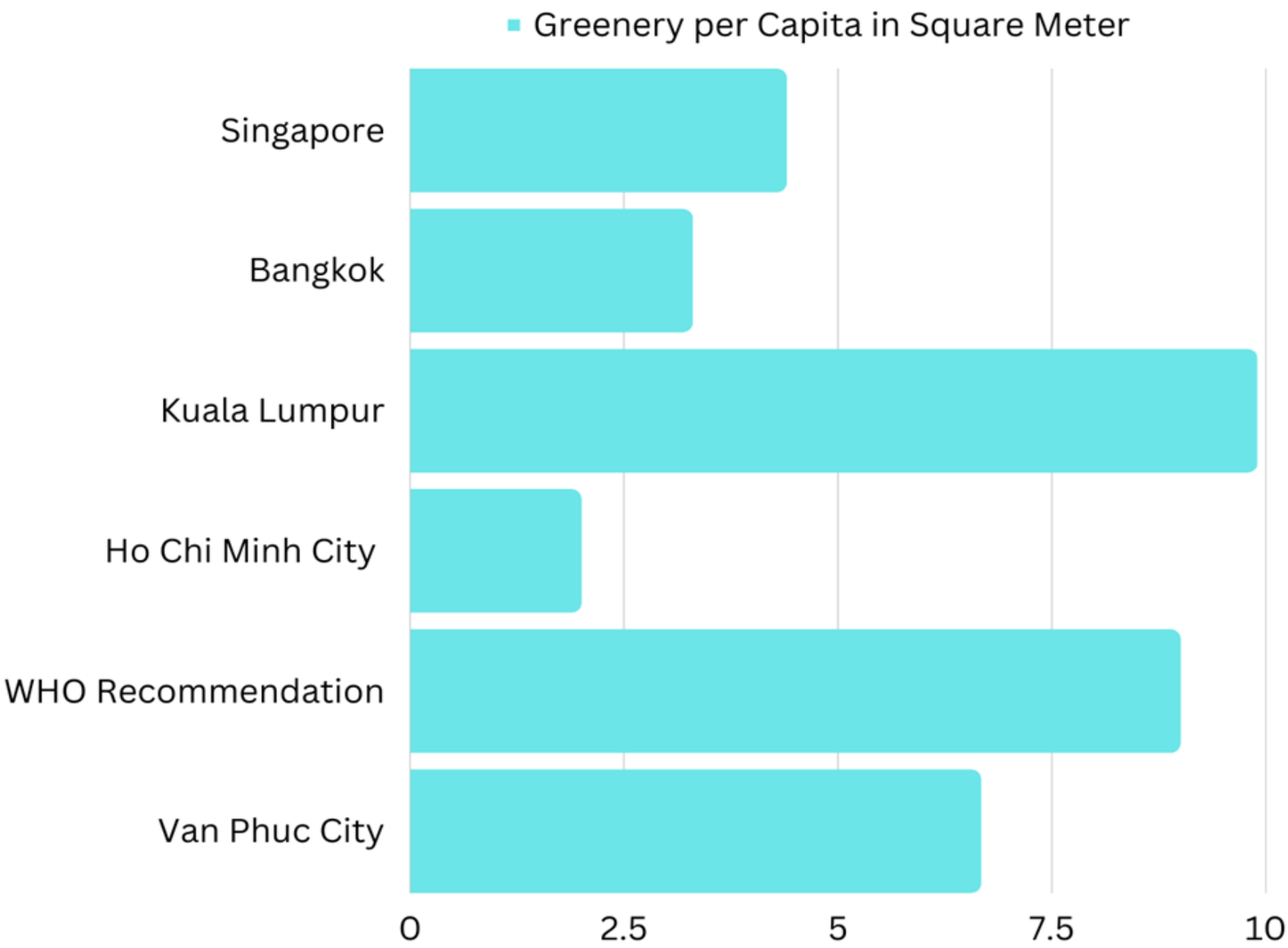
The area has a riverside park that stretches for 3.4 km and 15 smaller parks that allow the greenery per capita for the Van Phuc resident to be around 6.7 meter square per person, which is significantly higher than Ho Chi Minh City which measures at 2 meter square per person. In comparison to the Southeast Asian cities except for Kuala Lumpur and WHO's recommendation, Van Phuc's greenery per capita in square meter is higher, which is a great progress to boosting the community's health, maintaining the biodiversity, and abating carbon in the urban area.

Figure: Van Phuc Adjacent Programs


Administrative Center
Mall
Apartment
School
Hospital
Park

Greenery per Capita in the Southeast Asia Region

Cities/ Areas	Greenery per Capita in Square Meter
Singapore	4.4
Bangkok	3.3
Kuala Lumpur	9.9
Ho Chi Minh City	2
WHO Recommendation	9
Van Phuc City	6.67


Greenery per Capita in Square Meter
Singapore
Bangkok
Kuala Lumpur
Ho Chi Minh City
WHO Recommendation
Van Phuc City
0
2.5
5
7.5
10

Although Van Phuc is a future-proof, flood-resilient area that seems like an ideal living location, the site is the embodiment of gentrification, class division, and housing inequality in Saigon. According to the news report, the district displaced the original 700 residents of the area and provided compensation to those families at a rate 1/15th below the market rate. The unsettling displacement of the local residents and the unjust compensation resulted in prolonged lawsuits that have been ongoing since 2006.

A large portion of the land here is dedicated to building mansions and villas for the 1% population. The cost of living in the area goes up due to the construction of these ostentatious housing projects and drives away the long-term inhabitants of Thu Duc City. Furthermore, these mansions and villas have riverfront locations that strip away the rest of the communities' ability to share the ideal healthy, well-located living space. One hundred eighty-nine mansions and villas combine up to 41 ha, which makes up 20.7% of the Van Phuc area.

Figure: Van Phuc Villa Area

Figure: Van Phuc City Site View and Close-Up to Riverside Villas. Credit to: Van Phuc City

The thesis provides an alternative vision for Van Phuc City.

Instead of 189 villas, the mid-rise building proposed in this thesis can provide housing for 5278 households, as each midrise building takes up 0.7 hectares and provides housing for upto 91 households. That is 28 times the amount of households that are currently planned for the area planned for villas.

With the current urban planning, the population density of Van Phuc City is 227.3, which is 18.8 times less than the population density of Saigon. Van Phuc City can make space for more mid-rise apartments to accommodate and provide more housing to the average-income Saigonese in need of housing in a healthy and accessible area with a great range of amenities that normally are only available to the higher income brackets.

The developers can financially benefit more from adopting the Unity apartment design.

The average price of each villa is 4.2 million dollars. Selling 189 villas, the developers can yield 794.8 million dollars.

A 3-bedroom apartment in Thu Duc City averages around 170,000 thousand dollars. 5278 apartments can bring in 897.3 million dollars for the developers. By replacing the villas and providing 28 times more housing for middle-income families in need of affordable housings, the Van Phuc project owner can profit up to 102.5 million dollars.

Unfortunately, the developers finished constructing some villas at the riverfront. Still, the majority of the land can convert into mid-rise apartment buildings.

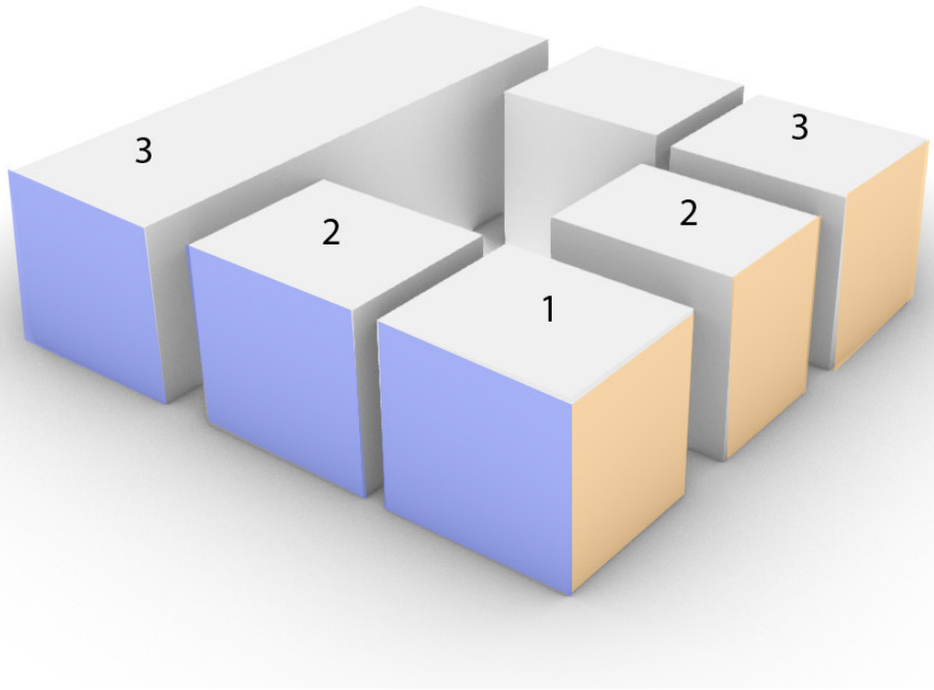
Figure: Apartment Building Replacement Proposal

Concept: Unity

As I read about vernacular Vietnamese architecture, I recognized the importance of having a community space as the core of the building for community engagement and natural ventilation. Plus, traditional Vietnamese houses typically followed the U-shape organization with 3 sections that created a partially enclosed garden and work area. Therefore, I thought of dividing the houses into 3 blocks at the front and three blocks on the side to give a nod to this Vietnamese architectural trait and divide the function of the space corresponding to each block. The design is also symmetrical which is a common trait of vernacular Vietnamese architecture and translates to the living harmony and balance between the residents, the building, and the surrounding environment.

The concept of my integration of net zero designs and vernacular Vietnamese architecture is Unity. The design project is the Unity between the past and the future, the historical architecture and the modern design, the Western idea, and the traditional Eastern principles. Although the United States and other European countries bring attention to net zero buildings, many of the strategies used in net zero housing can be found in vernacular architecture such as solar orientation or passive designs. Therefore, the unity of the two realms can localize the net zero ideas and allow a more seamless, sensible adoption of net zero that fits in the environmental, cultural, historical, and architectural context of Vietnam.

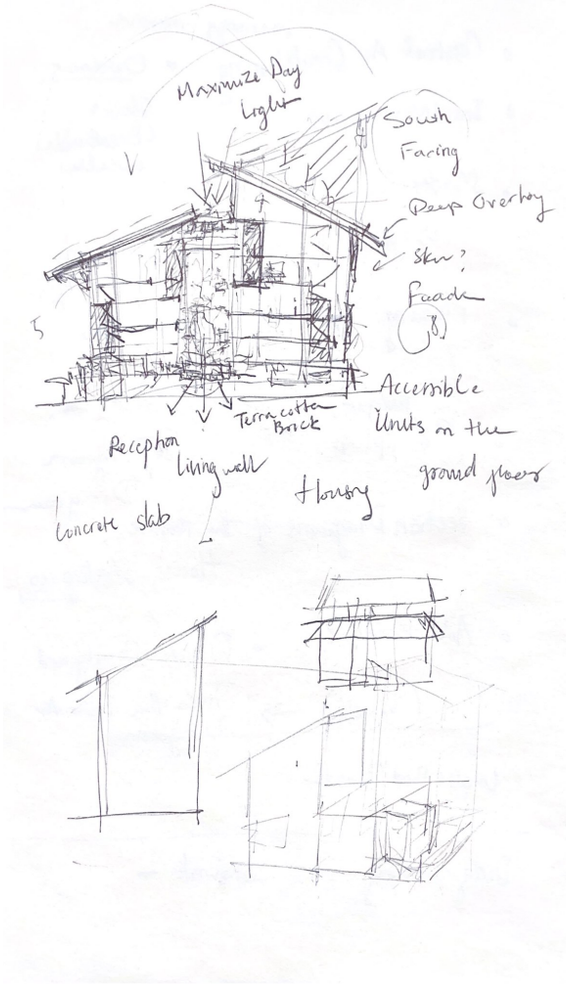
Figure: Concept Diagram

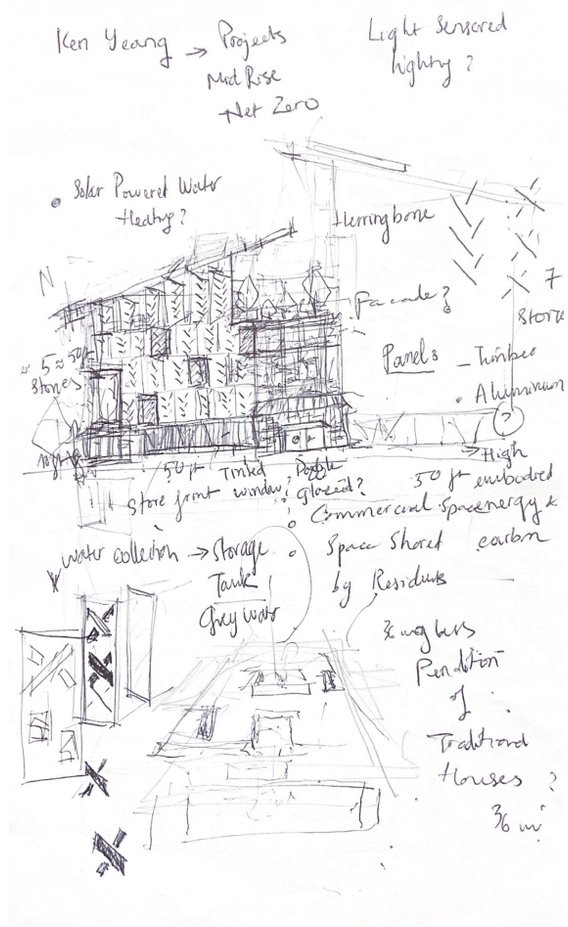

3
2
1
2
3

Concept: Sketch

Through a series of sketches, I gain insight into how the building will look and function. For me, sketching is a puzzle-solving process to arrive at a design solution that satisfies all the pre-determined conditions of Unity.

Figure: Concept Sketches


Maximize Day Light
South Facing
Roof Overhang
Skin? Facade
Accessible Units on the ground floor
Terracotta Brick
Reception
Living wall
Housing
Concrete slab


Ken Yeang → Projects
Mid Rise
Net Zero
Light Sensored lighting?
Solar Powered Water Heating?
Herringbone
Facade?
Panels
Timber
Aluminium
High
Commercial Spaces
Space Shared by Residents
Traditional Houses

Concept: Massing Model

In my concept model, I explore how the 2D planes evolve into 3D volumes. I realized through building the concept model that the building should be open. In terms of openness, the apartment building should be open to visitors and guests on the first floor to welcome and invite people into the building and see the design that unifies the Western net zero and the Vietnamese vernacular architecture.

Then, the project should be open through a series of open hallways, courtyards, screens, balconies, windows, terraces, and entryways to allow the new flow of air to replace the stagnate air for thermal comfort enhancement. Creating a screen at every facade or corner of the building, I want the building to breathe and share the same respiratory process as humans.

Figure: Concept Model

The first iteration is the reorganization of the working sketches into cohesive floor plans and elevations.

A typical Vietnamese apartment building will not have accessible units on the ground floor. Studying in the United States helps me recognize the need for accessibility spaces as the American Disability Act lays out stringent design requirements for buildings. Therefore, the first three apartments on the ground floor are accessible units.

Taking inspiration from the cage-like extension of Indochine apartment buildings, I randomize the placement of the balconies to mimic the organic order of these apartments' balconies and exteriorly disrupt the symmetry of the elevation. This choice carries the spirit of Ho Chi Minh City as the city's architectural landscape and buildings are sporadic and dynamic.

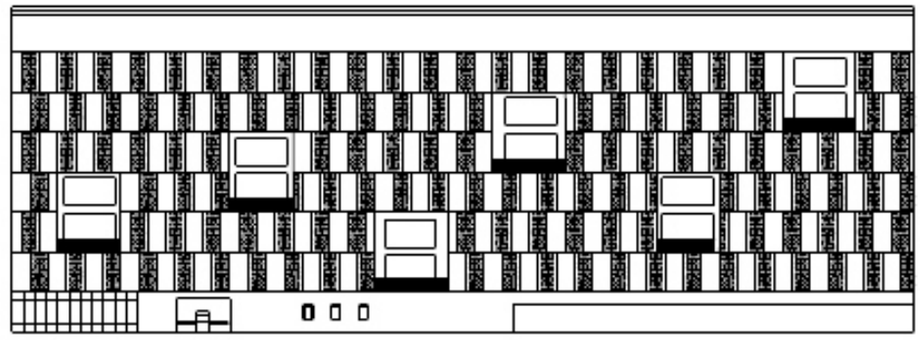
The two main circulation staircases of the building are located at the center of the building which optimizes access from all sides.

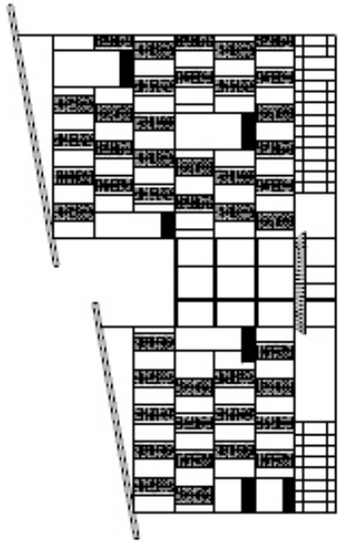
The architectural screen is inspired by the multitudes of brise soleil in Vietnam and the breeze block pattern. I started with a cross and developed the pattern by experimenting with different ways of overlapping the crosses. The floor-to-ceiling screens will double as solar filters and storm shutters that the residents can choose to keep open or closed depending on the weather conditions of the day.

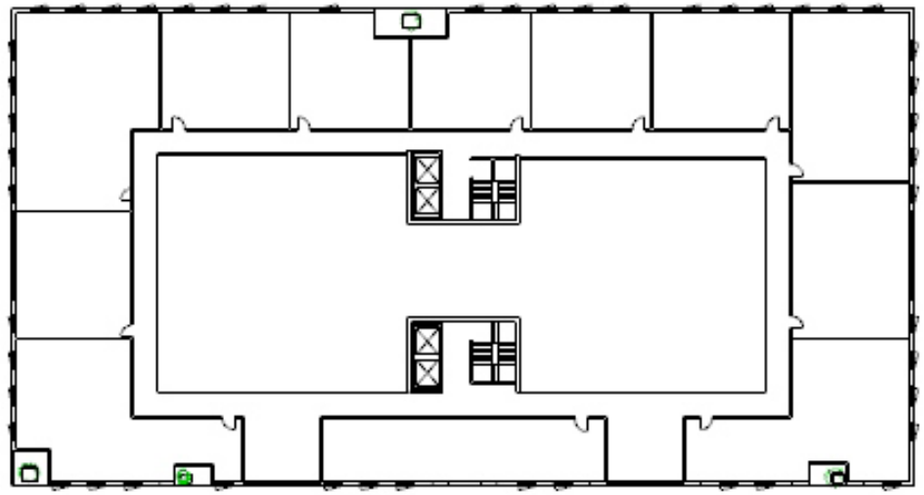
At the core of the building, the courtyard has two water features that cool off the surrounding environment through the cooling effect of evaporation.

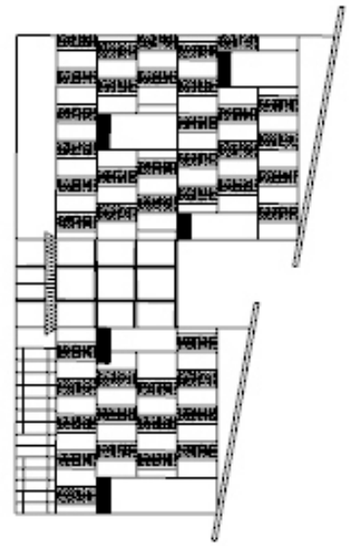
Since the site is at the center of the Van Phuc development, the apartment building should have commercial spaces for businesses to operate. I organize three commercial areas at each corner of the building to allow two sides of access for each business. My sketch idea for the commercial space also includes a vertical commercial space at the center of the eastern and western elevations of the building. However, with the dimensions I gave myself, the vertical commercial space is not plausible since that will interfere with first-floor circulation and reduces the number of units, which are limited already to 12 units on each floor.

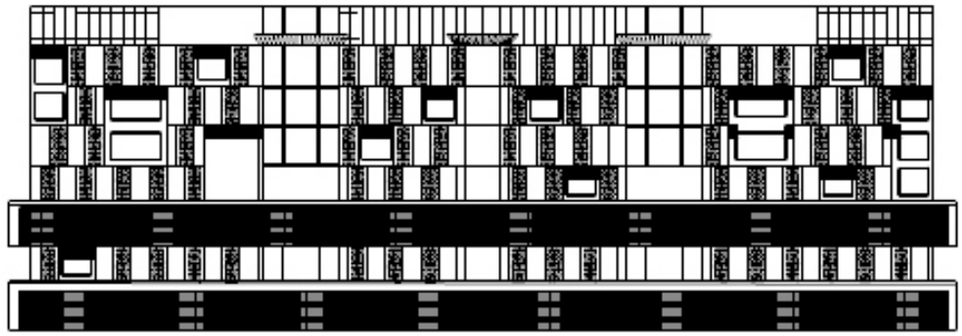
Figure: Iteration One's 1st Floor Plan and Elevation











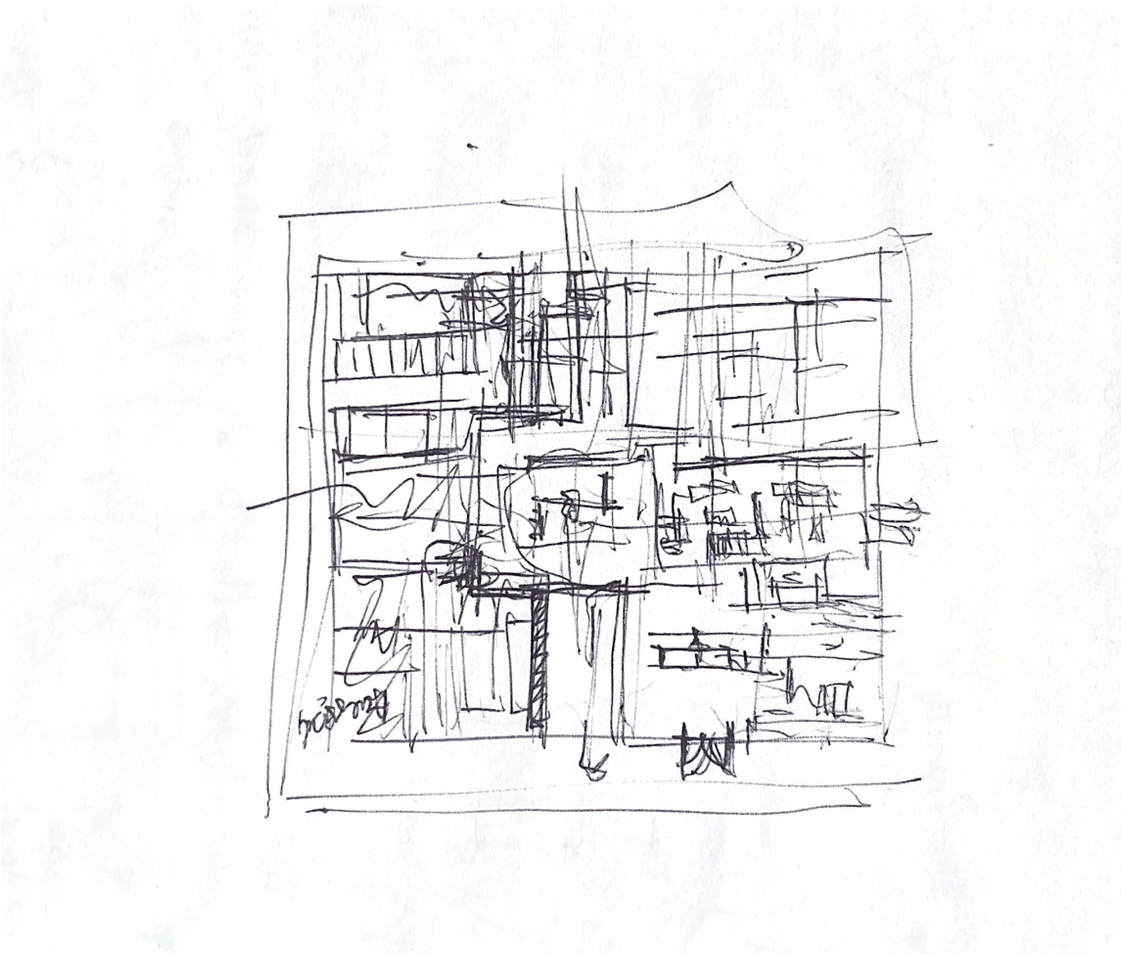
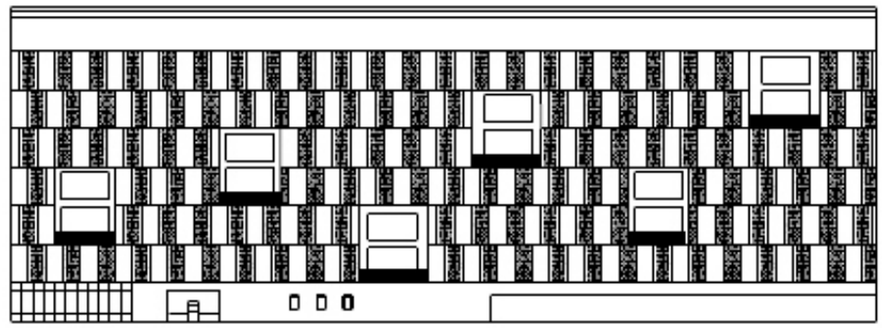
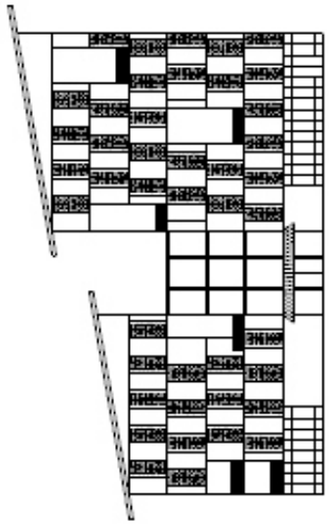
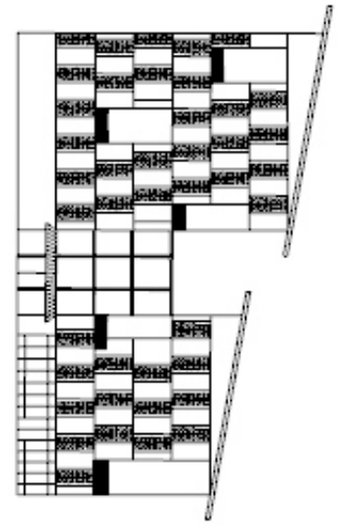
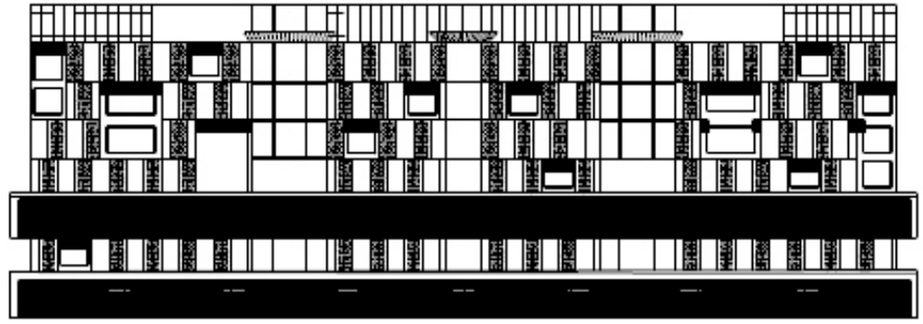


Figure: Iteration One's Ground Floor Plan and Elevation









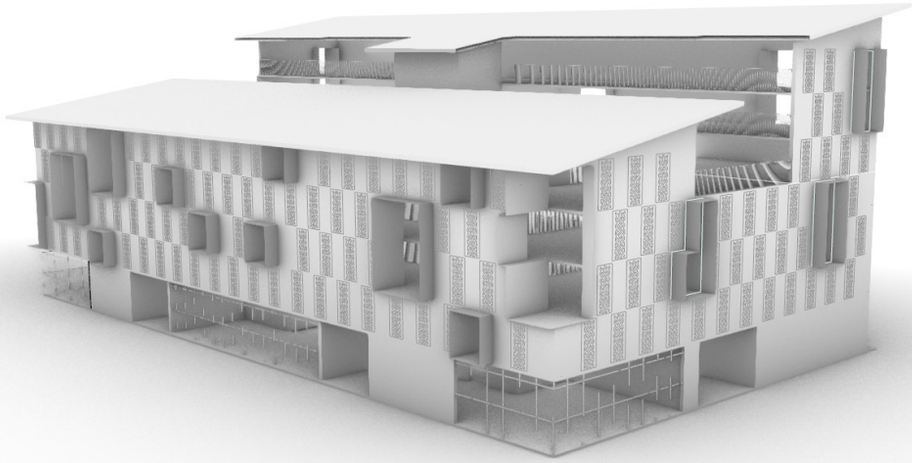
In the second iteration, I converted the floor plan and elevation into a 3D Rhinoceros model, but I did not like how closed-off the front facade looked. Therefore, in the third iteration, I decided to open up two vertical terrace stacks at the front building that function as the gardening area and community space. Plus, I used the same strategy for the East and West sides to create vertical commercial spaces.

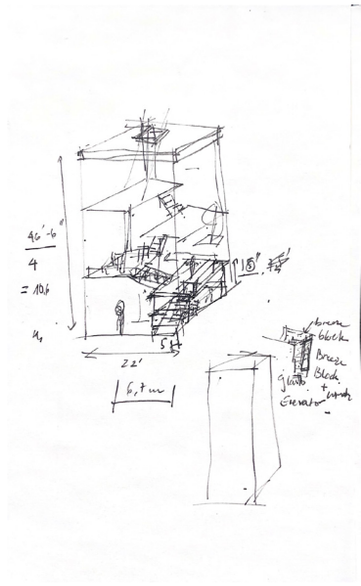
For the vertical commercial space, I want to separate the space from the rest of the building by having various floor heights and playful staircases that add to the dynamic experience of shopping or dining. Thus, the commercial space is set apart from the building through its extensive use of glazing that allows an uninterrupted view into the courtyard.

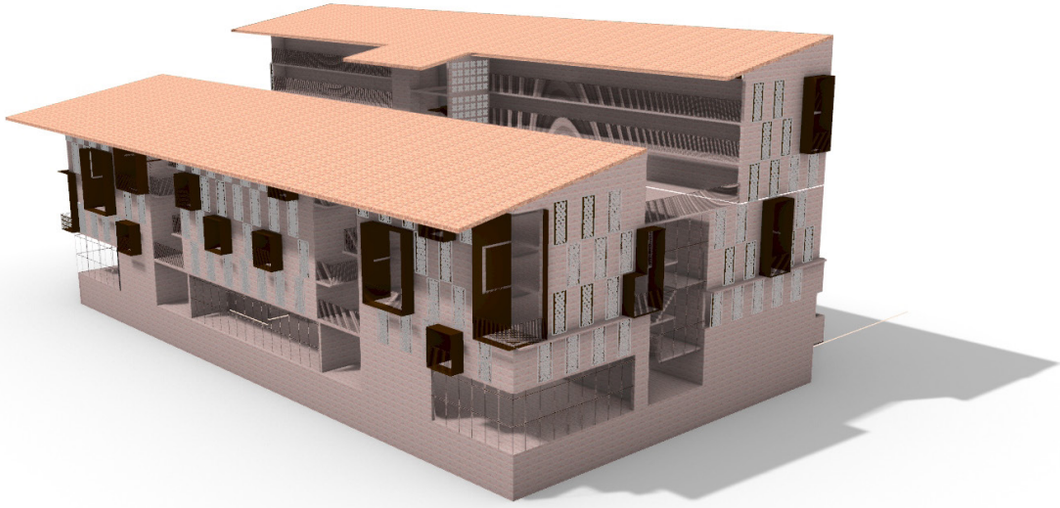
However, I soon realized that the deep overhanging roof that blocks direct solar rays also limits the sunlight that comes into the courtyard. Hence, the core space of the building turns into an unwelcoming chasm that is visually unwelcoming. Therefore, I conducted a series of solar analyses and decided that it is better to enlarge the courtyard, as well as the front and back building to maintain a harmonious proportion.

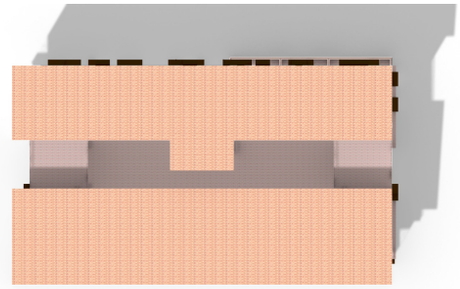
Plus, this building iteration has not addressed the sea level rise issue of Ho Chi Minh City. Through a deeper dive into the newly built buildings in Van Phuc, I discovered that most buildings elevated their main living space one level off the ground to adapt to the flooding risk.

Figure: Rendering of Iteration 2 (upper) and Iteration 3 (lower)









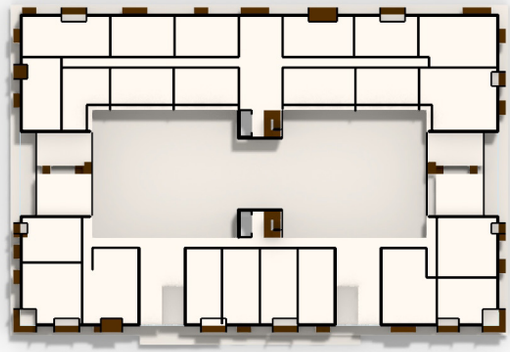
In the fourth iteration, the building now gained more floor area that allow more units, meaning more people can live in the Unity.

However, these new proportions brought in new design problems.

The old ground floor was now on the first level, which meant that people had to go up a series of stairs to access the commercial spaces. One arising concern is the visitors' willingness to climb up a series of stairs for the commercial spaces since they cannot access the building directly from the ground floor. Many of the recently new-built residential, commercial, and business buildings elevate the building by one level to adapt to the seasonal flooding and allow the continuation of their business without any disruption. Furthermore, many small businesses in the central district operate in old apartment buildings for more affordable rent. Therefore, consumers in Vietnam have adapted to the practice of climbing multiple levels of stairs to arrive at the commercial space. Still, this was a design challenge for me to tackle. The design of the ground floor's staircases should be appealing and inviting to pedestrians.

The floor plan of the back building arranges the units into two rows with each row facing either the north or the south. However, this arrangement of floor plans prevents cross-ventilation and makes the hallway closed off to daylighting.

Figure: Rendering, Floor Plan, and Roof Plan of Iteration 4



The Unity

Total Square Footage: 76,840 square feet | 7,139 square meter
Gross Square Footage: 333,390 square feet | 30,973 square meter
Residential Units: 91

After a series of iterations, we arrive at the Unity, the representation of the integration of net zero design and vernacular Vietnamese architecture. Unity solves most, if not all, of the design challenges faced by the past iterations.

At the ground level, the ramp replaces the stairs as the main circulation for accessibility. The ground floor also has public benches that allow pedestrians to rest. The benches are next to the trees that provide natural shade for the pedestrian. A cross-patterned opening adorns every corner of the ground floor to allow ventilation and add character to the building.

The first floor of the Unity centers around the green courtyard with native plants and gardens that have a surrounding body of water that generates the wind-chill effect to naturally cool off the area. For the accessible units' hallway, I create an alternating brick pattern that allows natural daylight to flood the hallway while maintaining a degree of privacy.

For the final version, the main building staircases have cross-patterned openings to allow the exchange of interior and exterior air. I also add in the sky bridges on the second, third, fourth, and fifth floors that connect the front building and the back building at the main circulation stacks of each building. This allows for more circulation connections between the front and the back building aside from the ground floor connections.

Figure: Rendering of the Courtyard

The Unity

Total Square Footage: 76,840 square feet | 7,139 square meter
Gross Square Footage: 333,390 square feet | 30,973 square meter
Residential Units: 91

The terrace on the fifth floor provides a private community area for the residents of the building since the courtyards are open for public use. The space also has its own green space that grows native trees and plants that provide shade and scenic views.

The new floor plan layout allows each apartment to have a north and south-oriented face that optimizes natural daylighting and, most importantly, cross ventilation. To keep the same number of units as before, I shorten the apartment's width, making each apartment longer. In a sense, the new shape of each apartment resembles the classic Saigon tube house floor plans.

Overall, the final version of Unity solves some of its unique design challenges and presents its own solution to integrate net zero designs and vernacular architecture.

Figure: Rendering of the Terrace

The rooftop photovoltaic panels exceed the Unity's electricity demand.

Assuming each solar panel has a capacity of 300 watts and there are 12.5 hours of sunlight per day, we can calculate the daily energy production per panel:

300 watts/panel x 12.5 hours = 3750 watt-hours or 3.75 kilowatt-hours (kWh)

The Unity has 2200 Photovoltaic Panels on the Rooftop. The total energy production for all 2200 solar panels in a day:

3.75 kWh/panel x 2200 panels = 8250 kWh

The total energy production for all 2200 solar panels in a month:

8250 kWh x 30 days = 247,500 kWh

According to Vietnam Electric Company, 68.15% of Vietnamese households use under 200kWh per month, which includes air conditioning electricity consumption. Assuming each Vietnamese household uses 200 kWh per month, 91 units in the Unity will comsume the following electricity amount:

200 kWh x 91 units = 18,200 kWh

A commerical building monthly consumes 1.875 kWh per square foot, which is 22.5 kWh per square foot for a year. Knowing the Unity has 34,400 square feet of commercial space, the total energy consumption of the commercial space is:

1.875 kWh x 34,400 square feet = 64,500 kWh

Excess energy for the other area, battery storage, and the grid after subtracting the total monthly energy production with the residential and commercial areas' energy consumption:

247,500 kWh - 18,200 kWh - 64,500 kWh = 164,800 kWh

The owner can sell the excess energy back to the grid or store the excess energy in batteries to supply electricity at night or during rainy season.

Figure: Solar Panels Installation. Credit to: VOX

Screen Windows

Screen Windows: Inspired by the brise soleil of the Vietnamese Modernist movement, these screen windows act as a solar filter that mitigates overheating the space while allowing natural ventilation

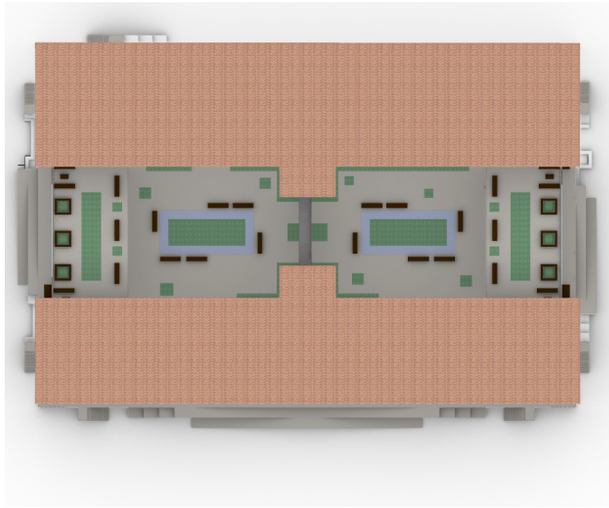
Courtyard

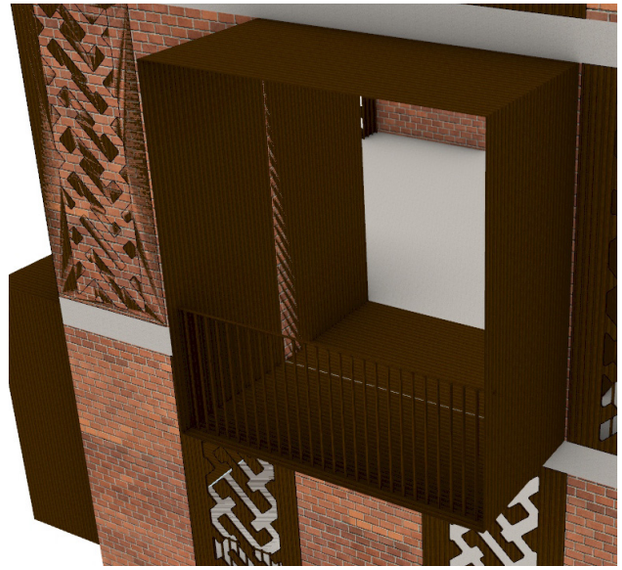
These courtyards allow better ventilation, creates green space, encourages community engagement, and provides pleasing scenery for the occupants and visitors.

Balconies

The balconies take inspiration from 20th-century Saigon apartment buildings' cage-like extensions and allow view access to the outdoor environment and function as a drying place for clothes.

Credit (left to right) to: Vietnamese Modernist Group, unknown, unknown





Green Walls

The green walls provide insulation for the building, which, in turn, reduces the cooling needs. Furthermore, green walls can improve air quality and abate carbon.

Community Garden

The shared gardens provide organic vegetables and fruits for the community, as well as strengthen the community's bond.

Composting Area

Composting area encourages residents to reduce waste, create a closed-loop system where waste can turn into natural nutrients for the soil and plants in the community gardens or courtyard, and abate carbon in the process.

Figure: Community Garden Renderings

Cross Ventilation

a Cross Ventilation improves indoor air quality, enhances thermal comfort, and reduces the energy consumption of the mechanical ventilation systems Furthermore, green walls can improve air quality and abate carbon.

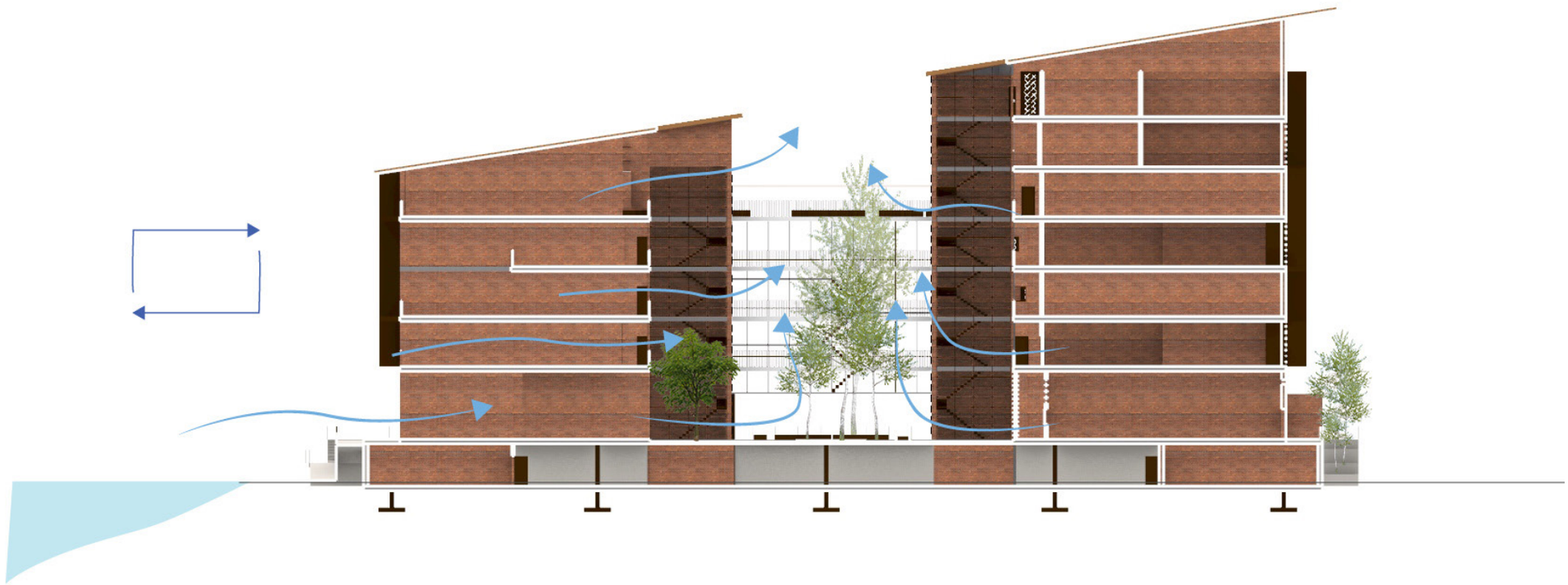
Stack Ventilation

Stack Effect comes into play with the open courtyard and balconies spaces to naturally ventilate the building and improve the thermal comfort for the residents.

Proximity to Water

Locating the apartment near the lake provides the building with the natural cooling effect of evaporative cooling as winds naturally blow over the lake surface, blow past the building, and cool the surrounding environment.

Figure: Ventilation Throughout the Building



Rainwater Collection

The project focuses on rainwater collection and the use of grey water for irrigating the garden and courtyard and flushing toilets. Plus, the rainwater collection is integrated in the courtyard, so the stormwater runoff can redirect towards the rain collection tanks at the ground floor.

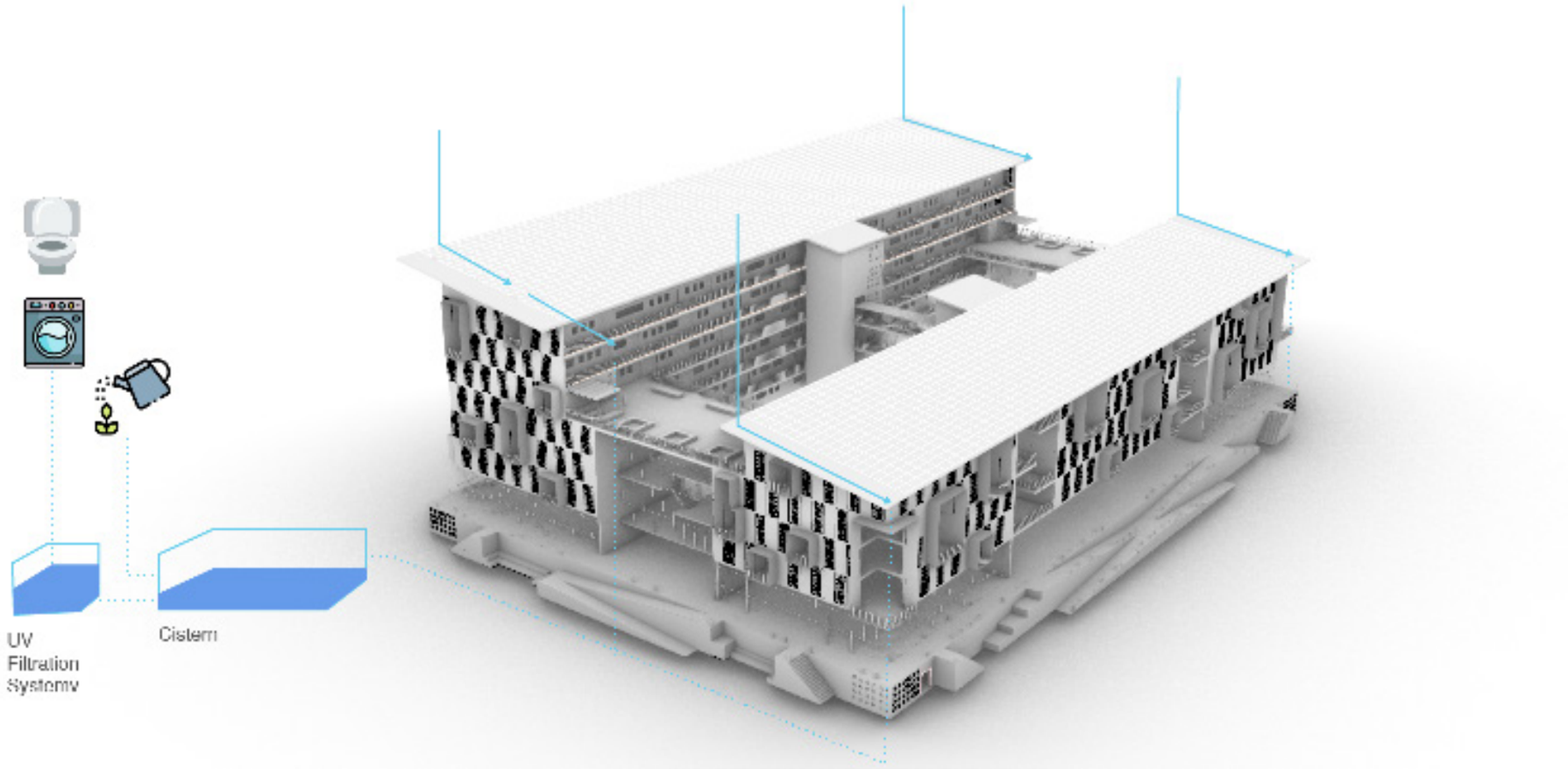
Hot Water

As for hot water, the building can implement an air-source water heat pump system that uses electricity to move heat from the air to heat the water or a solar-powered water heater that utilizes the rooftop solar.

Green Materials

The main materials for this project are bricks, glass, and fly-ash concrete. Although bricks do not have low-embodied carbon, they are locally available and plentiful. Fly-ash concrete, also known as green concrete, is a low embodied energy and carbon version of the typical energy-intensive concrete. The development of photovoltaic glass allows the glass to generate additional energy for the building.

Figure: Rainwater Collection System


UV
Filtration
Systemv
Cistern

Rooftop PV Panels

Rooftop PV Panels provide the apartment building with clean energy. Furthermore, the PV panels will reflect the incoming solar rays, which helps to cool down the roof and the building

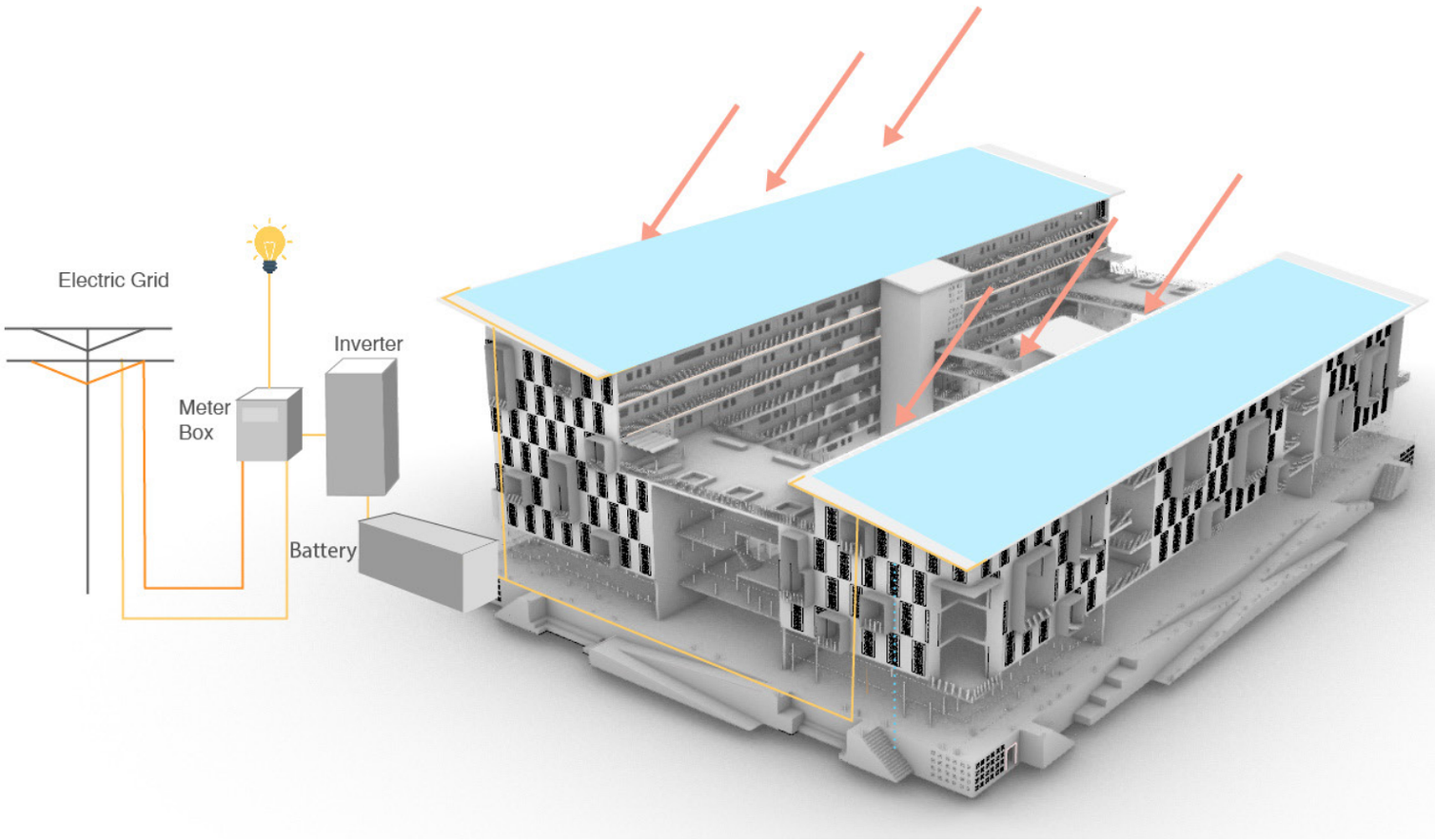
Deep Hallway

The deep hallway alludes to the deep porches of traditional Vietnamese architecture that provide shading while acting as an exterior circulation of the building

Insulation

To prevent heat gain, cellulose insulation can be blown into the cavities of the walls to create a dense layer of insulation that effectively controls heat gain and loss. Plus, the insulation is made from recycled paper and is resistant to moisture, which is essential in the tropical climate of Saigon.

Figure: Rooftop Solar Energy System


Electric Grid
Inverter
Meter
Box
Battery

Trees

The trees on the balconies, courtyard, and terracesnaturally filter dust, pollution, and sunlight which abates air filtering costs. Trees removes carbon dioxide from the air and produces oxygen. Plus, they also add to the landscaping and store water runoff.

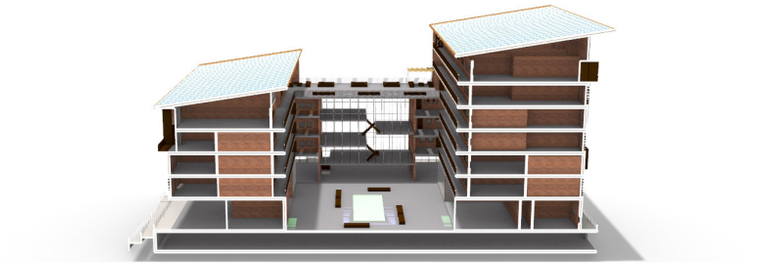
Daytime lighting

Residents can maximize the use of daytime lighting with the windows, courtyard, and balconies.

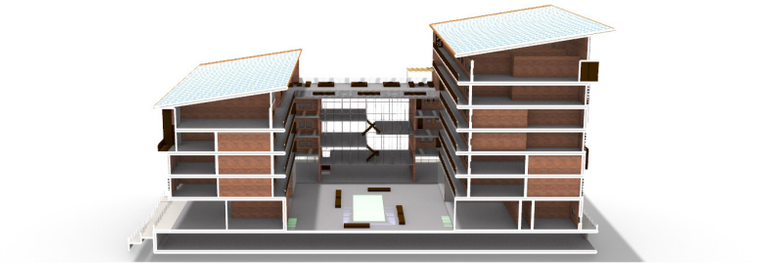
Elevated Living Space

Resembling traditional stilt houses, the project is elevated one floor above the ground as seen in Vietnamese vernacular architecture to prepare for the seasonal floods that historically peaked at 1.77 m. Plus, the floods are projected to be as high as 1.8m by 2100 in the RCP 8.5 Scenario. The first floor is raised 3 m above the ground level.

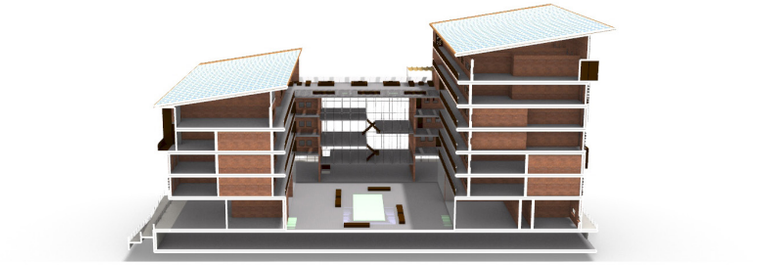
Figure: Equinoxes and Soltices



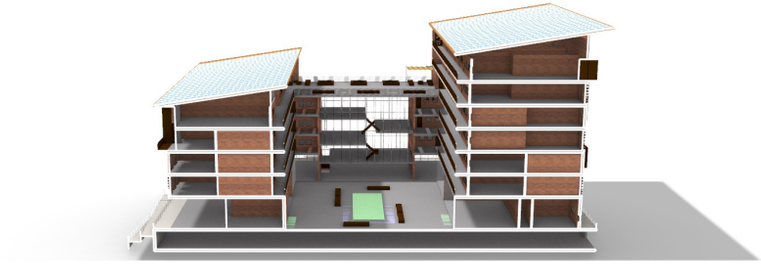
Spring Equinox: In the Northern Hemisphere, the beginning of spring is marked by the spring equinox. This event refers to the moment when the sun passes over the equator line.



Autumn Equinox: At the time of the autumnal equinox, the sun’s rays directly hit the equator, resulting in equal distribution of sunlight between the northern and southern hemispheres.



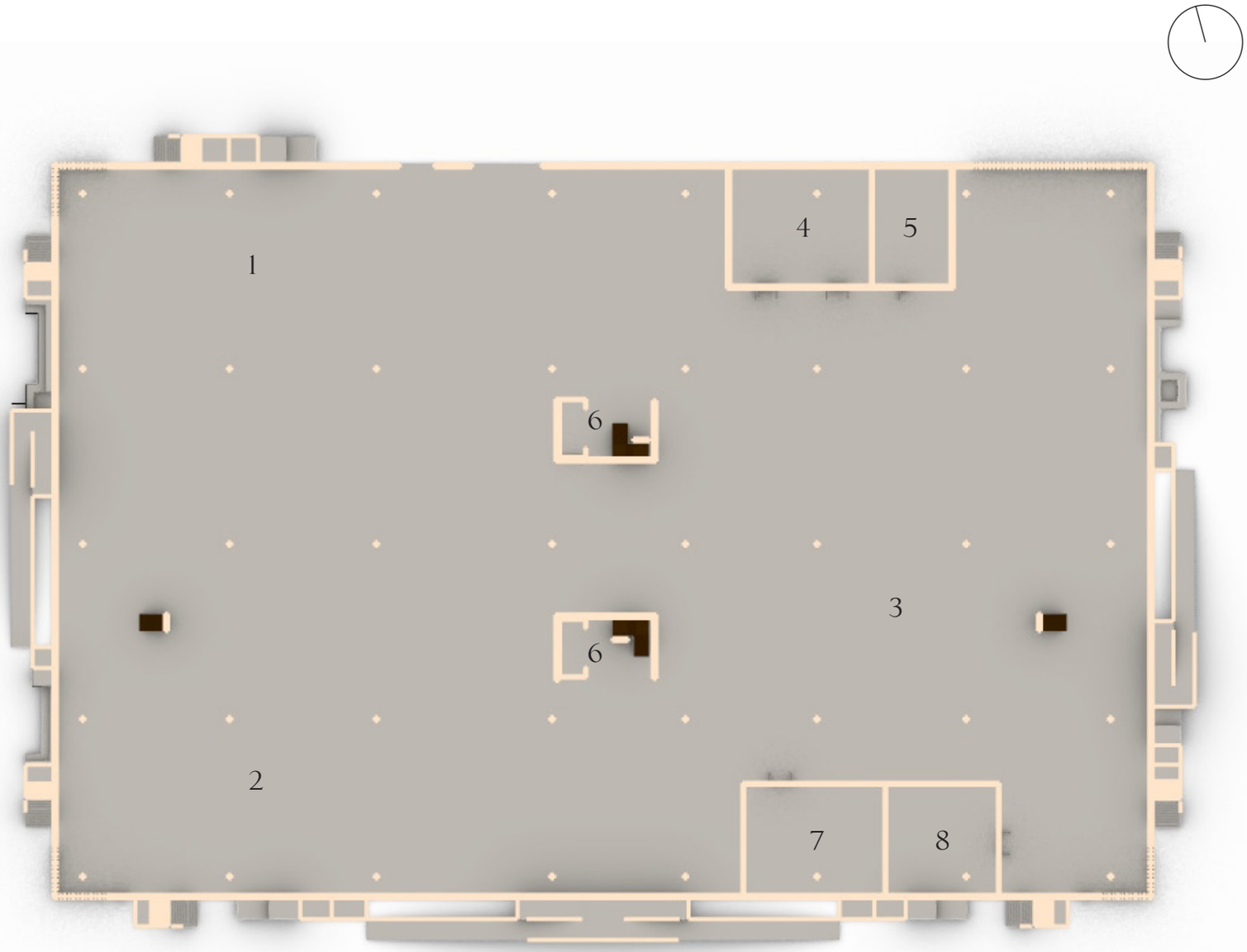
Summer Solstice: The sun shines on the Northern Hemisphere for the longest time of the year, and we have the shortest night. This day marks the beginning of summer.



Winter Solstice: When the Northern Hemisphere is tilted farthest away from the sun, this makes the day very short and the night very long. This day marks the beginning of winter.

FLOOR PLANS

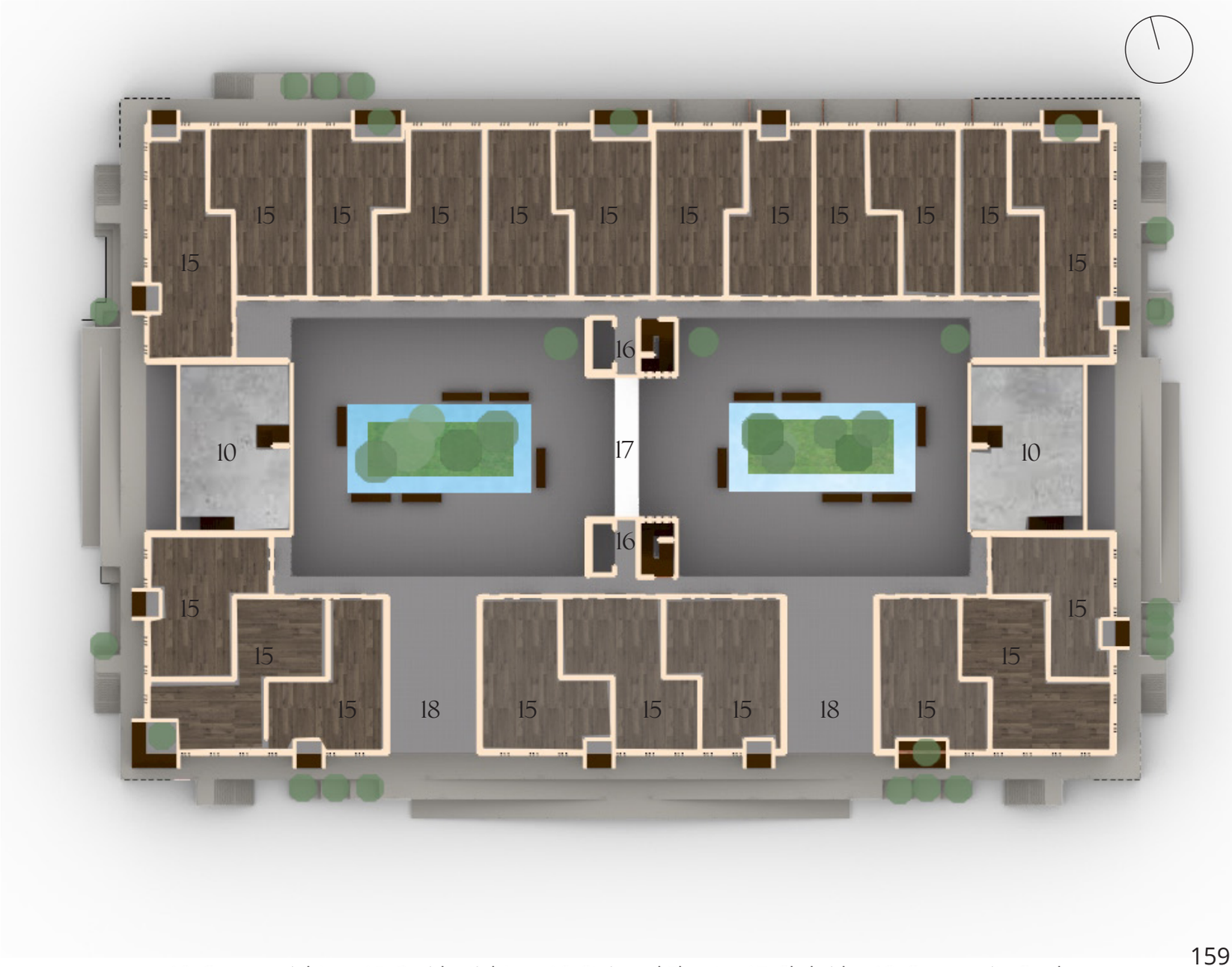
Ground Floor Plan



1. Car Parking 2. Motocycle/Scooter Parking 3. Bike Parking 4. Garbage Area
5. Compost Area 6. Main Circulation Entry 7. Water Tank Area 8. Mechanical Room

First Floor Plan

9. Courtyard 10. Commercial Area 11. Lobby 12. Office 13. Restroom
14. Entry Way + Multi-purpose Area 15. Residential Area 16. Stair and Elevator

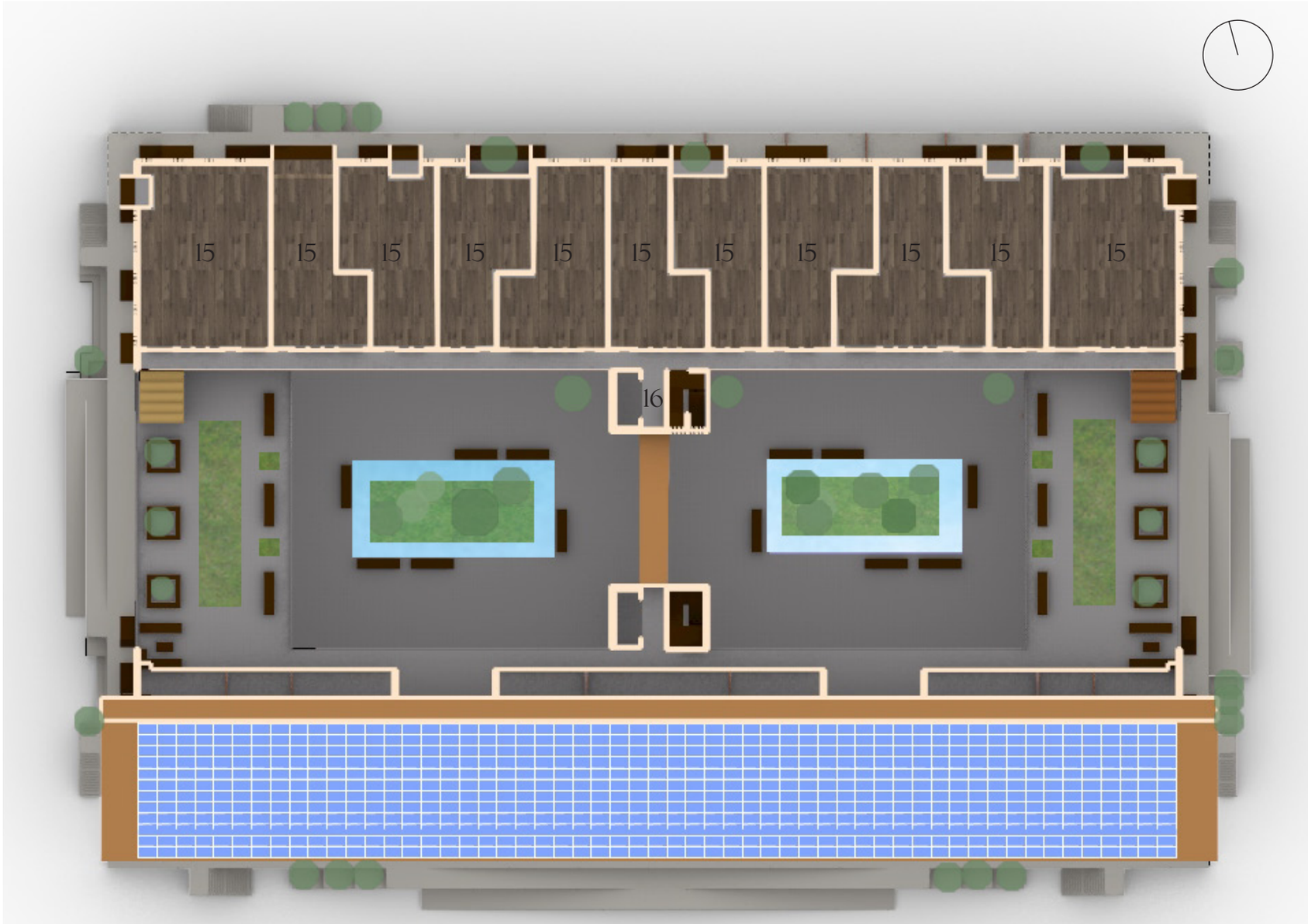


10. Commercial Area 15. Residential Area 16. Stair and Elevator 17. Skybridge 18. Community Garden

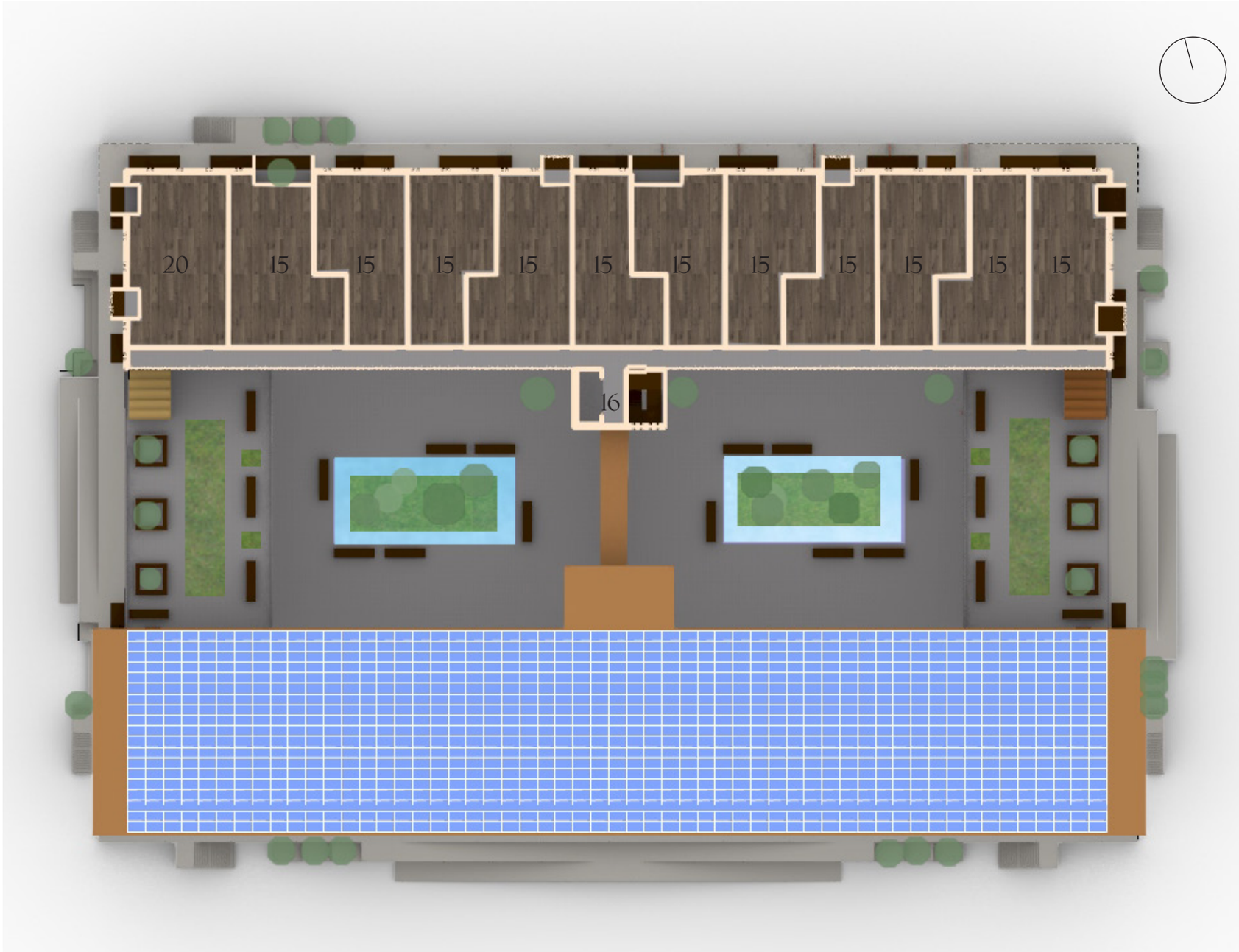
10. Commercial Area 15. Residential Area 16. Stair and Elevator 17. Skybridge 18. Community Garden

10. Commercial Area 15. Residential Area 16. Stair and Elevator 17. Skybridge 18. Community Garden

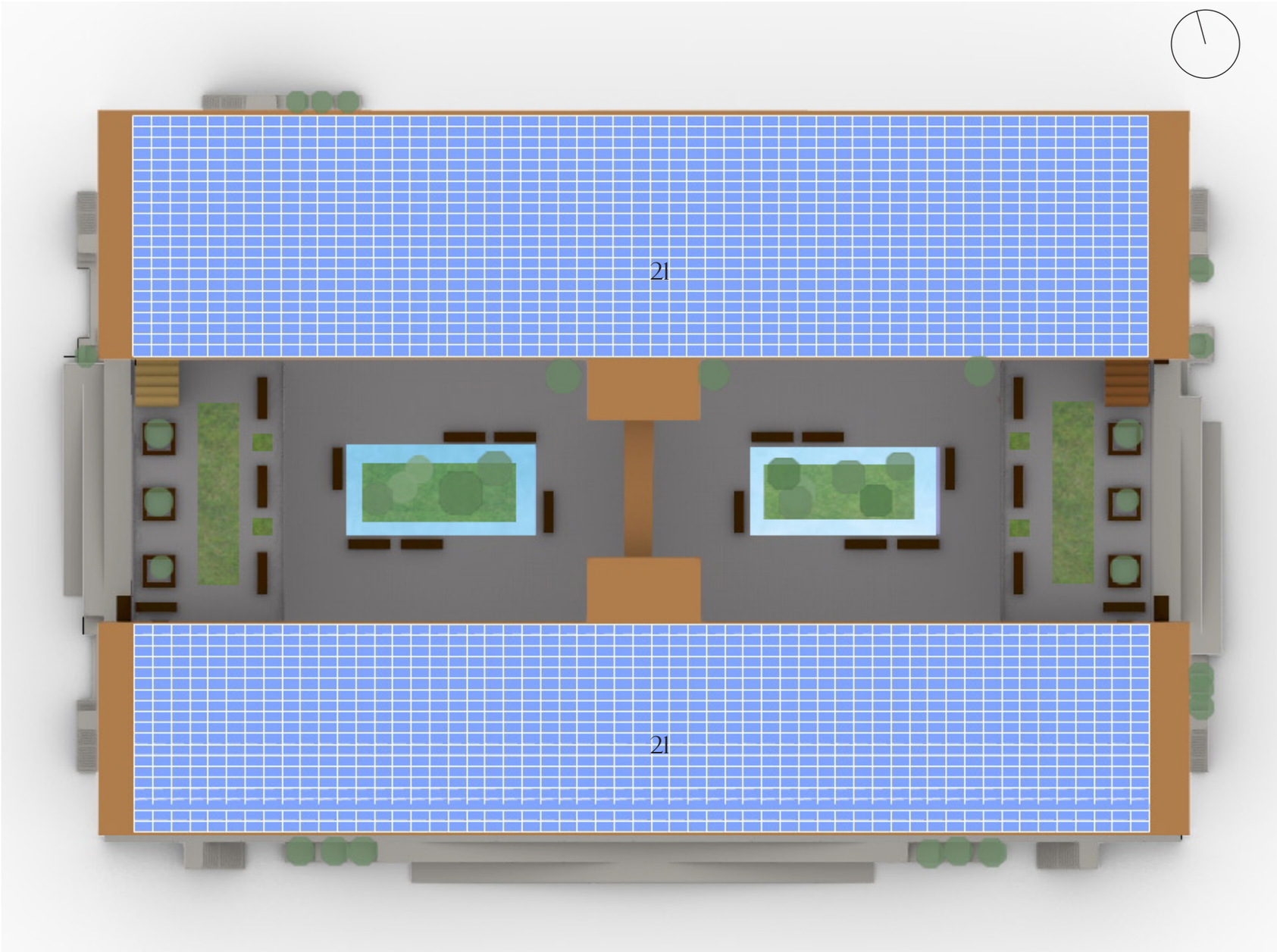
15. Residential Area 16. Stair and Elevator 17. Skybridge 18. Community Garden 19. Terrace



15. Residential Area 16. Stair and Elevator



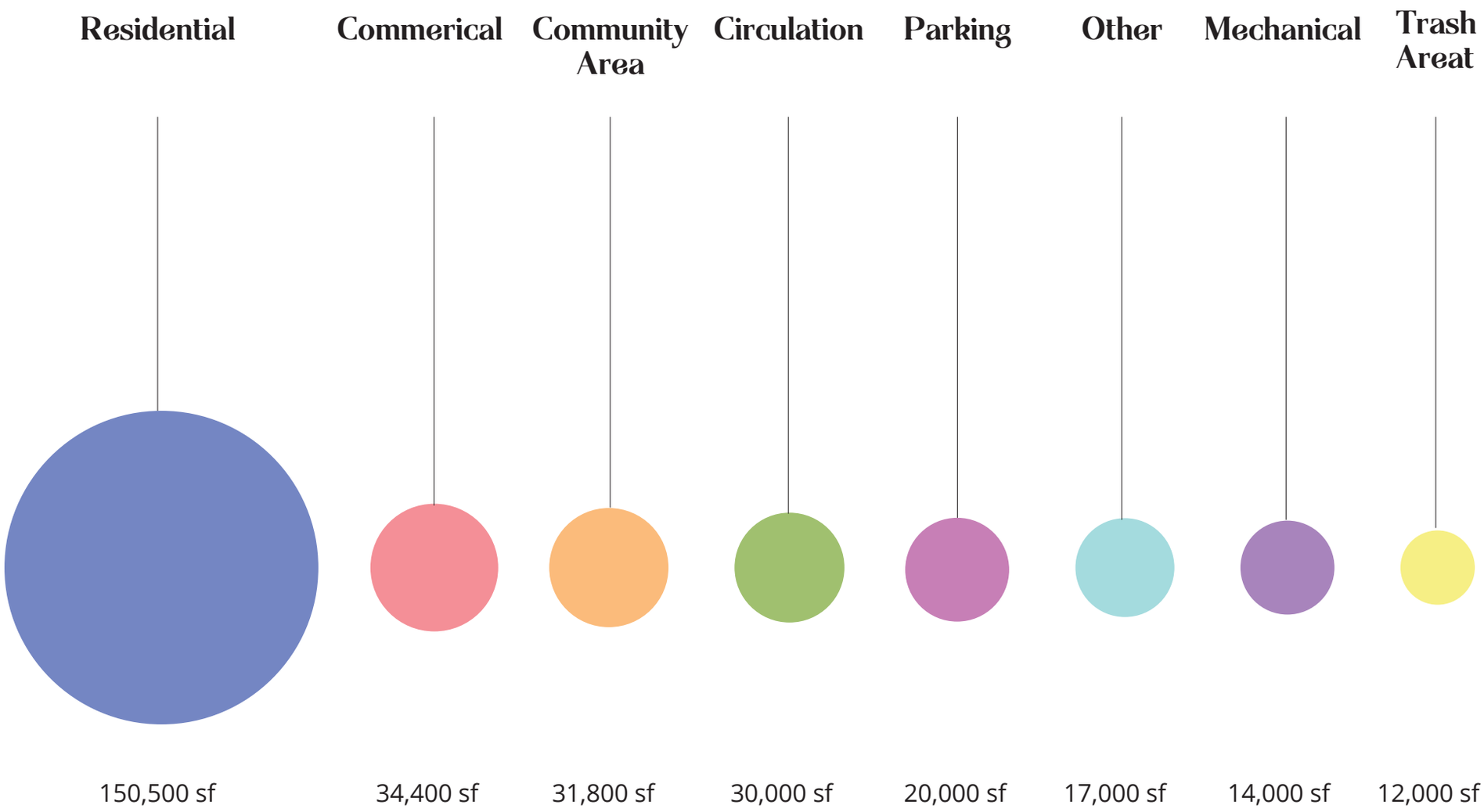
15. Residential Area 16. Stair and Elevator 20. Solar Battery Storage Room



21. PV Panels

Square Footage of Residential, Commercial, and Community Area

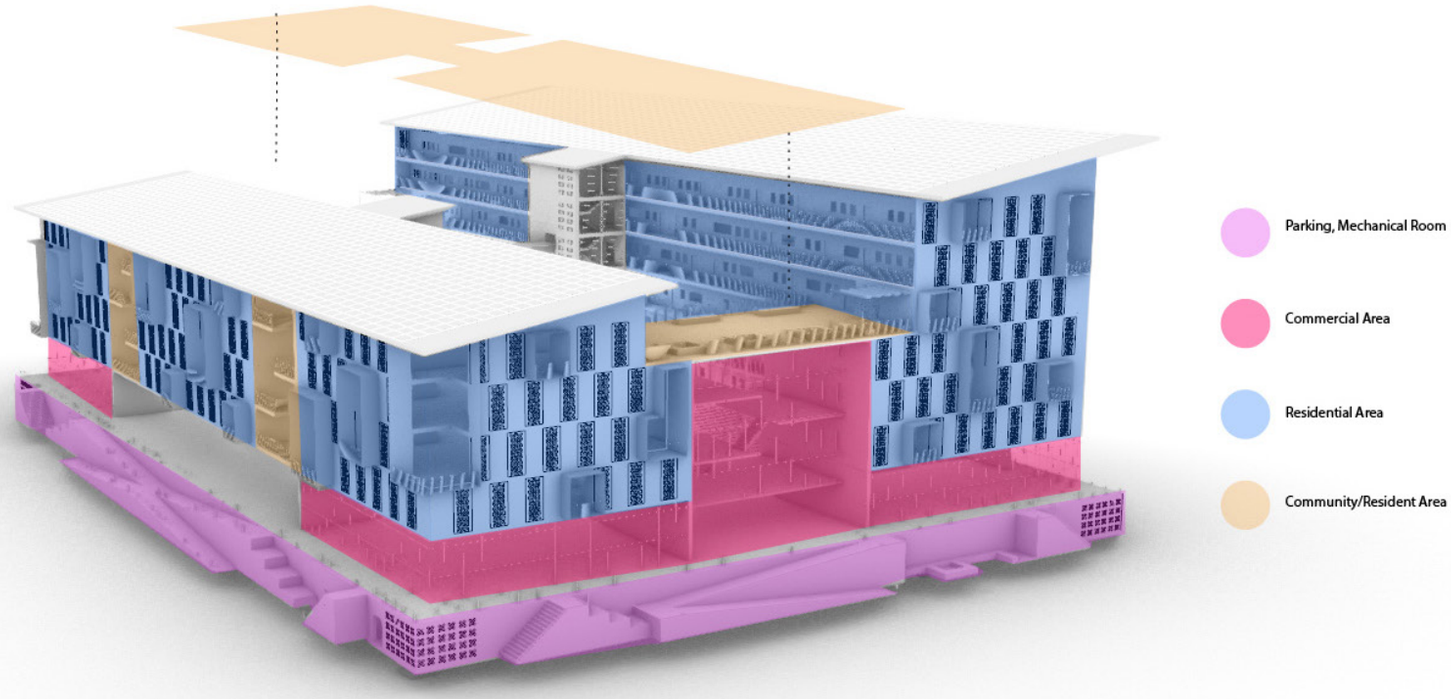
Floor	Residential (square feet)	Commerical (square feet)	Community Area (square feet)
Ground Floor	0	0	0
First Floor	4,720	17,870	15,790
Second Floor	29,300	7,130	14,000
Third Floor	29,300	3,340	2,000
Fourth Floor	29,300	2,650	2,000
Fifth Floor	27,200	3,390	9,340
Sixth Floor	15,360	0	0
Seventh Floor	15,360	0	0



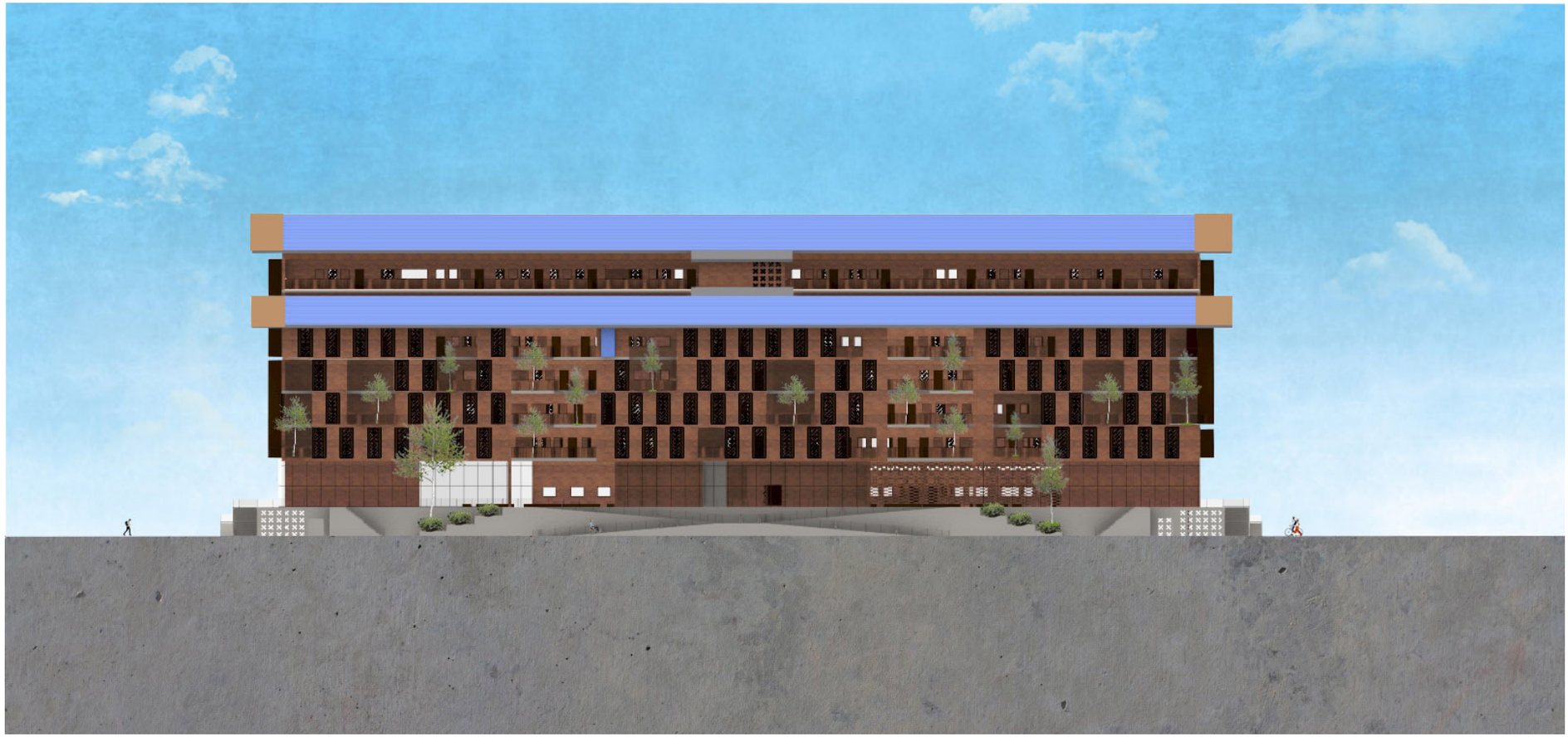
* Numbers are rounded to the hundreds

ELEVATIONS

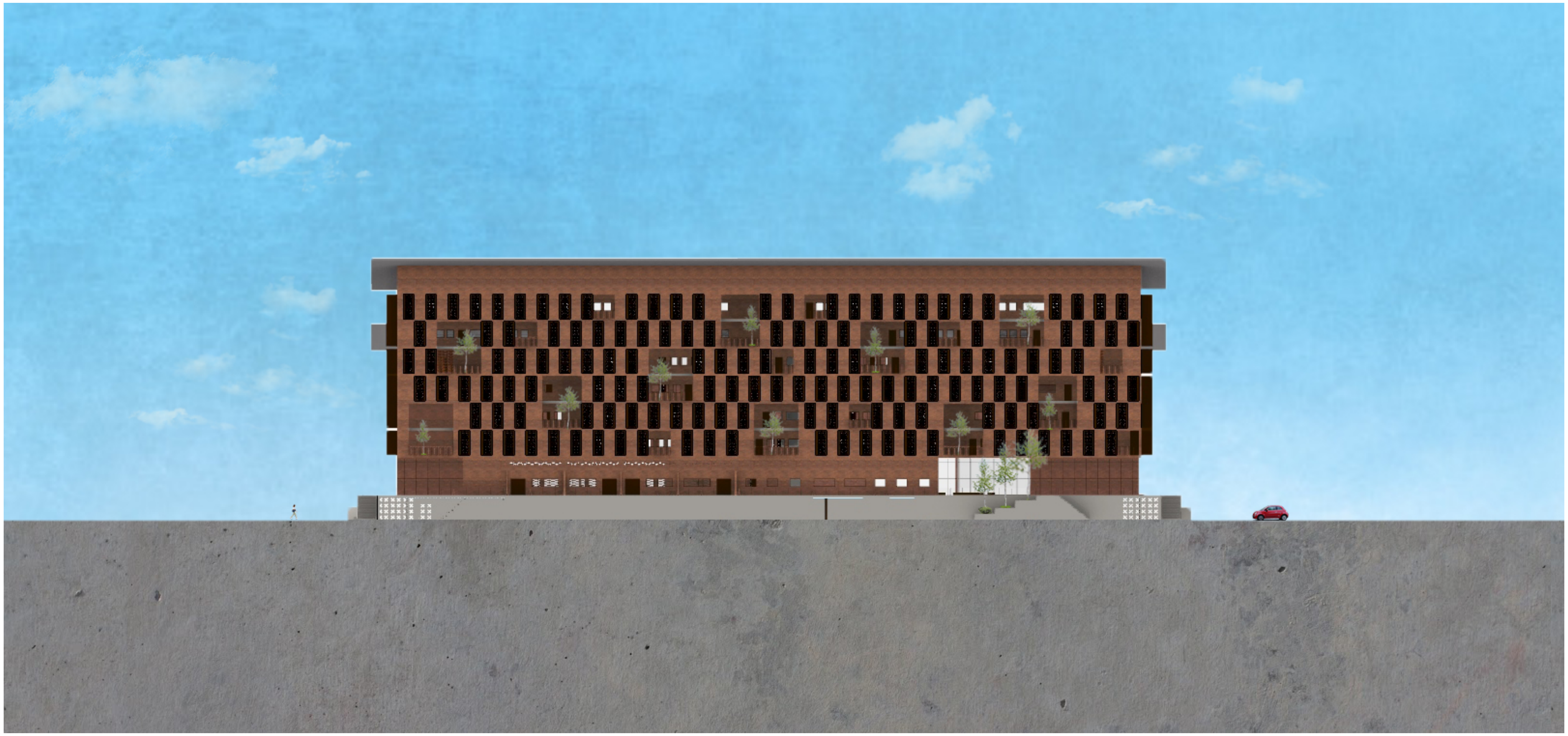
Program Diagram



South Elevation

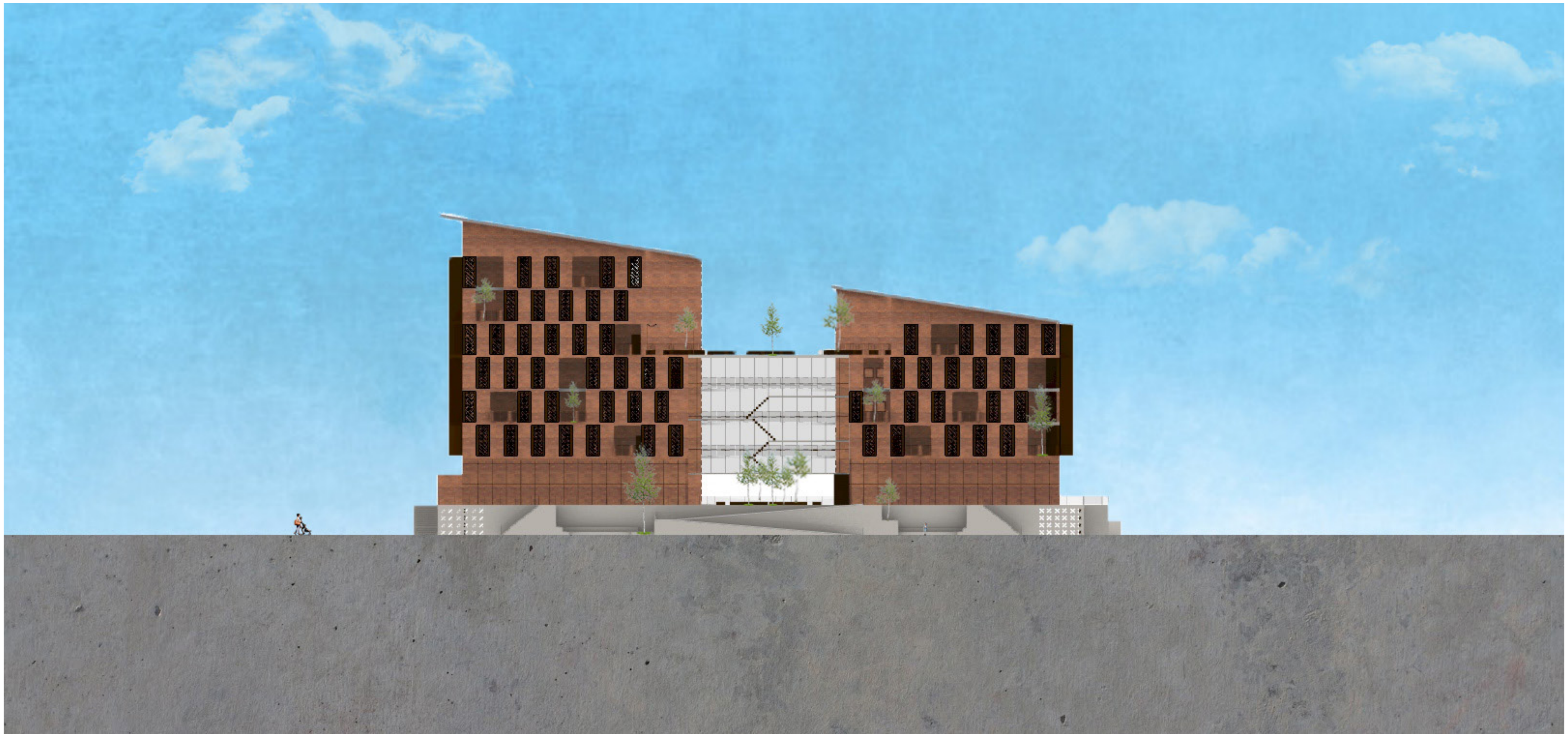


North Elevation

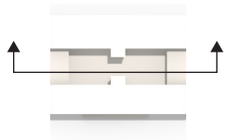


East Elevation

West Elevation

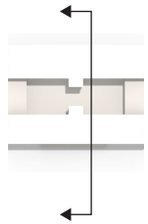


SECTIONS

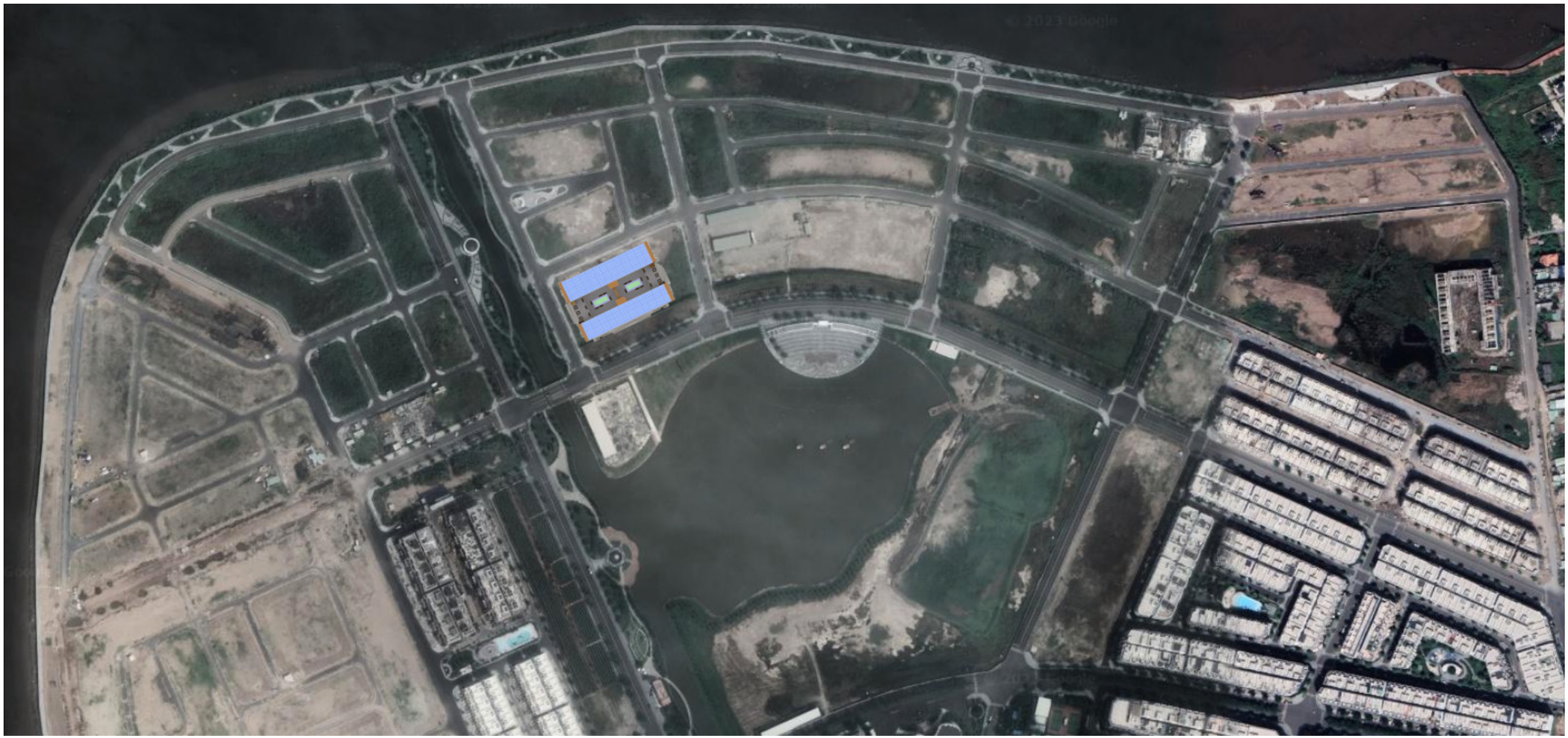


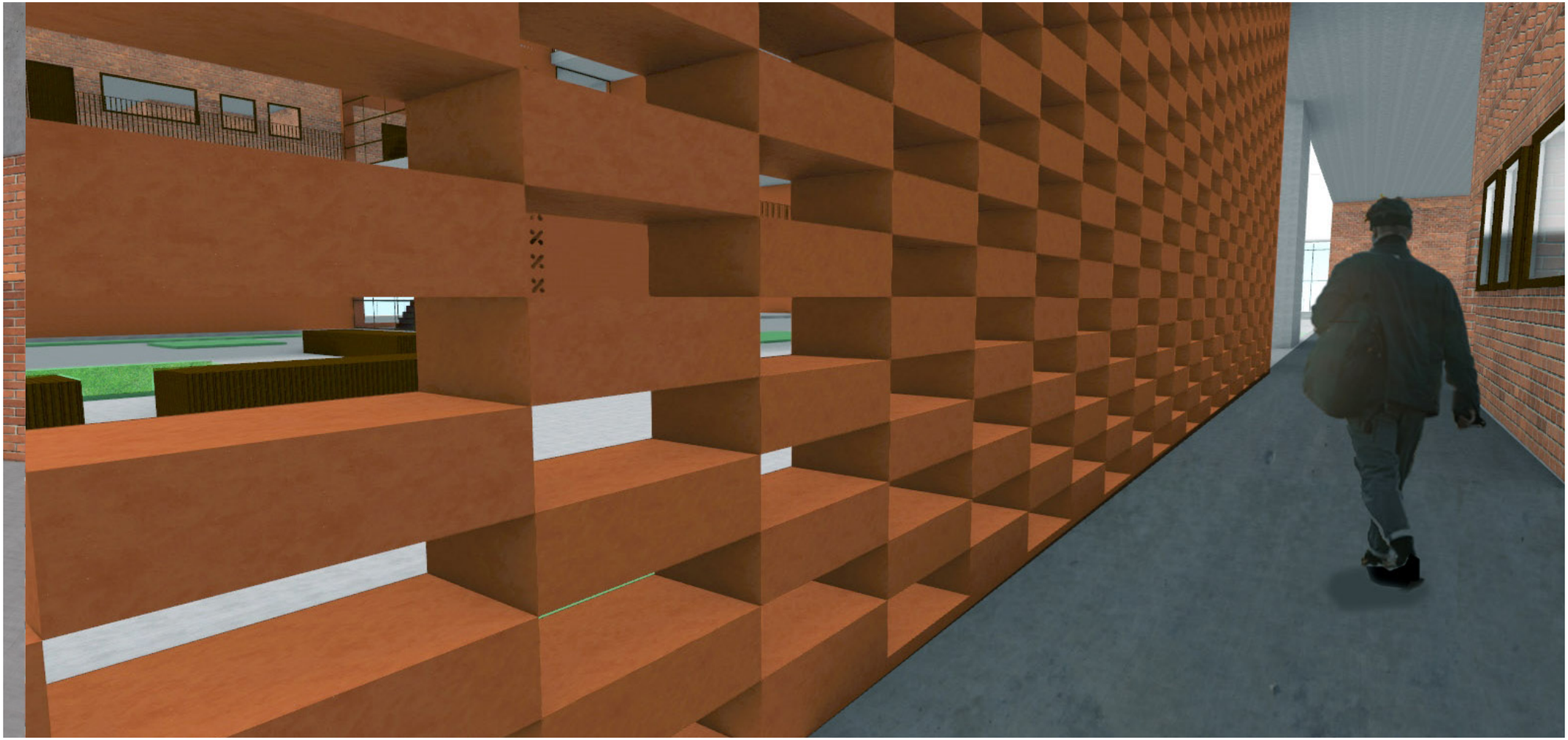
Section 2

Section 3

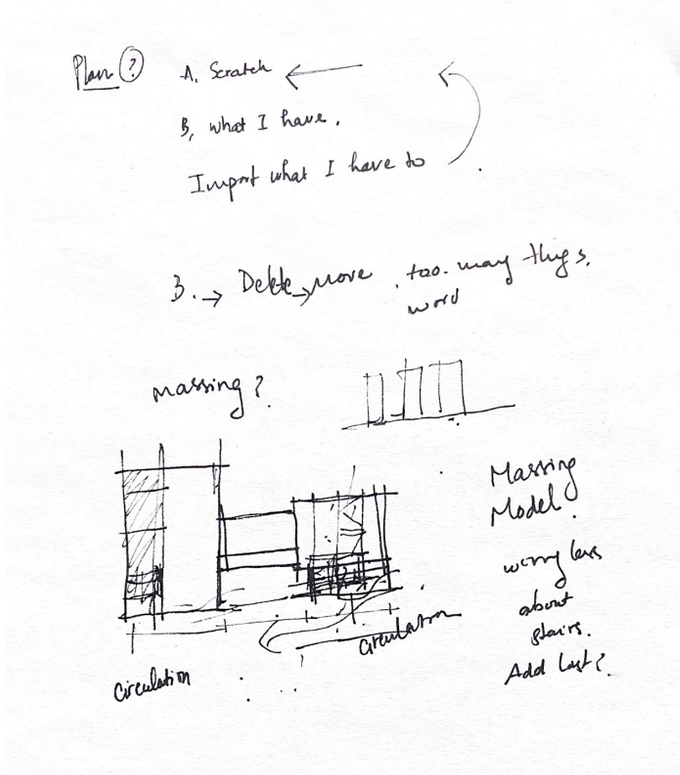


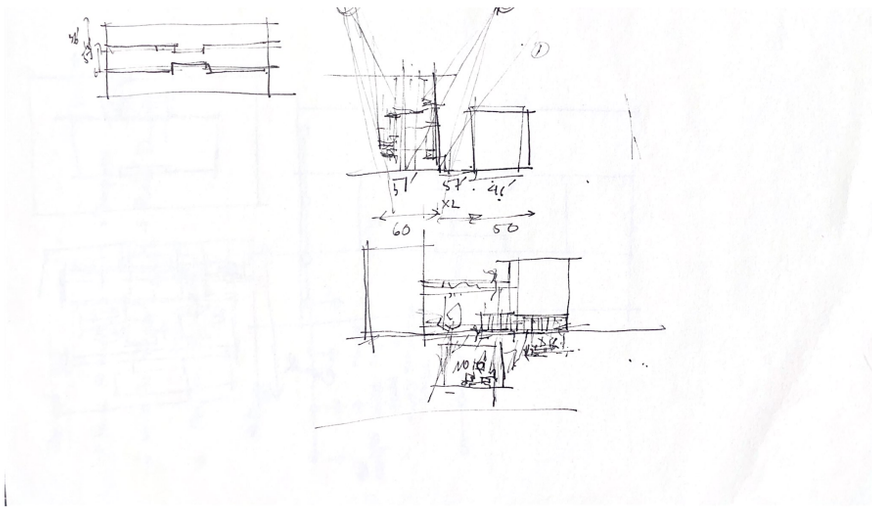
SITE PLAN

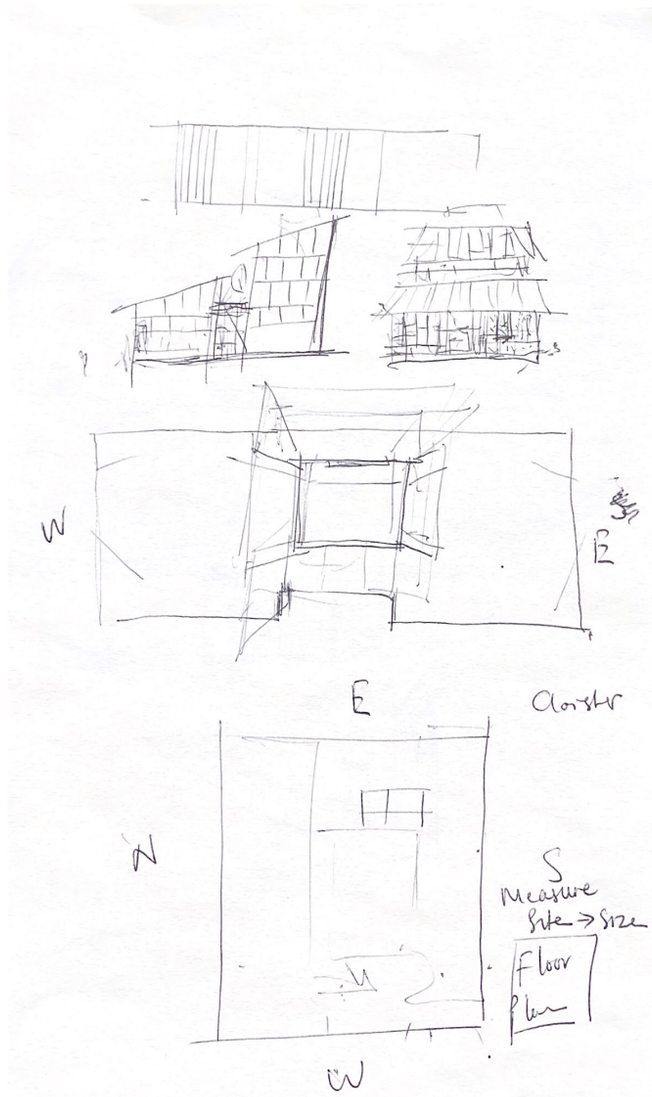




Renderingvvv


Plan ?
A. Scratch
B, what I have.
Input what I have to
3. → Delete, move . too. many things. word
massing ?
Massing Model
worry less about stairs. Add last?
Circulation
Circulation


57'
57'
41'
60
XL
50


W
E
E
Cloister
N
S
Measure Site → Size
floor Plan
W

PART III: CONCLUSION

Figure: Rendering of the Ground Level

CONCLUSION

Conclusion further discusses the design process, the project limitations, and future plans.

As with many of my design projects, I started this thesis design proposal by making a series of sketches in my notebook. Sketches are powerful, suggestive thinking and visualization tools that hold many possibilities and potentials waiting to be unravelled under the tip of my graphite.

Inspired by Vietnamese vernacular architecture and the openness of the complexes' courtyards, the floor plan centers around a courtyard that encourages community engagement and activities. Soon, I transferred my sketch into the first drafts of 2D elevations and floor plans to evaluate the strength and weaknesses of the design.

As the design evolved, I simultaneously modeled the building in Rhinoceros and conducted the research, so the design altered as I understand more about the site, Ho Chi Minh's city environmental challenges, net zero strategies, and vernacular architecture precedents. Plus, through regular critiques with my advisor, I soon realized that the proportions of my original courtyard in relation to the building mass and roof are not ideal for optimizing daylighting. Therefore, I restarted with new dimensions and courtyard forms that address the previous issues. Design decisions were carefully made as I questioned the sustainability value added to the building. I also considered whether my design solutions tackle the flooding and sinking challenges that Ho Chi Minh City currently faces.

Thus, the design project prompts me to think about the occupants' comfort and how to best create a built environment that responds to human needs for thermal comfort, entertainment, community engagement, space, and functionality.

For me, every design project involves a problem-solving process that requires my attention to details and the big concepts. Coming out of every project, I grow more as a thinker, designer, and learner.

Limitations

For me, this thesis still faces many limitations and challenges.

The most sustainable buildings are the existing buildings. Unfortunately, most of the solutions provided by this new built apartment do not apply to the existing building stock. Some renovation solutions such as damproofing or elevating the living space can prepare the residents for the future flooding scenarios, but this thesis is not meant for renovations.

Despite the government's endorsement of net zero designs, people might not receive the new changes well as they are used to the old ways of living. We are approaching a time for the city and people to apply adaptive and mitigating strategies on a wide scale very fast as Ho Chi Minh City is among the top five most affected cities by the coming sea level rise. Therefore, the city needs to mentally prepare the people for the drastic changes, as well as partially funding the renovation projects.

Since there are no precedents, part of the initial prototype build would be to collect data so that these ideas can be applied more broadly.

The developers and city officials are in control of deciding the built projects and the designs. Therefore, they still have the tendency to choose highly profitable projects, which are high end, extravagant skyscrapers or mansions despite the negative environmental consequences. Thus, the high level of difficulty and cost of training the construction workers might drive contractors away from building the vernacular and net zero integration projects.

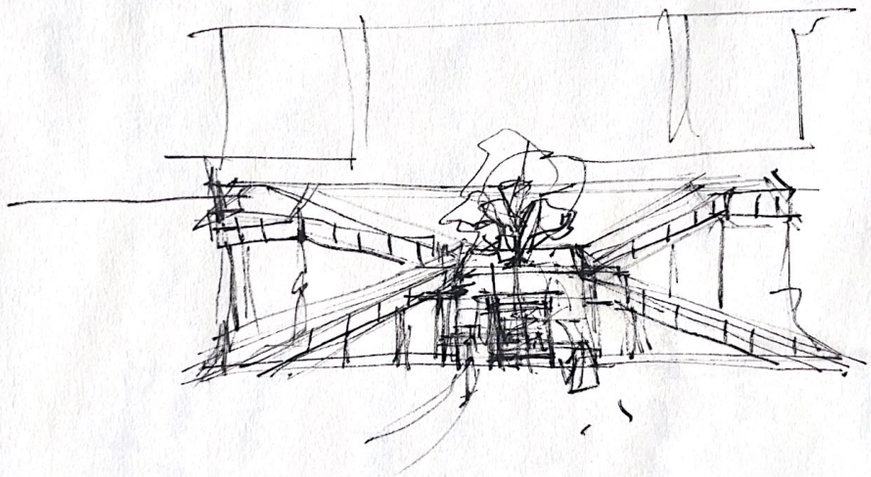
The site of this project does not have much constraint in constrasts to the site that locates in a densely populated neighborhood, which is more common in Ho Chi Minh City.

With the current sea level rise projections, Vietnam is spiraling towards irreversible losses and damages that start with the disappearance of the South of Vietnam. This thesis is an attempt to suggest adaptive measures in the built environment that adopts the vernacular architecture values and net zero strategies.

Moving forward, Ho Chi Minh City should adopt a net zero design, carry out environmental analysis, train the builders, and build the first pilot projects to test out the prototype and collect data to inform the next stage of net zero developments and retrofits in Vietnam.

I am optimistic that Vietnam will abide by its net zero commitment by 2050 with the current pace of investment and policy development that incentivizes net zero practices. Plus, the people of Ho Chi Minh City have had extensive experience withstanding the flooding, so the design proposal can meet the people's need for a flood-resilient design guide.

This thesis serves as an example that a new design project can incorporates the latest technology to prepare for the future while maintaining the past architectural and cultural identity of the land. In a sense, half of Saigon will be underwater by 2100 but the resilience of these culturally and environmentally sensible projects will maintain and carry on the city's rich heritage by staying afloat.



Citations

Flavelle, Christopher. “Rising Seas Will Erase More Cities by 2050, New Research Shows (Published 2019).” The New York Times, 29 October 2019, https://www.nytimes.com/interactive/2019/10/29/climate/coastal-cities-underwater.html. Accessed 13 December 2021.

Insightguides.com. Accessed November 19, 2022. https://www.insightguides.com/destinations/asia-pacific/vietnam/historical-highlights.

“World Bank Climate Change Knowledge Portal.” Home. Accessed November 19, 2022. https://climateknowledgeportal.worldbank.org/.

“Viet Nam.” BIOFIN. Accessed November 19, 2022. https://www.biofin.org/viet-nam#:~:text=Viet%20Nam%20is%20listed%20as,are%20sea%20bird%20species%2C%20653.

“CO2 Emissions by Country.” Worldometer. Accessed November 19, 2022. https://www.worldometers.info/co2-emissions/co2-emissions-by-country/.

“Vietnam’s Circular Economy: Decision 687 Development Plan Ratified.” Vietnam Briefing News, September 15, 2022. https://www.vietnam-briefing.com/news/vietnams-circular-economy-decision-687-development-p lan-ratified.html/.

Raitzer David. “Publications.” Asian Development Bank. Asian Development Bank, October 6, 2022. https://www.adb.org/publications.

Malacaster, Alice. “The Impact of the Built Environment on Climate Change – and of Climate Change on the Built Environment.” DesignOpen. Accessed November 19, 2022. http://www.open.ac.uk/blogs/design/the-impact-of-the-built-environment-on-climate-change-and- of-climate-change-on-the-built-environment/#:~:text=Why%20is%20the%20built%20environmen t,than%20any%20other%20individual%20sector.

“Vietnam.” Vietnam - Place Explorer - Data Commons. Accessed November 19, 2022. https://datacommons.org/place/country/VNM?utm_medium=explore&mprop=count&p opt=Person&hl=en.

"COP27 Reaches Breakthrough Agreement on New 'Loss and Damage' Fund for Vulnerable Countries." Unfccc.int. Accessed December 20, 2022. https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnera

"Progress Report: Vietnam's Pursuit of Net Zero." Vietnam Briefing News, November 28, 2022. https://www.vietnam-briefing.com/news/vietnam-net-zero.html/.

"The Vibes." Infinitive. Accessed December 20, 2022. http://infinitive.com.vn/about.aspx.

O, Kientruc. "Kientruc o." KIENTRUC O. Accessed December 20, 2022. https://kientruco.com/.

Architecture, Tropical Space | Vietnam. "Tropical Space: Không Gian Nhiệt Đới: Vietnam Architecture." Tropical Space | Không Gian Nhiệt Đới | Vietnam Architecture. Accessed December 20, 2022. https://tropicalspaceil.com/.
1+1>2. Accessed December 20, 2022. http://112.com.vn/.

Global Future Cities, "Ho Chi Minh City," accessed May 4, 2023, https://www.globalfuturecities.org/socialist-republic-viet-nam/cities/ho-chi-minh-city.

Vietnam Travel, "Overview of Ho Chi Minh City," accessed May 4, 2023, https://vietnamtravel.com/overview-of-ho-chi-minh-city/#:~:text=Ho%20Chi%20Minh%20City%2C%20also,business%20capital%20of%20the%20country.

Stephenson, Hannah. "Thu Duc: A Saigon District Modernising the Vietnamese Way," The Culture Trip, accessed May 4, 2023, https://theculturetrip.com/asia/vietnam/articles/thu-duc-a-saigon-district-modernising-the-vietnamese-way/.

VietnamNet, "The dream city: Thu Duc or Saigon?," accessed May 4, 2023, https://vietnamnet.vn/en/the-dream-city-thu-duc-or-saigon-683753.html.

ASHRAE, "Psychrometrics," accessed May 4, 2023, https://www.ashrae.org/technical-resources/bookstore/psychrometrics.

Nguyen, Anh-Tuan, and Sigrid Reiter. "Analysis of Passive Cooling and Heating Potential in ... - Uliege.be." Accessed May 4, 2023. https://orbi.uliege.be/bitstream/2268/99725/1/CISBAT%20final%20paper.pdf.

Gendre, Ines. Greenly, “Representative Concentration Pathway (RCP): What Is It?,” accessed May 4, 2023, https://greenly.earth/en-us/blog/ecology-news/representative-concentration-pathway-rcp-what-is-it.

Anh Ngoc Le et al, “Climate trends and climate change scenarios in Ho Chi Minh City,” IOP Conference Series: Earth and Environmental Science 964 (2022): 012009.

Paolo Scussolini et al, “Adaptation to Sea Level Rise: A Multidisciplinary Analysis for Ho Chi Minh City, Vietnam,” Water Resources Research 53, no. 12 (2017): 10464-10482, https://doi.org/10.1002/2017WR021344.

Tran, Mi. Vietcetera, “Ho Chi Minh City Is Sinking Fast,” Vietcetera, May 10, 2019, https://vietcetera.com/en/ho-chi-minh-city-is-sinking-fast.

Lan Anh. Kinh te & Moi truong, “Tại sao tốc độ sụt lún tại TP.HCM ngày càng cao?” Kinh te & Moi truong, August 30, 2021, https://kinhtemoitruong.vn/vi-sao-toc-do-sut-lun-tai-tphcm-ngay-cang-cao-71538.html.

U.S. Environmental Protection Agency, “Particulate Matter (PM) Basics,” accessed May 4, 2023, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

Universiti Teknologi MARA (UiTM). “‘Green-mix’ concrete: An environmentally friendly building material.” ScienceDaily. www.sciencedaily.com/releases/2015/05/150526093237.htm (accessed May 4, 2023).

Zero Energy Project, “Twelve Steps to Affordable Zero Energy Home Construction & Design,” accessed May 4, 2023, https://zeroenergyproject.com/build/twelve-steps-affordable-zero-energy-home-construction-design/.

Nicola Cooper, “Urban planning and architecture in colonial Indochina,” Journal of Southeast Asian Studies 42, no. 1 (2011): https://doi.org/10.1017/S0022463410000557.

Khu đô thị Vân Phúc, “Vân Phúc: Không ngập nước,” accessed May 4, 2023, https://khudothivanphuc.com.vn/.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