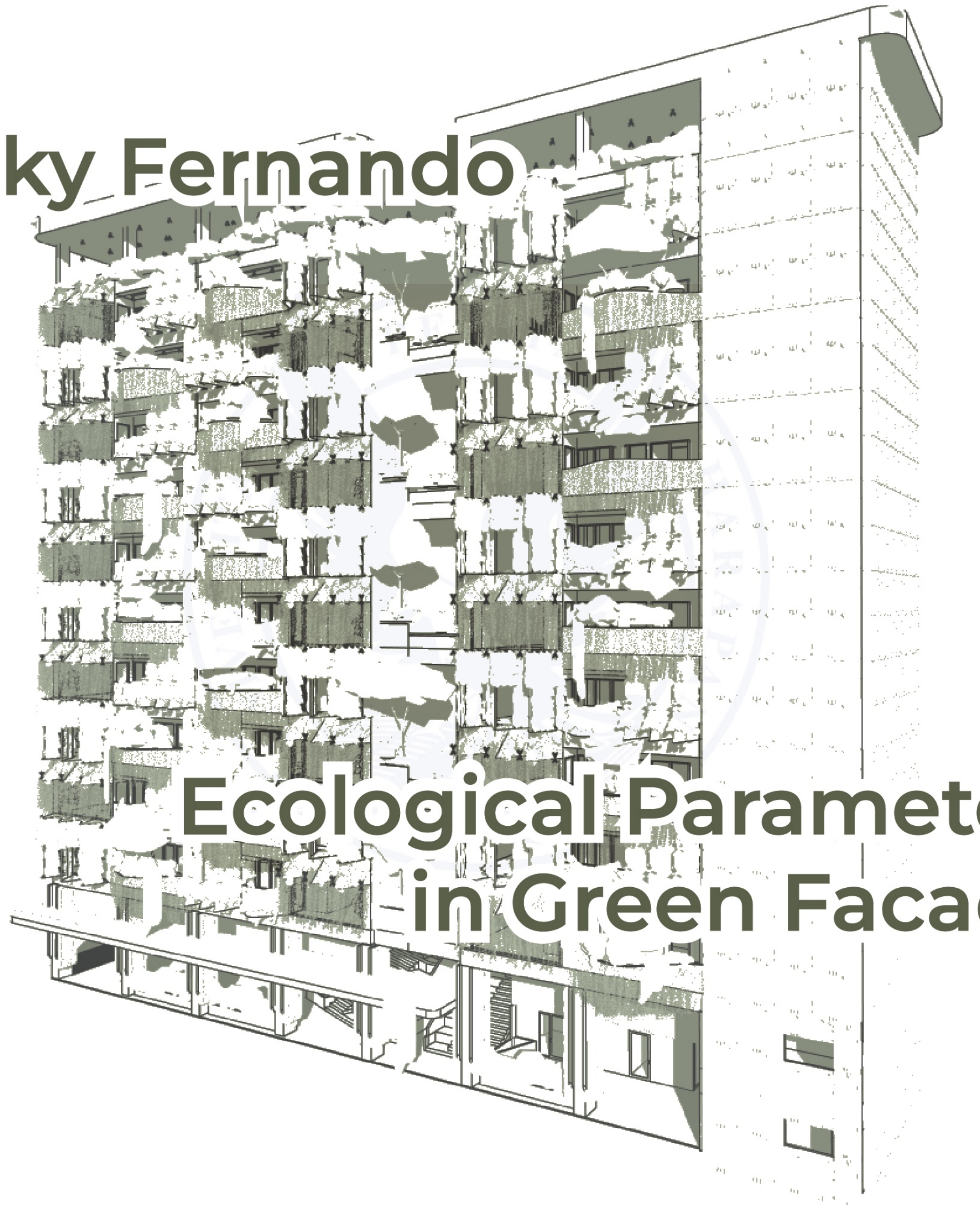
Pelita Harapan Design Report

Ricky Fernando



Ecological Parameter in Green Facade

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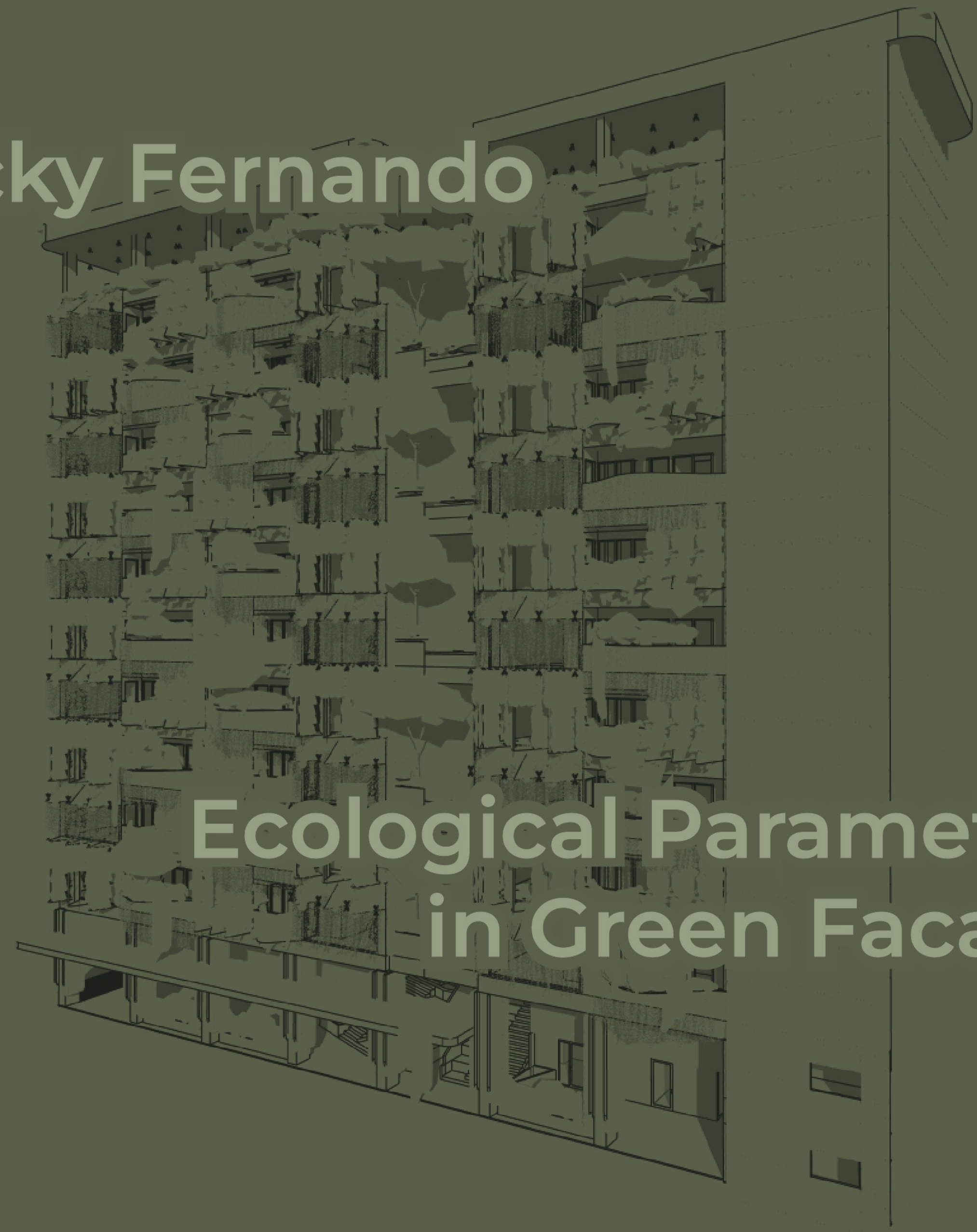

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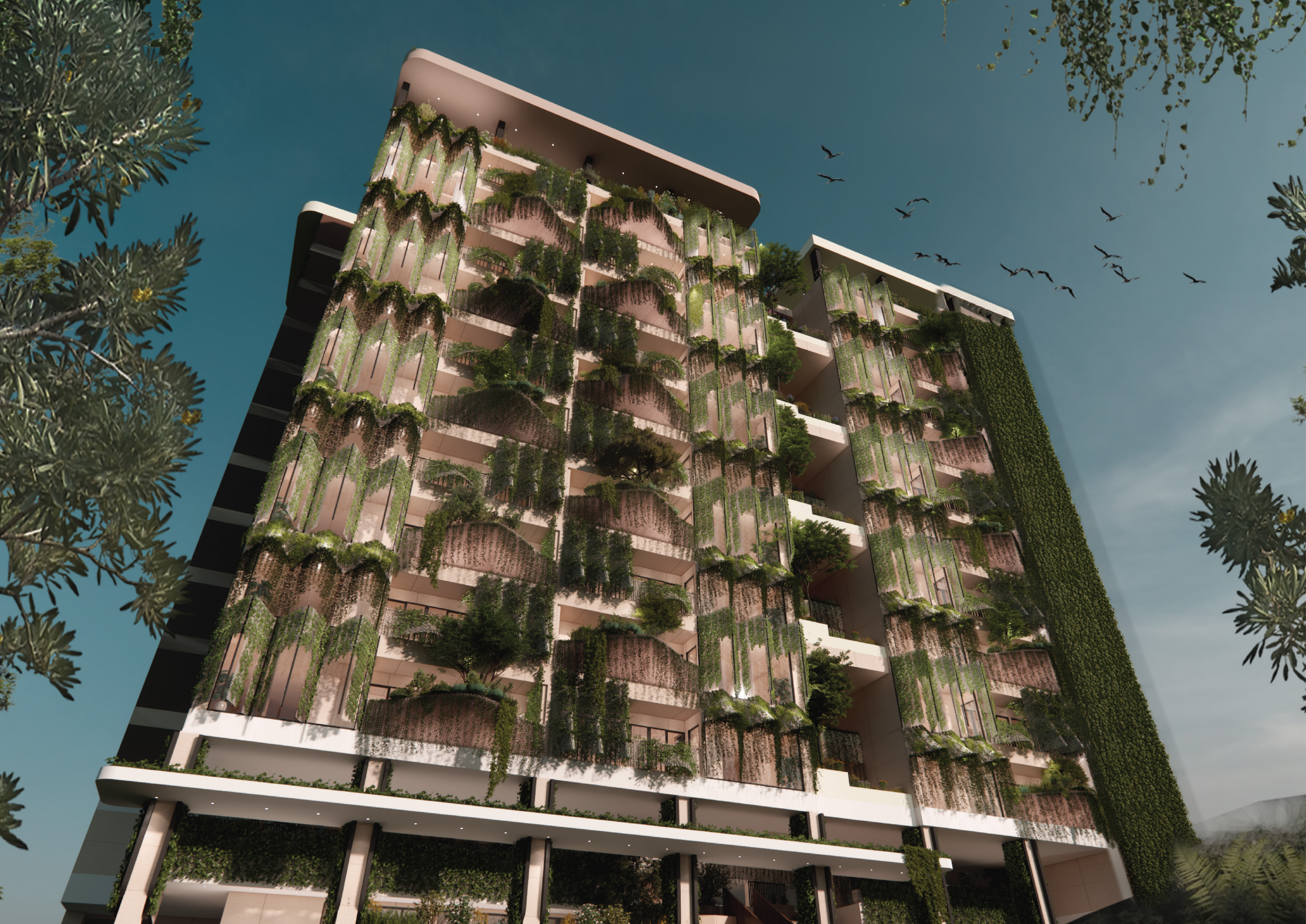


1 [previous] Final look of finished project

2 Front view of the parametric generated green facade

Project Details

Author	Ricky Fernando
Title	Integration of Parametric Tools in Green Facades of Vertical Housing as Ecological Compensation
Output Type	Building Design Proposal
Function	Residential
Location	Nusantara, East Kalimantan
Research Period	August 2024 to May 2025

About Research

Description

“Evolutionary applications using parametric applications to generate, analyze, and select design iterations.” (Toker, 2022)

This project applies all three potentials of parametric tools to determine how the implementation of green facades on vertical housing can be optimized for ecological benefits, thus qualifying as a form of ecological compensation.

Ecological compensation in this project is carried out as an environmentally conscious effort, considering that the 43,000 m² site of the Goverment Employee (*ASN*) 3 apartment complex in IKN was originally a green area.

Questions

1. What are the ecological compensation parameters that can be applied through green facades?
2. How can ecological parameters be implemented using parametric tools in vertical housing?
3. How does the implementation of parametric tools in green facades within vertical housing influence ecological aspects?

Methodology

The research on the Integration of Parametric Tools in Green Facades for Vertical Housing as Ecological Compensation follows a linear progression by utilizing simulation-based research methods. The simulation approach is carried out through parametric tools in the study of green facade design aspects. On a broader scale, the simulation method is divided into three sub-methods: literature review, parametric tool exploration, and prototype development.

Dissemination

The "Integration of Parametric Tools in Green Facades of Vertical Housing as Ecological Compensation" was developed through the Architectural Thematic Design Studio (August to December 2024) and the Architectural Integration Design Studio (January to May 2025). Throughout this process, the project underwent several review sessions in collaboration with Alien Design Consultant in December 2024, and February, March, & April 2025, aimed at gaining valuable design input. The feedback gathered during these reviews is utilized to produce main outcomes: the thesis defense.

Result

Integration of Parametric Tools in Green Facades of Vertical Housing as Ecological Compensation utilizes several parameters, with the primary parameter determining the fulfillment of ecological compensation—ecological metric—being the Green Plot Ratio (GnPR).

As the main parameter in this project, the Green Plot Ratio serves as a tool to test the effectiveness of the ecological compensation offered by the proposed design. This metric works by comparing the total amount of vegetation present on the site and building (Total Leaf Area) with the Site Area of the building.

In the exploration of green facade elements within the case study, alternative proposals were developed according to the division of the Green Plot Ratio matrix on the site (Ground GnPR) and the Green Plot Ratio of each tower of the *ASN* 3 Apartment Complex in IKN (Existing Building GnPR). Eventually, the GnPR value of the existing building is compared with the GnPR resulting from the design intervention (Potential GnPR).

At the *ASN* 3 apartment complex in IKN, the initial calculation of the existing design resulted in an Existing GnPR value of 0.73397. Meanwhile, the design proposal for the *ASN* 3 apartment complex in IKN achieved a GnPR value of approximately 3.0275. This indicates that the intervention produces four times more vegetation than the existing design. Moreover, the GnPR value of ~3.0275 signifies that the design—with a footprint of approximately 1,100 m² per tower—can provide ecological compensation equivalent to vegetation planted on a 130,182.5 m² area (43,000 m² x 3.0275).

3 Hundertwasser’s concept of green facade

Introduction

Urban expansion is occurring massively in both developed and developing countries by increasing building density—through construction—in the remaining urban areas or by opening up new land in areas that were previously non-urban. (Blei, 2011; Musa et al., 2017) By 2030, nearly 5.87 million km² of land is projected to be converted into urban areas, with approximately 1.2 million km² designated specifically for urban expansion. (Seto et al., 2012) This expansion significantly alters the surrounding regions, and the process—driven by deforestation and land degradation—has negative impacts on ecological systems. (Gómez-Baggethun et al., 2013a; Reed, 2015)

Several efforts have been made to reduce the rate of new land conversion for urban purposes, including the compact city approach, which promotes vertical urban development as one of its key strategies. (Lin, 2016) This type of development is often praised for its potential environmental, social, and economic benefits. However, in reality, when compared to other building typologies, high-rise buildings are among the least ecological, as they consume approximately 35% more energy and resources throughout their lifecycle—from construction and operation to maintenance and eventual demolition. (Shelton et al., 2013; Yeang & Richards, 2007)

In response to urban expansion—both horizontal and vertical—which has adverse ecological impacts, it is crucial to pursue ecological compensation efforts, particularly through the provision of green spaces. The utilization of unused passive areas within vertical urban development presents an opportunity to introduce green spaces. (IGES, 2023; Pfoser & Kammerbauer, 2024) The application of vegetation on facades—and rooftops—(green facades) of vertical buildings offers multiple benefits: it enhances the urban landscape quality and contributes to a healthier and more sustainable environment. (Pfoser & Kammerbauer, 2024)

From another perspective, the implementation of green facades in urban spaces not only benefits the environment, but also humans as an integral part of the ecosystem. As noted, social practices not only affect which ecosystem services are produced through the management of urban ecosystems, but also who in society benefits from them. (Andersson et al., 2007; Ernstson, 2013; Gómez-Baggethun et al., 2013b) Therefore, the residential function is incorporated into the vertical typology as part of the study on green facades as a means of ecological compensation.

Ecological compensation is defined as an effort to reduce, offset, or remediate the impacts of development on ecosystems and their components. This approach involves providing ecological value in alternative areas and is considered a last-resort option, applied only when there are no other means to prevent the exploiters from extracting, damaging, or clearing new land. (Olsson Johanna Alkan et al., 2023) Ideally, ecological design should be grounded in man-made spaces, and the integration of natural environments into urban spaces serves as a strategic starting point for nature to respond to urban conditions. (Hough Michael, 1984; Ian L. McHarg, 1995; Wang et al., 2005) Ecological compensation through the implementation of green facades in vertical housing exemplifies one way in which the natural environment can be integrated into the urban fabric.

In the effort to implement ecological compensation, there are variables that determine the measurability of an ecosystem's characteristics, referred to as ecological parameters. (Agency, 2021) To assess research potential, the green space ratio parameter—which compares green areas such as parks, gardens, and other vegetated zones to built-up areas—is used as the primary parameter in the study of green facades in vertical housing as a form of ecological compensation. (Ong, 2003)

Ecological parameters are significantly influenced by the measurements, metrics, and methods used to evaluate the effectiveness of an element in contributing to the environment or providing ecological compensation. (Zawarus, 2022a) This process requires tools capable of processing measurable inputs, data, surveys, and other relevant information—namely, parametric tools. Although parametric tools are more commonly associated with form-finding processes, their application in research offers broader possibilities, including performance analysis and design optimization through simulations that account for multiple scenarios. (Arbulu et al., 2024; Zawarus, 2022a, 2022b)

Through the potential offered by parametric tools, the success parameters (minimum thresholds for the creation of) ecological compensation become the primary focus of this research on green facades, followed by the effectiveness (design optimization & green space ratio) of the compensation offered and its impact on users as well as the programming in vertical housing. (Gatley & Walker, 2014)

4 Site of *ASN* 3 apartment complex in IKN—as a tangible example of the phenomenon of urban expansion

Aims and Objectives

This research aims to explore the potential of green facades as an ecological compensation strategy in vertical housing, with a focus on the application of ecological parameters through parametric tools and the resulting ecological impacts. Specifically, the objectives of this research are as follows:

1. To identify ecological compensation parameters that can be applied to green facades.
2. To understand the application of ecological parameters utilizing parametric tools in vertical housing.
3. To assess the ecological impacts of implementing parametric tools in green facades within vertical housing.

The design process for the strategy is based on the context and research methodology. In the exploration phase of the green facade elements/media in the case study, alternative proposals are made according to the division of the Green Plot Ratio matrix on the site (Ground GnPR) and the Green Plot Ratio for each tower of *ASN* 3 apartment in IKN (Existing Building GnPR). Ultimately, the GnPR of the existing building is compared with the GnPR resulting from the design intervention (Potential GnPR).

5 Random greeneries placement identified in the existing design of ASN 3 apartment tower in IKN

Questions

What are the ecological compensation parameters that can be applied through green facades?

Ecological compensation policies in the form of green facades, both implicitly and explicitly, include how the optimal implementation of green facades serves as a form of compensation. Zoning Regulations in the United States and Singapore's LUSH (Landscaping for Urban Spaces and High-rises) even include methods for calculating ecological compensation in the form of vegetation—one of which is green facades. Based on several considerations, the Green Plot Ratio (GnPR) is selected as the main approach adapted as an ecological metric to determine the fulfillment of ecological compensation.

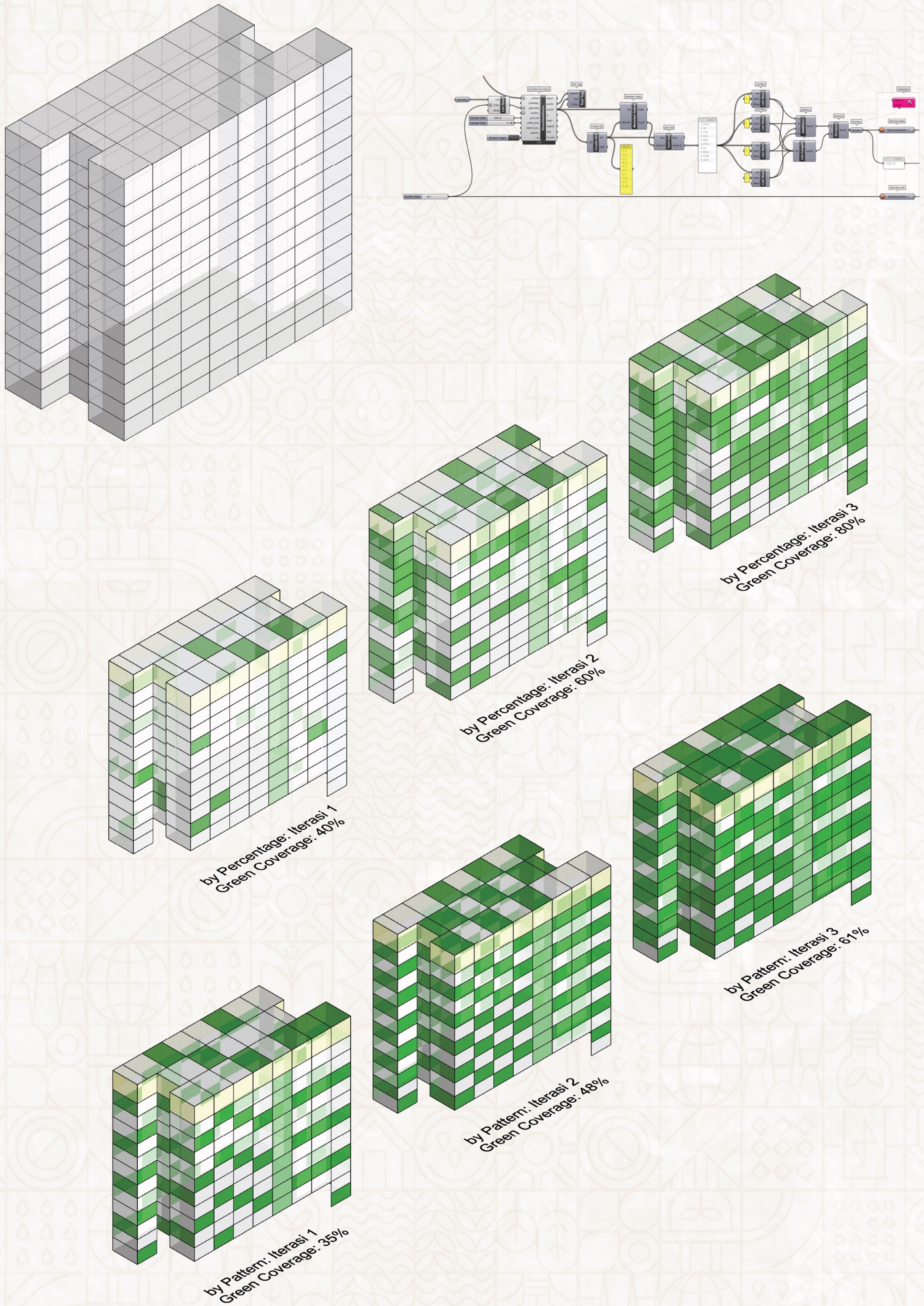
How can ecological parameters be implemented using parametric tools in vertical housing?

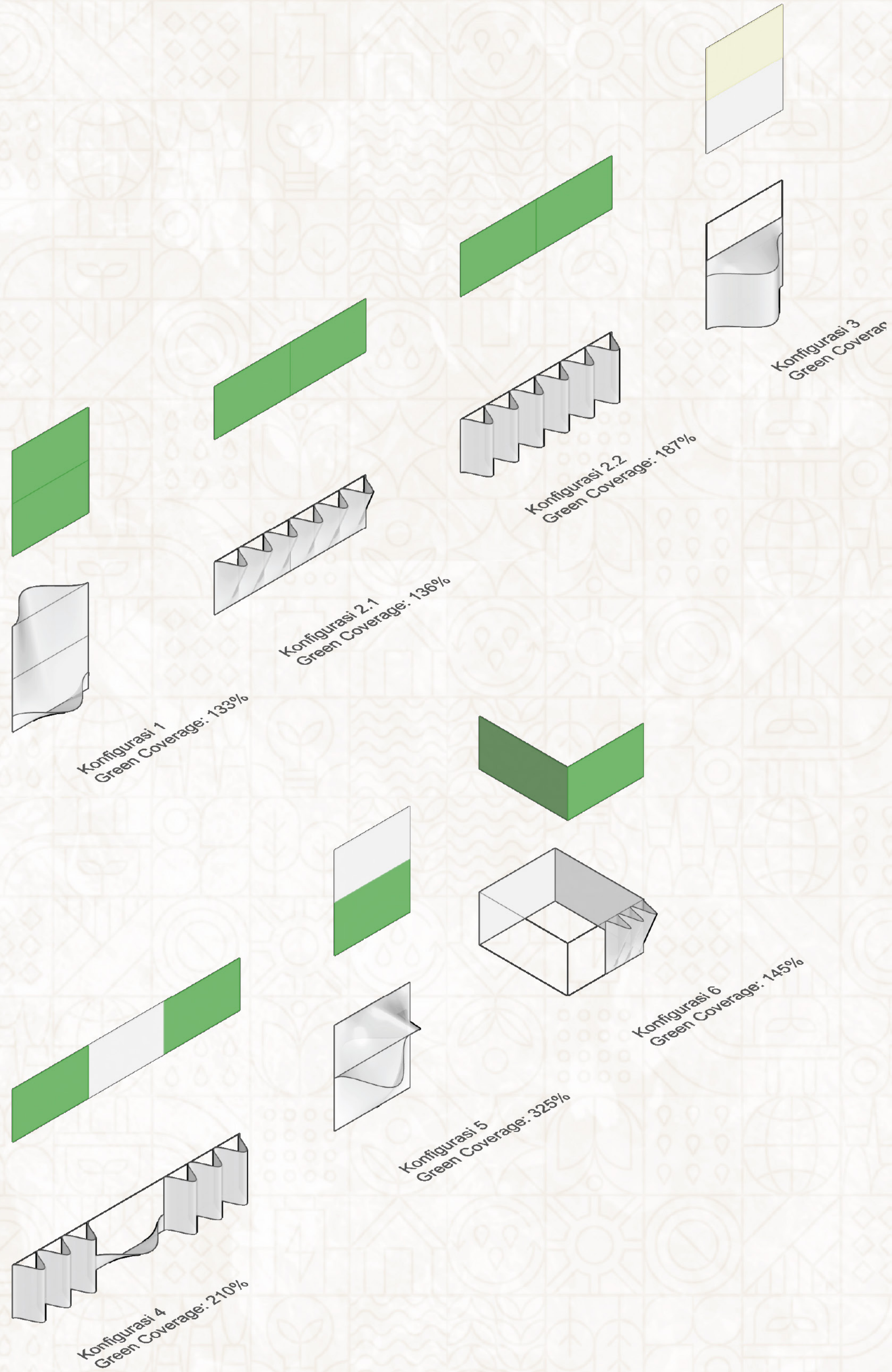
The integration of ecological parameters in the green facade design process of the *ASN* 3 apartment in IKN, utilizing parametric tools, is carried out through several phases [fig. 7]:

1. **Target of Algorithm:** The making of grid massing structure
2. **Logic of Algorithm:** Integration with grasshopper definition
3. **Algorithm Result:** Parametric generated green area
4. **Intepretation of Algorithm:** Configuration of green area
5. **Module Form Exploration:** Maximizing surface form
6. **Implementation and Visualization:** Configuration overview

6 Ecological compensation parameters represented in diagram

7 [overleaf] Applications of parametric tools in generating design iterations


by Percentage: Iterasi 1
Green Coverage: 40%
by Percentage: Iterasi 2
Green Coverage: 60%
by Percentage: Iterasi 3
Green Coverage: 80%
by Pattern: Iterasi 1
Green Coverage: 35%
by Pattern: Iterasi 2
Green Coverage: 48%
by Pattern: Iterasi 3
Green Coverage: 61%

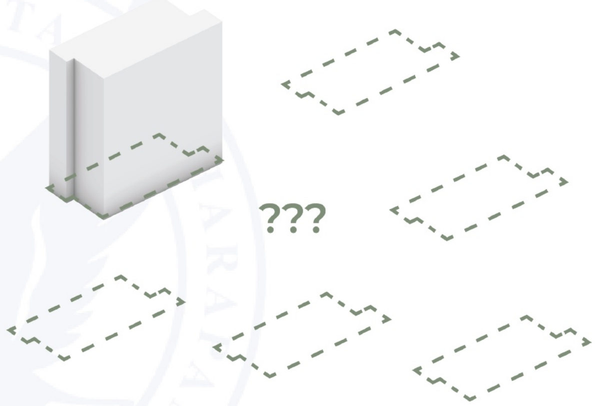

Konfigurasi 1
Green Coverage: 133%
Konfigurasi 2.1
Green Coverage: 136%
Konfigurasi 2.2
Green Coverage: 187%
Konfigurasi 3
Green Coverag
Konfigurasi 4
Green Coverage: 210%
Konfigurasi 5
Green Coverage: 325%
Konfigurasi 6
Green Coverage: 145%

Questions

How does the implementation of parametric tools in green facades within vertical housing influence ecological aspects?

The planning process of green facades depends on several parameters that determine their optimization. The design aspect parameter is one of the initial parameters where parametric tools can be integrated. Fulfillment of this parameter encourages green facades to not only be aesthetically appealing, but also promote sustainability and the well-being they offer. (Manouchehri et al., 2024) The design aspect parameter includes several aspects, with those affecting ecological performance such as:

1. **Placement**
   The placement points of green facades are crucial, as several green facade categories require additional structures, specific opening points, light intensity, and accessibility for maintenance.



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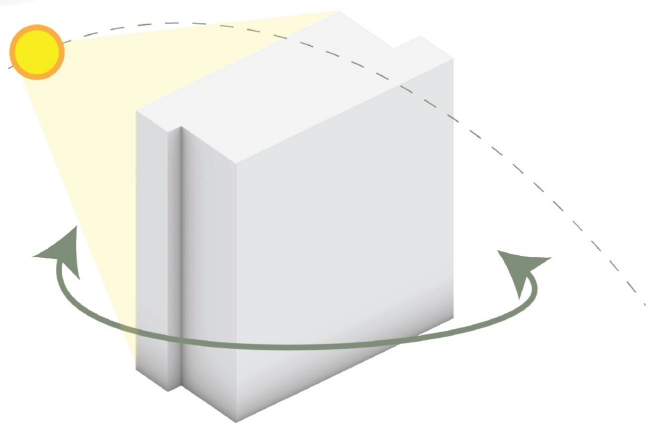
2. **Orientation**
   Since green facades are plant-based, sunlight is essential for their growth, making the building's orientation a key factor. In addition to benefiting the green facade, building orientation helps determine which areas receive excessive sunlight, allowing green facades to function as shading elements.



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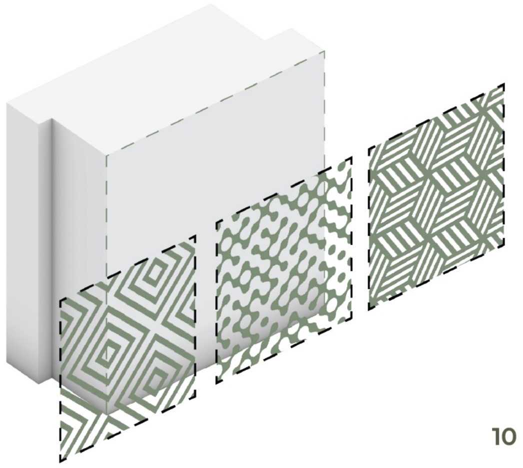
8-12 Implementation of parametric tools in green facades illustrated

3. **Coverage Pattern**
   The coverage pattern of the green facade on building surfaces determines the functions or benefits it offers to the building individually. A fully plant-covered building creates a different effect compared to one with vegetation only on selected floors. One implication is how the "chances for special view" aspect of the green facade is presented—if the entire building is covered in plants, outward views from inside may be obstructed.



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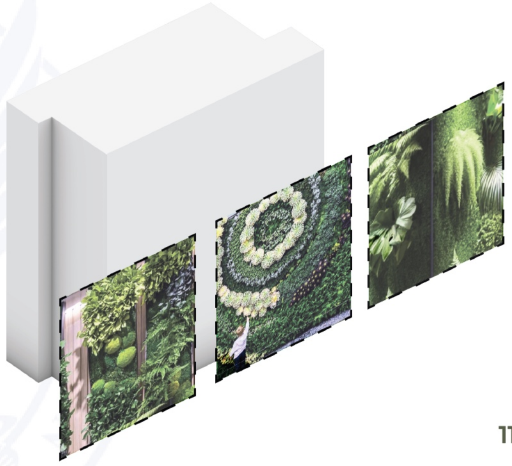
4. **Vegetation Mix Selection**
   Green facades will appear monotonous and lack aesthetic appeal if composed of a single plant species. A mix of different plant types, on the other hand, promotes biodiversity and enables the formation of a new ecosystem on the green facade.



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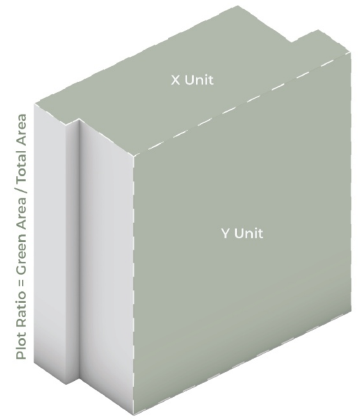
5. **Fulfillment of Ecological Metrics**
   The GnPR policy stipulates that fulfillment of ecological metrics is a prerequisite for obtaining a building permit.



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Context

Capital City of Nusantara, Indonesia

The relocation of the national capital is a response to several urgent issues concerning the current capital (Jakarta), such as unequal and non-inclusive economic growth, as well as increasingly severe environmental and geological problems. This move was formalized through the enactment of the Capital City Law (*UU IKN*) in 2022.

The design of the new capital, named *Ibu Kota Nusantara* (hereinafter referred to as IKN), is divided into eight clusters comprising six economic clusters and two supporting clusters, based on the core concept of a smart green city. The development of IKN is planned across several timelines [fig. 13] as follows:

- **2022 – 2024**

In this initial phase, the construction of core and basic infrastructure is carried out to accommodate at least 500,000 residents, along with the initial phase of relocating civil servants (*ASN*).

- **2025 – 2035**

This period focuses on the continued relocation of the governmental center, along with urban consolidation through innovation and economic development, aiming for sustainable development.

- **2035 – 2045**

Development of competitive infrastructure to position the city alongside major cities in Southeast Asia and beyond.

- **2045 and beyond**

The city is envisioned to become an eco-friendly zero-emission metropolis, ranked among the top 10 most livable cities, and potentially the first city globally with a population exceeding one million that fully embodies these principles.

(Tentang IKN, 2022)

As part of the initial phase of infrastructure development and the relocation of civil servants (*ASN*), between 2022 and 2024, housing projects for *ASN* have become a key focus and are being actively pursued toward completion. As of November 2024, there are four *ASN* apartment complex projects (*Rusun ASN* 1–4 IKN), along with several other apartment projects for defense and security personnel. These developments include a total of 47 towers, comprising 2,820 residential units and supporting facilities in each tower. All are targeted for completion by the end of 2024 and are scheduled to be occupied starting January 2025.

The *ASN* 3 apartment complex is one of the residential developments in IKN aimed at accommodating civil servants who will be relocated between the end of 2024 and 2025. In this research, *ASN* 3 apartment serves as the case study of vertical housing.

13 Development Timeline Collage of the Nusantara Capital City

14 The Master Plan of Rusun *ASN* 3 IKN

Context

Government-Developed Vertical Housing: Goverment Employee (*ASN*) 3 Apartment Complex in IKN
[Kompleks Rumah Susun ASN 3 IKN]

Legend:
1. Tower 1
2. Tower 2
3. Tower 3
4. Tower 4
5. Tower 5
6. Tower 6
7. Sport Facilities
8. Main Gate
9. Secondary gate

The *ASN* 3 Apartment Complex in IKN is designed on a site area of 43,000 m² [fig. 14-15] with the following planning regulations:

- Building Coverage Ratio (BCR - 35%) : 15,050 m²
- Floor Area Ratio (FAR - 2) : 86,000 m²
- Green Coverage Ratio (GCR - 30%) : 12,900 m²
- Basement Footprint Coverage : 25,800 m²
- Building Setback : 8 m

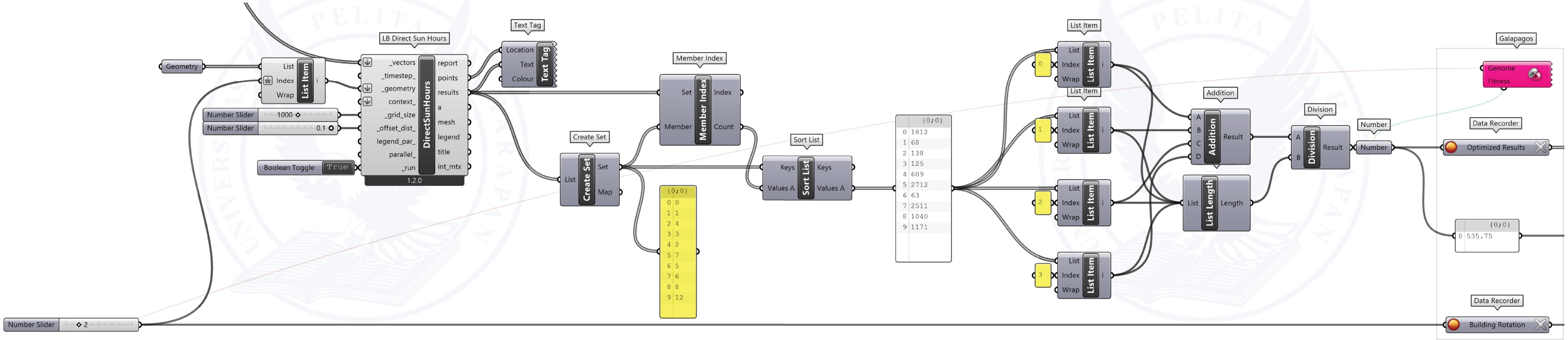
The towers of the *ASN* 3 Apartment Complex in IKN serve as the case study in this research. Among the six towers in the complex, each possesses unique characteristics that merit further exploration. In the investigation of green facade implementation potential, the tower offering the most optimal advantages is selected based on parametric potential in design iteration selection.

Literature studies indicate that the effectiveness of green facades heavily depends on orientation. To maximize their benefits—such as providing shading and fulfilling plants' sunlight needs for photosynthesis—proper orientation is essential. A simulation study [fig. 16-17] was carried out to analyze the building orientation in the *ASN* 3 Apartment Complex in IKN.

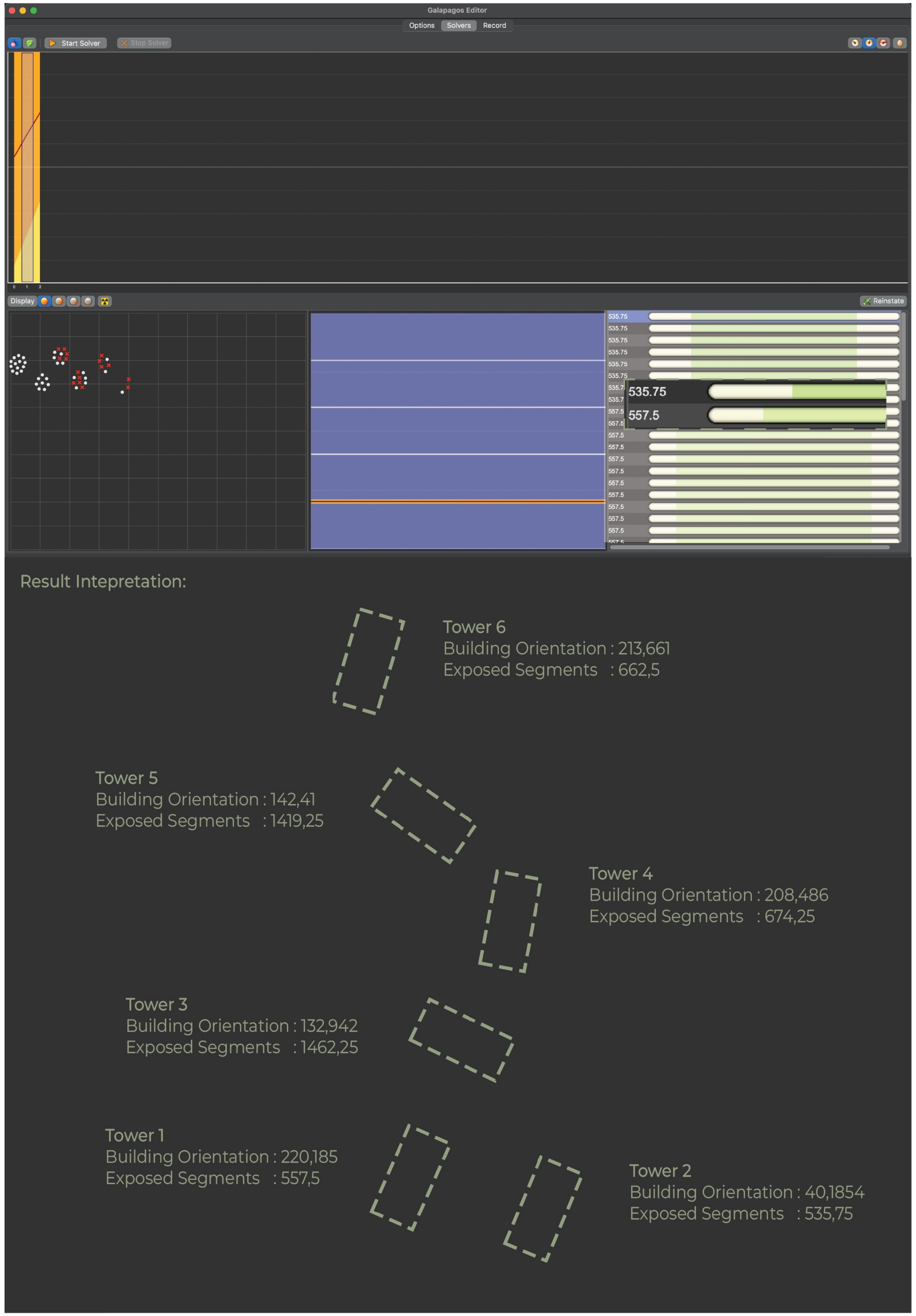
This study involved dividing the surface (facade) of each tower into smaller segments, followed by a sunhour analysis simulation conducted on these segments. The purpose was to determine how many segments on each tower receive less than four hours of sunlight per day—below the daily requirement for vegetation on green facades.

The simulation data [fig. 18] served as input for parametric tools and yielded results showing that Tower 2 has the fewest segments exposed to less than four hours of sunlight per day (535.75 out of a total of 1708 segments per tower), while Tower 3 has the highest number, at 1462 segments. Based on the simulation results, Tower 2 is selected as the primary focus for green facade design on vertical housing as a strategy for ecological compensation.

15 Block plan of the *ASN* 3 Apartment Complex development in IKN



16 Grasshopper algorithm for Sunhour Analysis Simulation on ASN 3 Apartment Tower in IKN



17 Visualization of Sunhour Analysis Simulation on ASN 3 Apartment Tower in IKN

18 Result of Sunhour Analysis Simulation on ASN 3 Apartment Tower in IKN

Methodology

1. Literature Review

In the study of integrating parametric tools into green facades in vertical housing as a form of ecological compensation, it is important to clearly define each variable, the relationships between variables, as well as the methods used in the analysis. A literature review was conducted to identify and explore several key aspects, namely: the potential and impact of green facades, their implementation strategies, relevant case studies, ecological metrics to assess the success of ecological compensation, and design criteria for green facades in vertical housing that effectively provide ecological benefits. The findings of the literature review are presented as follows:

a. **Green Facades**

A Green Facade is the simplest form of integrating greenery (plants/vegetation) into vertical buildings (vertical green). By using climbing plants that cover the building's surface (facade), green facades are categorized into several types. Based on their definitions, the three are defined as follows:

- Green Facade

A traditional method of growing climbing plants on the building surface (facade), either from the ground or from pots.

- Wall Vegetation

Spontaneous plant growth on joints or cracks in the structure—without human intervention—and usually found on old buildings or monuments.

- Living Wall System

Pre-fabricated panels that are already planted or in-situ panels. This is a modern form of vertical greenery that utilizes contemporary technology. The difference from a green facade: living wall systems support vegetation rooted in planting media within containers, not directly on the wall.

(Elgizawy, 2016; Mir, 2011; SIPA, n.d.)

b. **Vertical Housing**

Vertical housing is one of the outcomes of Vertical Urban Development, which aims to minimize the expansion of new land for urban use (Lin, 2016). It is defined as a vertically structured (tall) building that functions as a residence; a type of multi-dwelling unit—meaning it is inhabited by more than one family—and is commonly referred to as an apartment (Thakkar, 2021). Vertical housing is categorized into several types based on height:

- Low-rise buildings

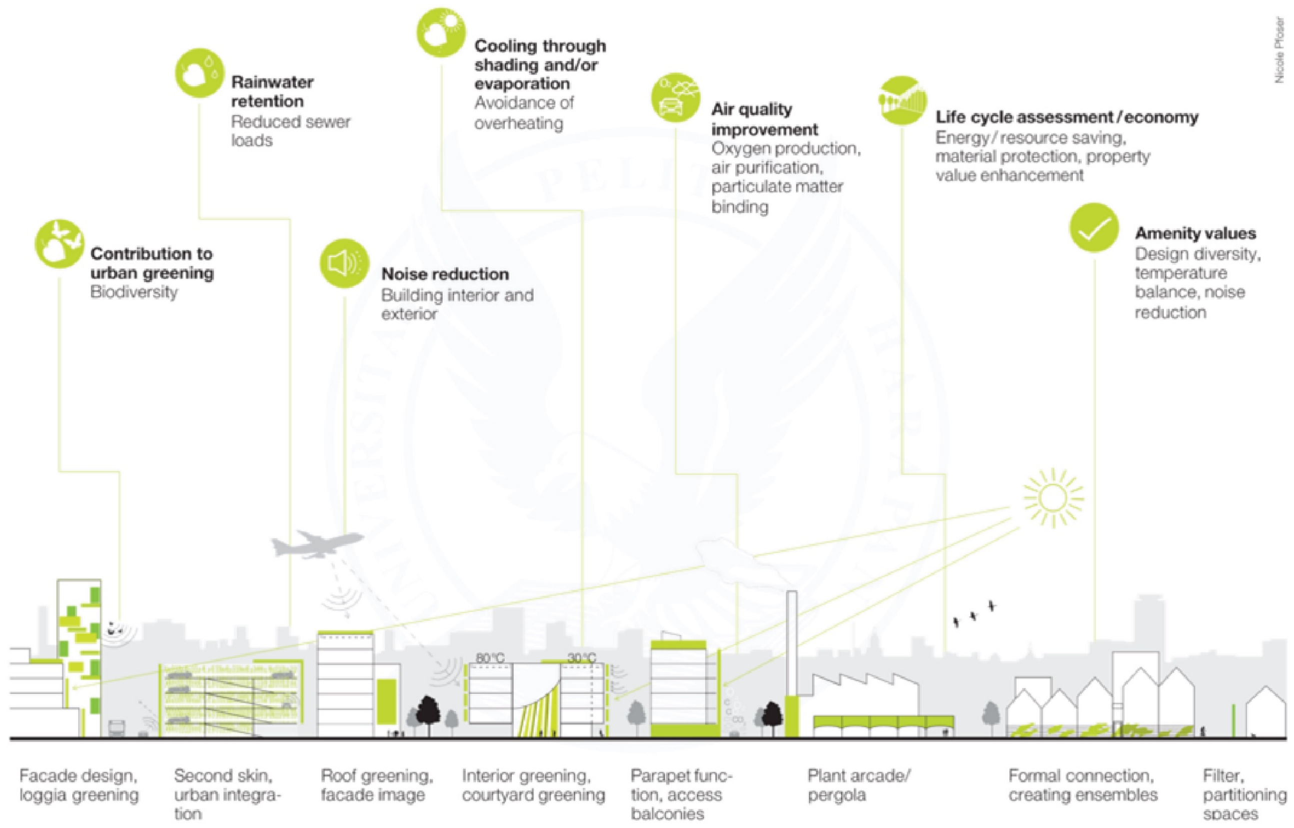
These buildings typically consist of 1–4 floors. Examples: Low-rise multi-family buildings, dual occupancy, multi-dwelling housing, manor house.

- Mid-rise buildings

These buildings typically consist of 5–12 floors. Examples: Residential buildings, shop-top housing, residential flats.

- High-rise buildings

These buildings typically consist of more than 12 floors. Example: Residential high-rise.



19 Potential applications of green facades & key benefits for the building and its surroundings

c. **Ecological Compensation**
Ecological compensation is the final step in the mitigation hierarchy. This hierarchy, which stems from the Strategic Environmental Assessment (SEA) and the Environmental Impact Assessment (EIA), is divided into three stages:

- Avoidance
  a. Actions taken to avoid activities that could cause ecological damage, aiming to minimize environmental harm;
  b. This stage occurs in the early cycle of the project.
- Reduction
  a. Actions to reduce ecological impacts when avoidance is no longer feasible;
  b. Takes place during the construction phase and is monitored throughout the entire process.
- Compensation
  a. Aims to balance residual impacts through offsetting or supporting measures;
  b. Designed at the beginning of the project cycle, implemented and monitored throughout the entire project duration.

(Moulherat et al., 2023)

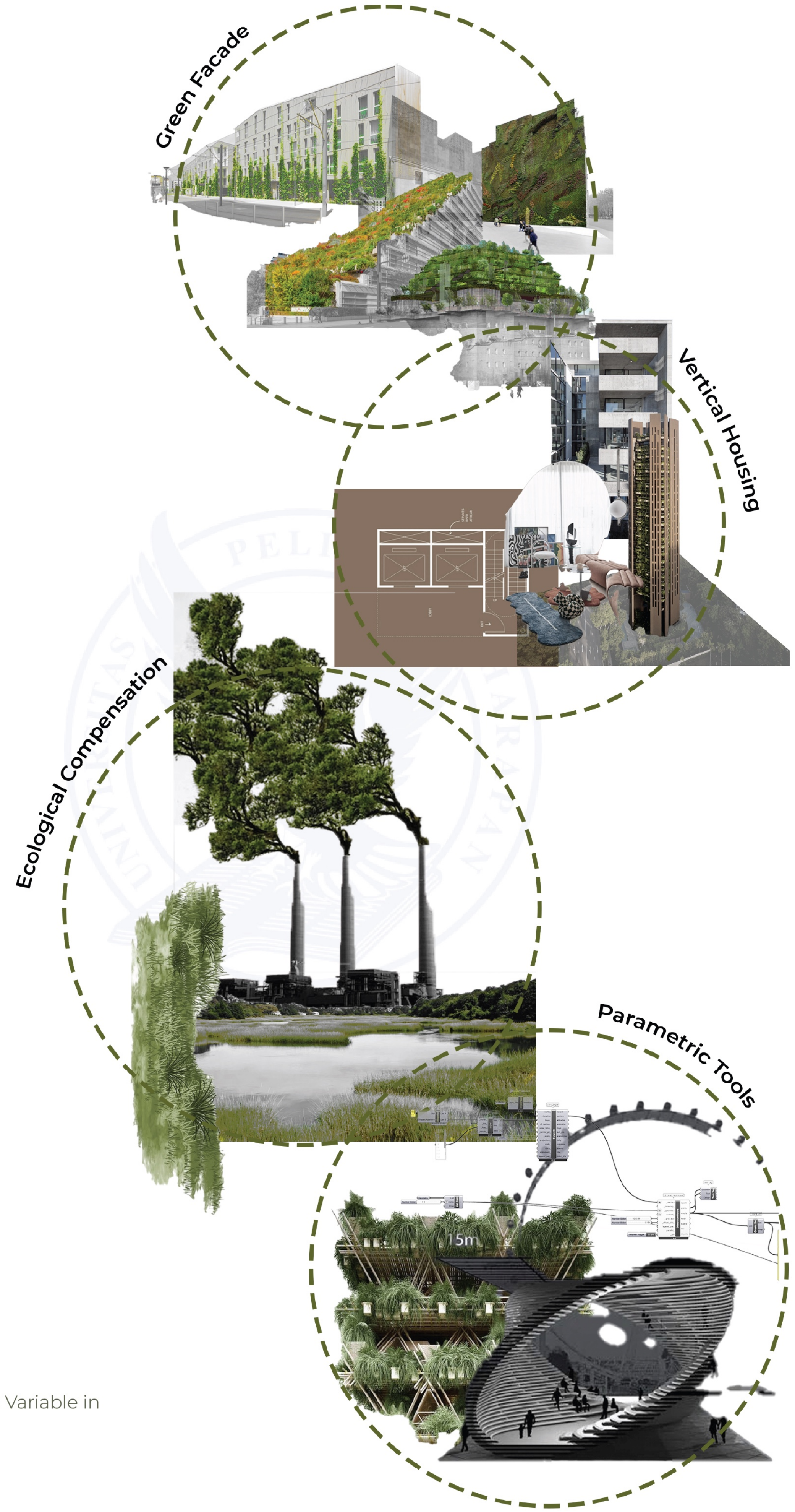
d. **Parametric Tools**
Parametric in architecture serves as an additional "ammunition" in the architect's toolkit. Parametric tools demand parametric thinking—a nonlinear way of thinking on a small scale that is linear on a larger scale (Toker, 2022). In discussing the parametric approach—as both a tool and a design method—several key terms need to be understood:

- Parameter
This term is borrowed from mathematics, where it describes a specific equation. A parametric equation is a set of functions based on a single variable. Simply put, a parameter is a variable processed alongside an explicit variable (explicit relationship).

- Parametric Modelling
This refers to the method that produces an "output" represented by geometric models.

- Parametric Thinking
This is the understanding of parametric logic—including comprehension of parameters, explicit variables (relationships), and outputs—and the ability to leverage the potential of parametric tools. David Karle and Brian Kelly define parametric thinking as a method of connecting both tangible and intangible systems into a design without relying on specific tools.

(Jacobus et al., 2023)



20 Explanation of Each Variable in the Literature Review

e. **Implementation of Green Facades in Vertical Housing**

Beyond the effort to green the city, green facades are implemented due to the potential and benefits they offer. In their application to residential buildings, green elements provide positive impacts on the health and well-being of residents and visitors in general, while also increasing property value, with proven effective outcomes such as:

- In suburban slum housing, children require less ADHD medication when their environment is greener.
- Environments with abundant greenery offer residents a lower likelihood of experiencing anxiety disorders.
- There is a negative correlation between green environments and depression.
- Higher tree density in housing areas correlates with lower rates of cardiovascular disease.

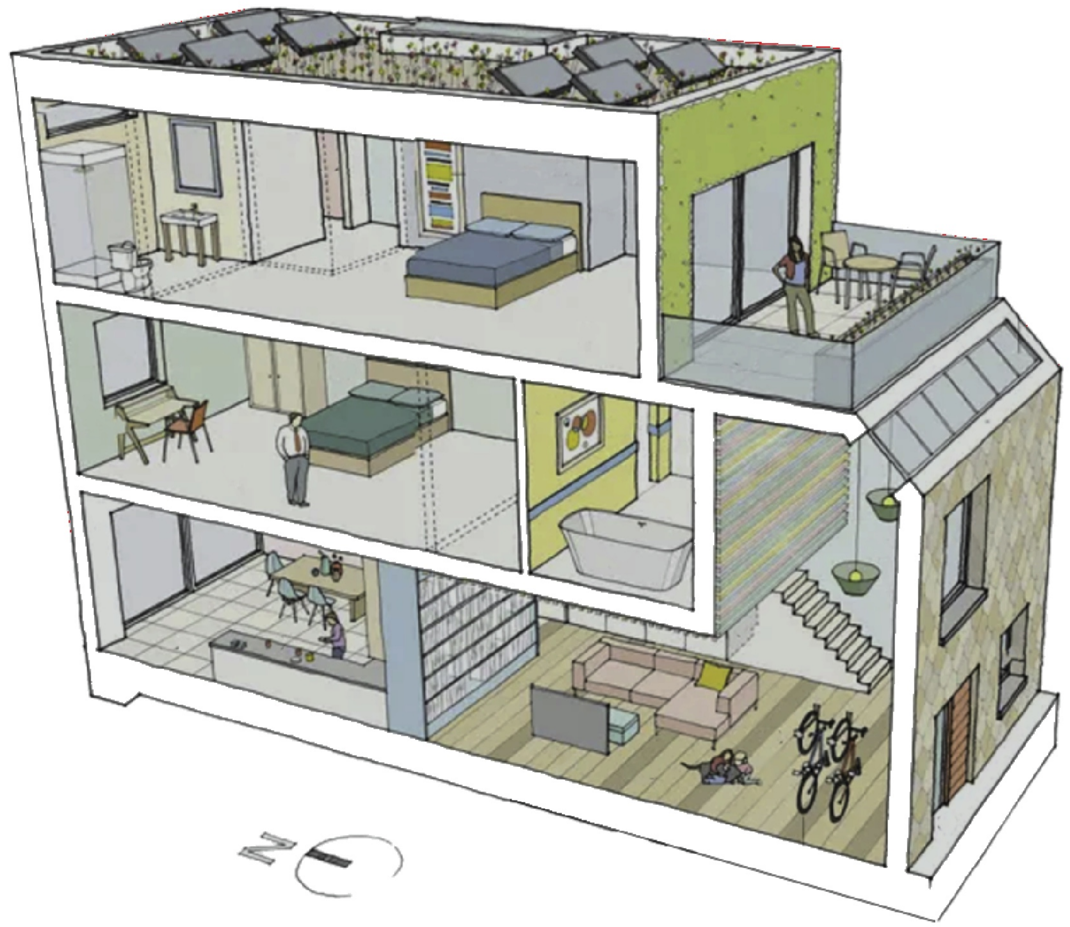
(ELCA | European Landscape Contractors Association, n.d.)

f. **Green Facade as Ecological Compensation**

Green facades, through the provision of greenery or as part of the landscape, have been classified as one form of ecological compensation. The extent to which and how green facades are considered ecological compensation remains a subject of further study, with the outcome being the identification of which ecological aspects are intended to be compensated.

There is no uniform approach to the design of compensatory measures and to how compensation needs should be assessed and balanced against the benefits of the compensatory measures.

(Jönsson Ingemar & Kristianstad Högskolan i, 2020)



21 Description of a 'Happy House' according to Happy by Design

++ **Case Study: Oasia Hotel Downtown, Singapore | WOHA**

In the absence of a uniform standard in designing compensatory actions, policies have emerged to regulate this issue. Oasia Hotel Downtown serves as a case study that illustrates how such policies can facilitate ecological compensation in the form of green facades.

Oasia Hotel Downtown was designed with full attention to Singapore's Landscaping for Urban Spaces and High-rises (LUSH) 3.0 policy, which includes regulations regarding the Green Plot Ratio (GnPR). The GnPR policy governs how vegetation that would typically be planted on the building site can be relocated to specific areas within the building's design. Trees, palms, shrubs, turf, and vertical greenery [fig. 22] are all counted as ecological compensation components under the GnPR framework. Oasia Hotel Downtown successfully achieved a Green Plot Ratio (GnPR) of 1110% [fig. 23], meaning the building has integrated vegetation with a weight more than 10 times what could have been planted on the original site.

DECLARATION OF GREEN PLOT RATIO

Category	Unit	Sub-category	LAI Value	Canopy Area/m²	Qty/Planted area	LEAF Area
			(A)	(B)	(C)	(A)x(B)x(C)
Trees	no	Open Canopy	2.5	60	No.	
	no	Intermediate Canopy	3.0	60	No.	
	no	Dense Canopy	4.0	60	No.	
	no	Intermediate columnar canopy	3.0	12	No.	
Trees	m^2	Planted at ≤ 2.0m trunk to trunk	(as above)	NA	m^2	
Palms	no	Solitary	2.5	20	No.	
	no	Cluster	4.0	17	No.	
Palms	m^2	Solitary(trunk to trunk ≤2m)	2.5	NA	m^2	
Shrubs	m^2	Monocot	3.5	NA	m^2	
	m^2	Dicot	4.5	NA	m^2	
Turf	m^2	Turf	2.0	NA	m^2	
Vertical greenery	m^2		2.0	NA	m^2	
					(X) Total Leaf Area (m^2)	
					(Y) Site Area	
					(X / Y) Green Plot Ratio	

22 The overall GnPR calculation template

23 Oasia Hotel; one of the projects that adopts an ecological compensation measurement approach through the Green Plot Ratio

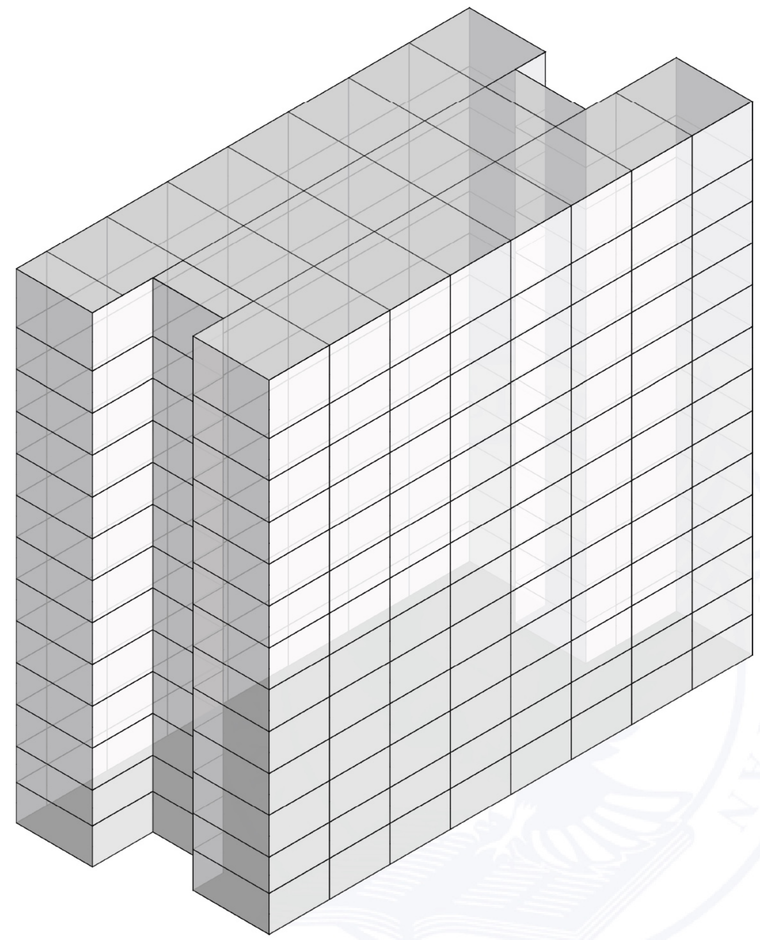
Methodology

2. Parametric Exploration

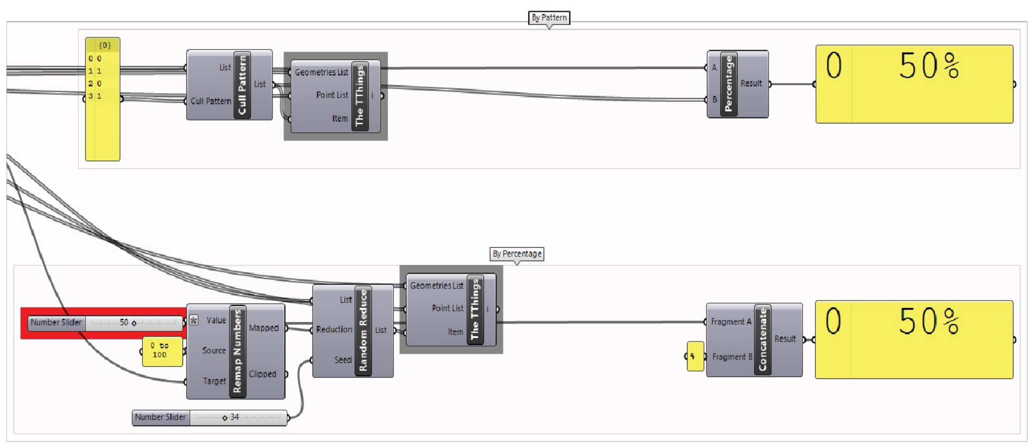
Exploration of parametric tools is carried out by utilizing the parametric potential previously described, with the main capability being as a tool for modeling, analysis, and selecting design iterations – to generate, analyze, and select. In this study, parametric tools are used in two main parts: the site analysis of the *ASN* 3 Apartment Complex in IKN and the determination of the most ideal green facade configuration in fulfilling ecological metrics.

As the first part of the use of parametric tools—namely, the site analysis of ASN 3 Apartment Complex in IKN (Context – Government-Developed Vertical Housing: ASN 3 Apartment Complex in IKN)—has been completed, the parametric exploration will now focus more on how green facade interventions will be implemented on Tower 2 of the ASN 3 Apartment Complex in IKN [fig. 24-30].

a. **Grid Masing Structure: Target of Algorithm**
The case study of ASN 3 Apartments in IKN features a design that undergoes simplification using a grid system.



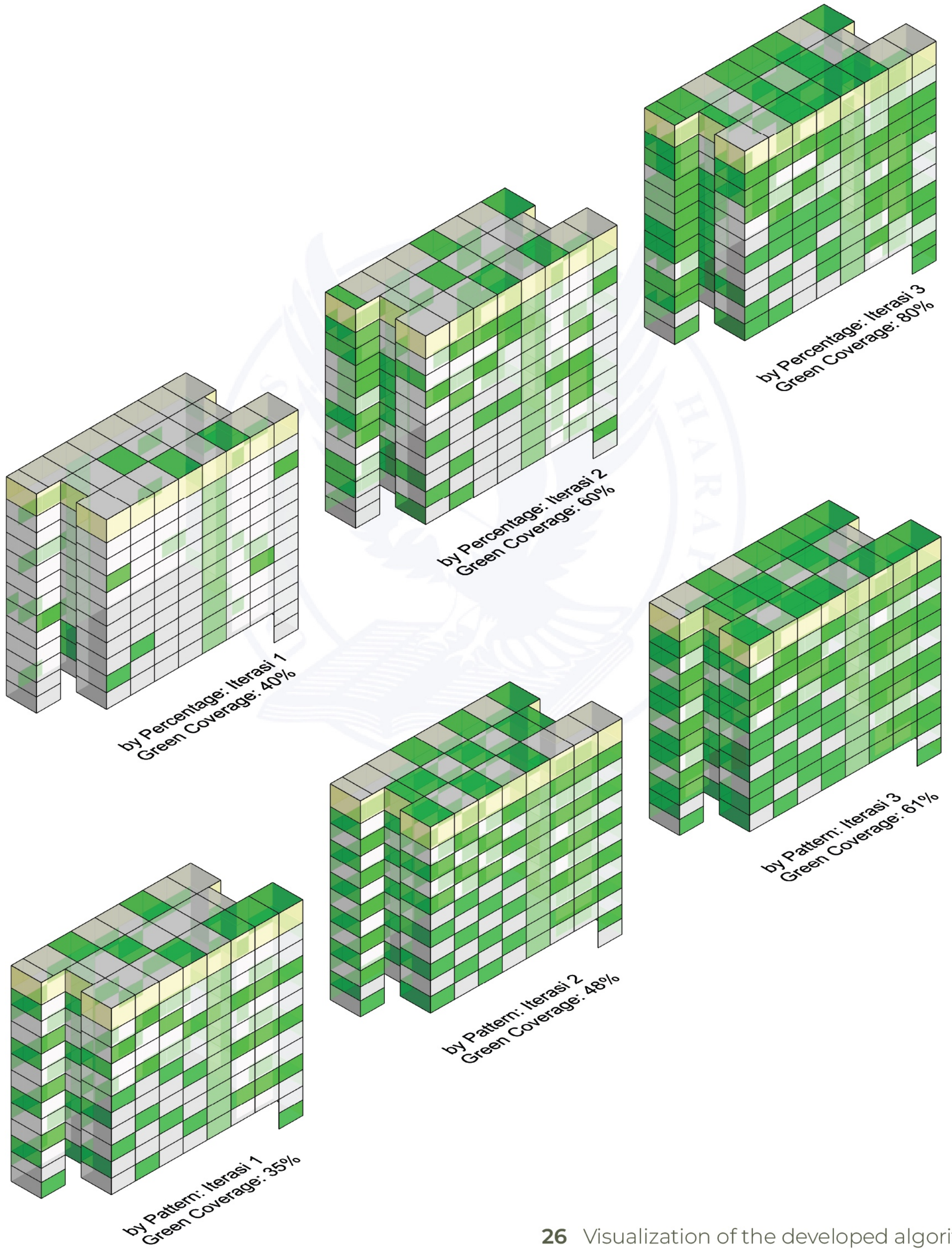
b. **Grasshopper Definition: Logic of Algorithm**
The building mass grid serves as the basis for the parametric algorithm, utilizing two approaches: Percentage-based and Pattern-based.



24 Building mass of the ASN Apartment Tower is simplified and divided into a grid

25 Main logic in the algorithm for placing green facades on the ASN Apartment Complex

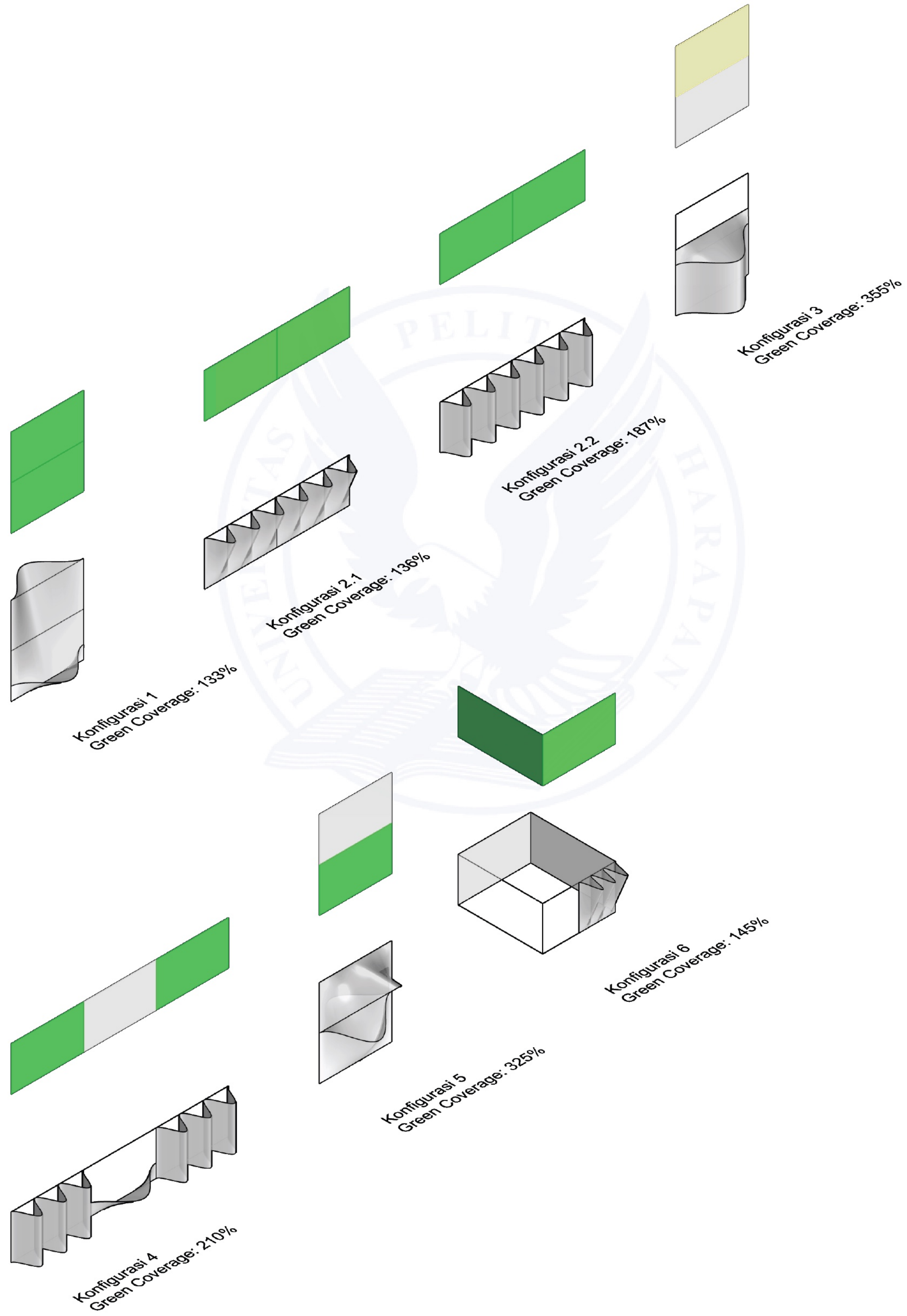
c. **Parametric Generated Area: Algorithm Result**
An algorithm that separates four categories for each facade module: Empty area (white); Openings with potential as green facades (yellow); Openings that are green facades (light green); and Areas that are green facades resulting from parametric simulation (green).



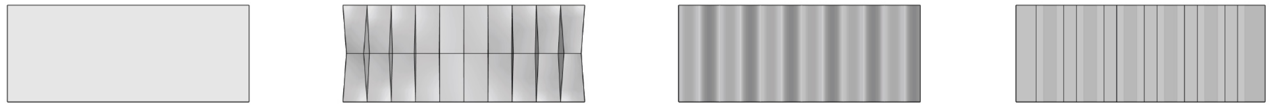
26 Visualization of the developed algorithm; three iterations logic

27 Configuration discoved from the visualization; further developed

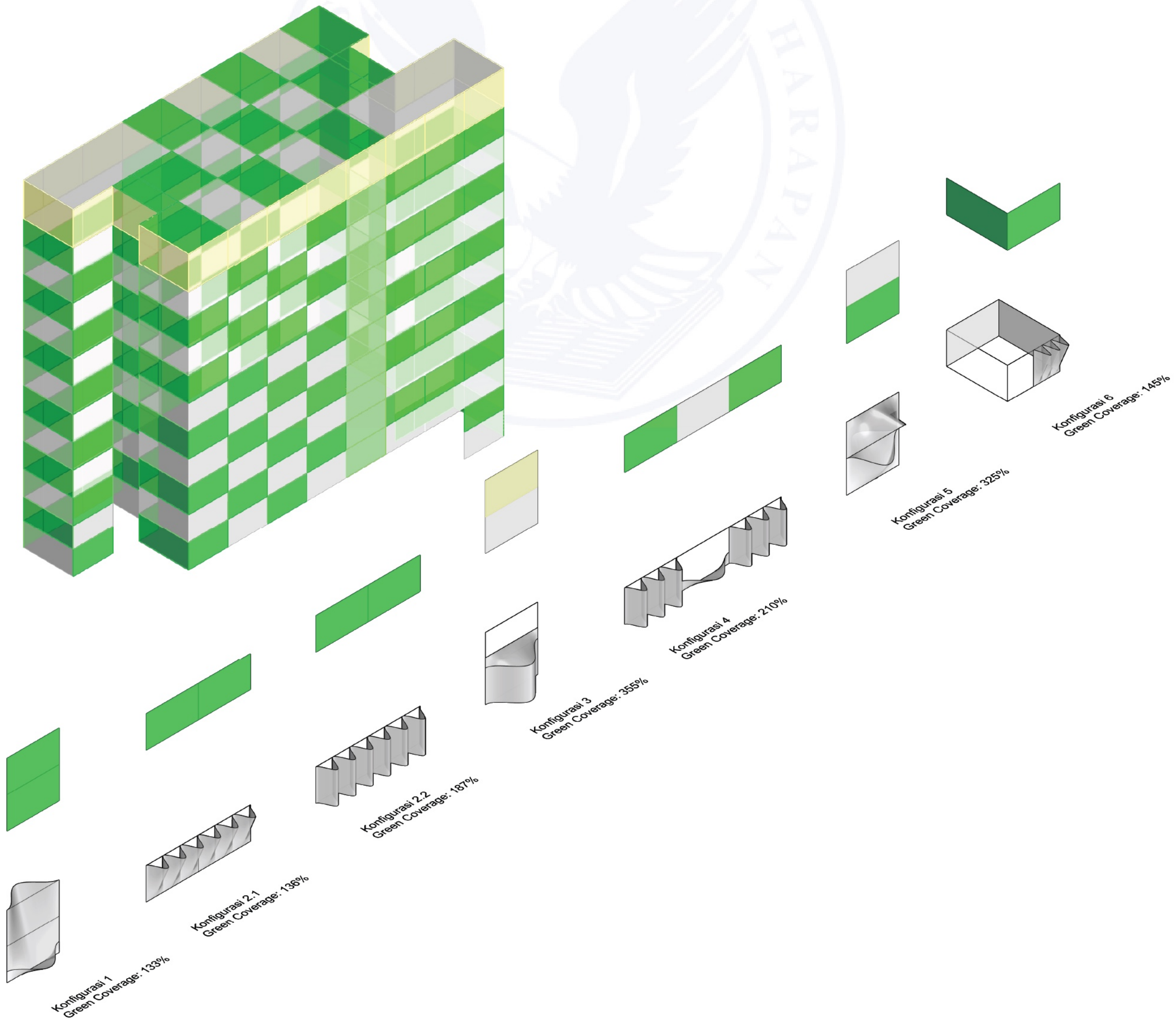
d. **Configuration of Green Area: Intepretation of Green Area**
The parametric algorithm generates several identifiable possibilities (configurations). Each identified configuration is then visualized in form.



e. **Maximizing Surface Form: Module Form Exploration**
The diverse forms encourage a study to determine which shape or sequence is most suitable for green facades. This research expects a significant contribution from green facades to provide ecological compensation, serving as an effort to maximize surface area through specific forms.



f. **Configuration Overview: Implementation and Visualization**
This algorithm divides the building mass into small grids, identifying each grid as either a green facade or not. The result is several green facade configurations with diverse forms and patterns. These configurations then go through the visualization stage to examine how the green facade can be practically applied to the building.



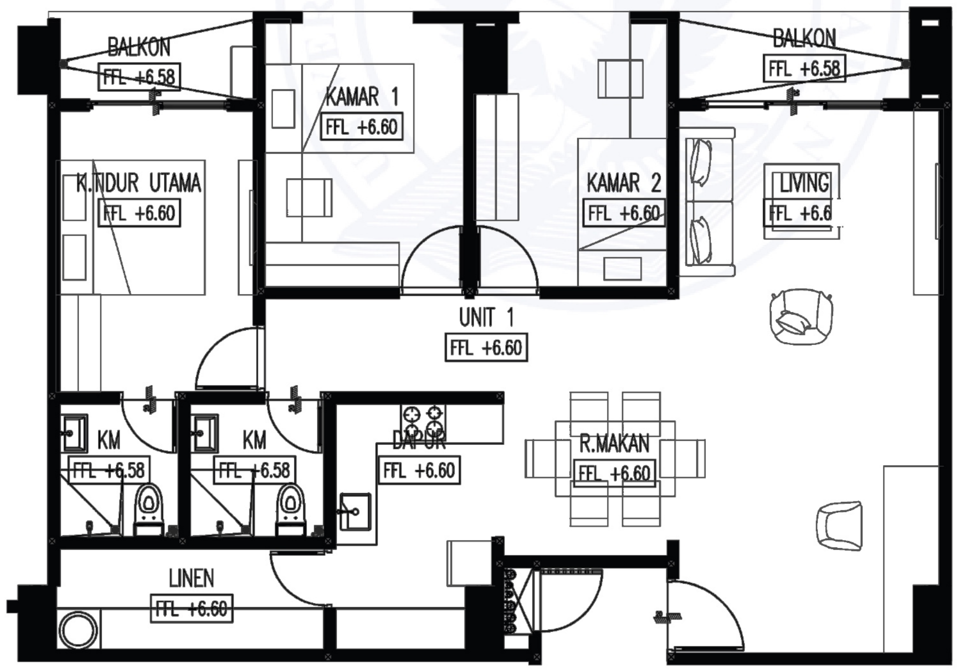
28 Study on several surface forms

29-30 Processual transition of green facade module implementation, including the results of its exploration; visualized

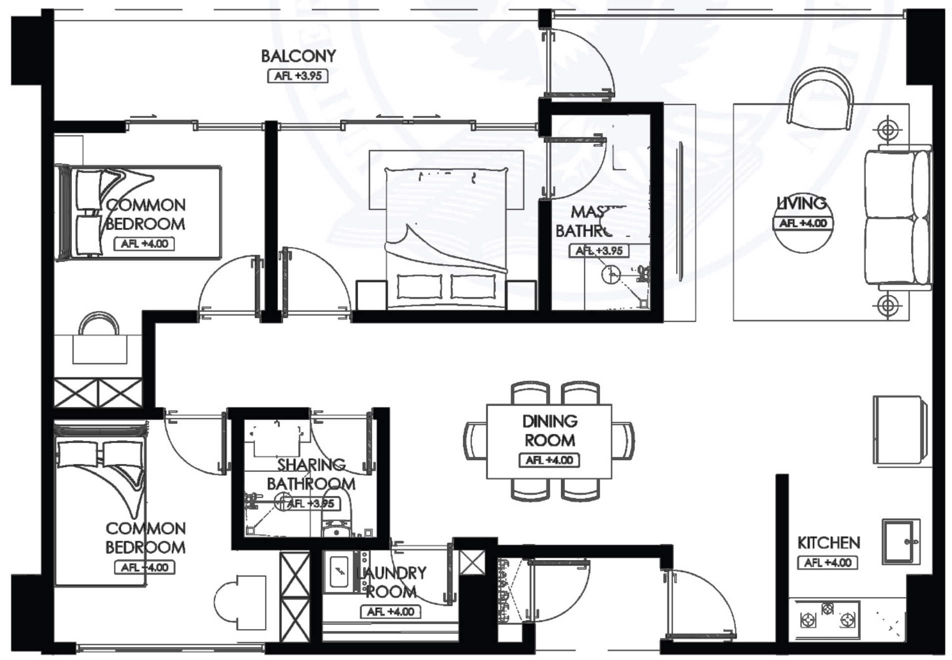
++ **Response to the initial tower design: Adjustment of unit layout**

The provision of green facades generated by parametric tools prompted several changes to the typical unit layout of the ***ASN*** 3 Apartment Tower to achieve the following points:

a. A balanced distribution was achieved, with each unit having one green element and one white (non-green) element, by merging the two original balconies — one on the left and one on the right, initially separated by a small window for the common bedroom in the middle — into a single elongated balcony on one side, accompanied by a large window as an alternative access point.
b. A more accessible balcony was provided by adding a window element in the living area, allowing the balcony to be accessed by all unit residents, with a primary focus on residents of the master bedroom and common bedroom 1.
c. To emphasize other vegetated areas — namely the void and the corridor — one common bedroom was reoriented to face the corridor and void, providing an additional green view for residents in common bedroom 2.



31

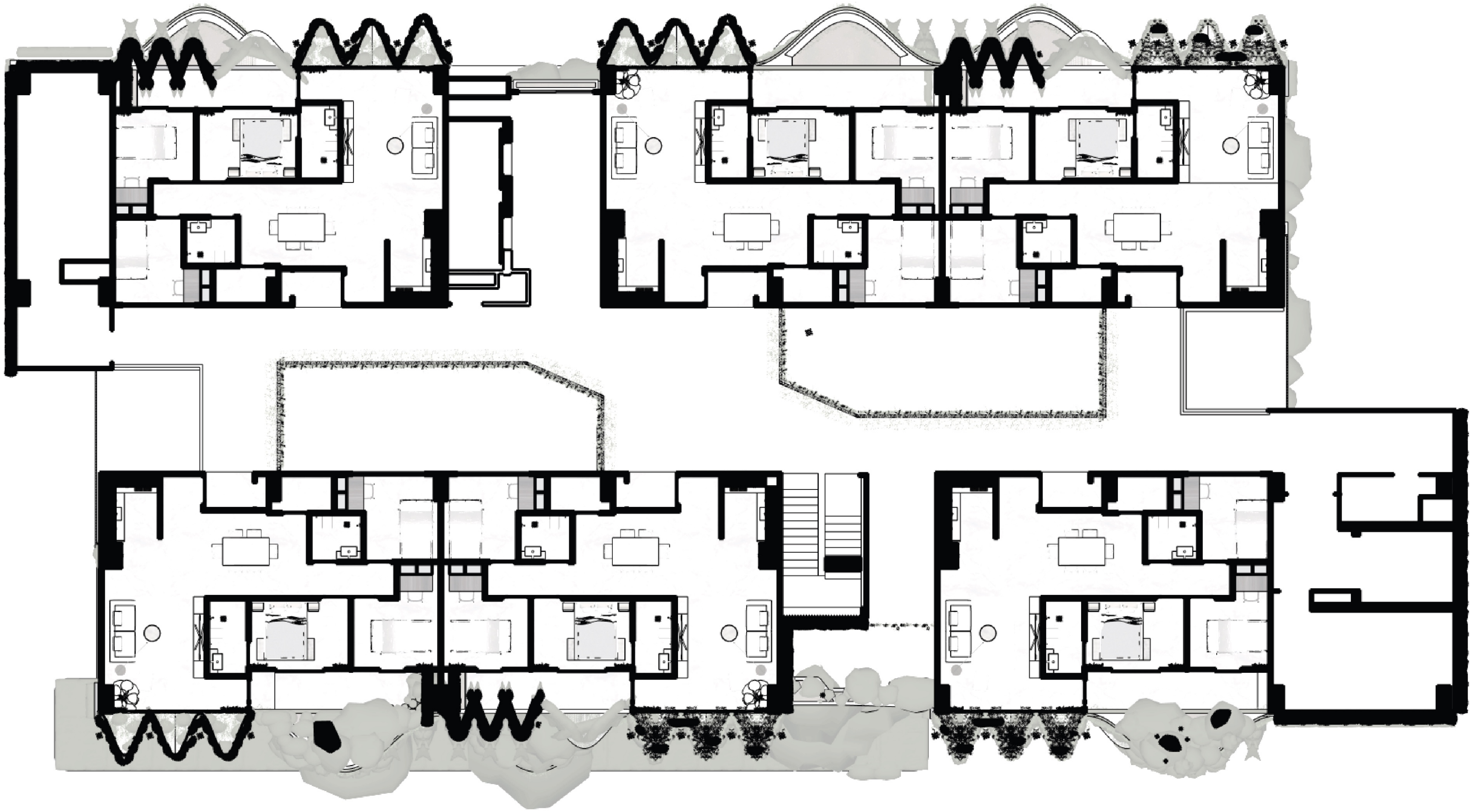


32

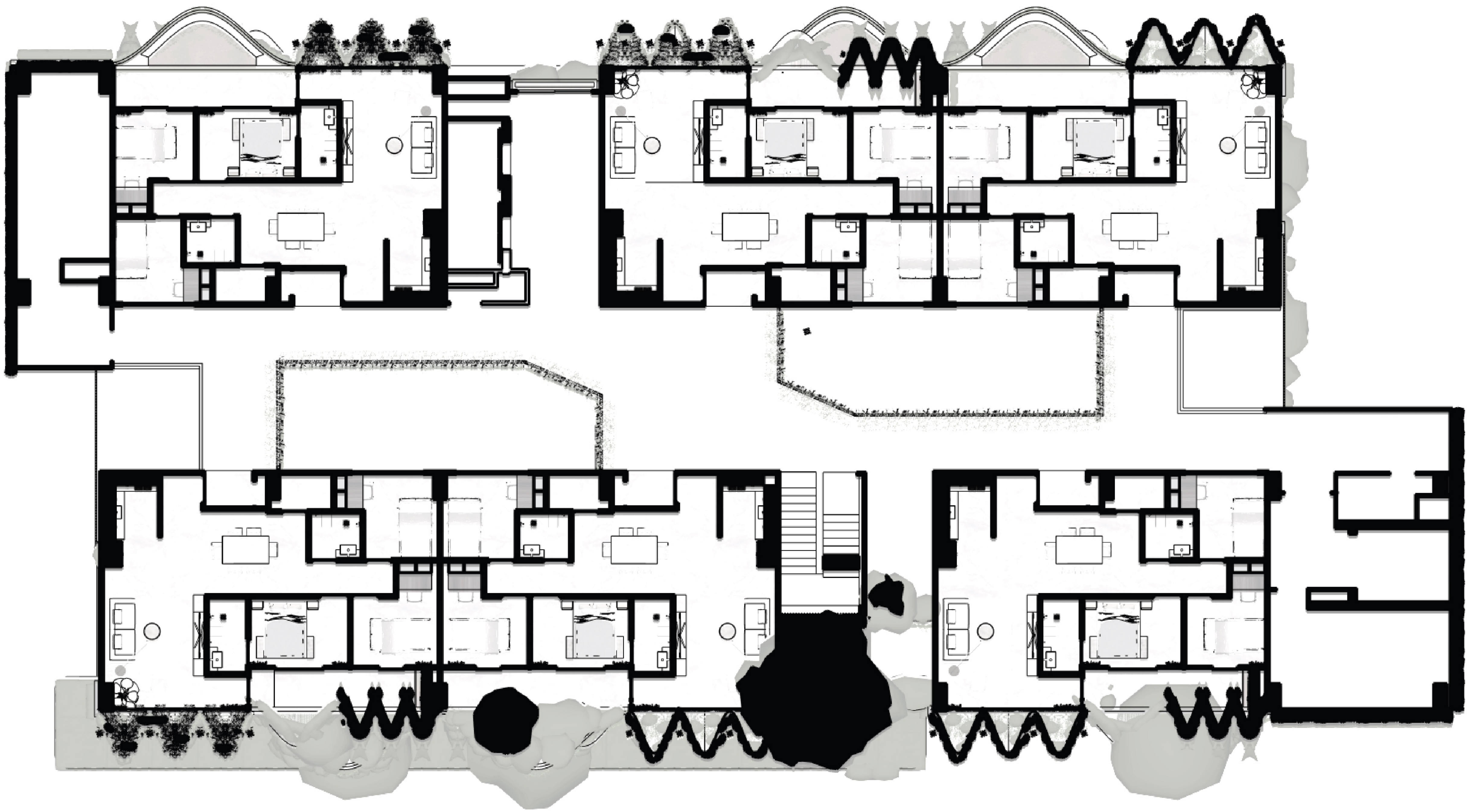
31 Before: Initial unit layout of the Alien DC design

32 After: Unit layout after the intervention

33 Unit layout changes implemented in the overall typical odd floor plan



34 Unit layout changes implemented in the overall typical even floor plan.



Methodology

3. Prototype Development

The development of prototypes becomes an important stage in the parametric exploration of green facades in vertical housing, particularly in testing aspects such as how the green facade is implemented on parts of the building, how vegetation integrates with the facade, its connections, construction methods, and other related aspects. During the design process, several prototypes emerged as studies, explorations, and mediums for conveying ideas.

a. **Building Elements Prototype**
The first trial in the development of the prototype was conducted as a comprehensive study on how different placements and forms of vegetation on various parts of the building influence the outcome, and to determine where—or in what form—the vegetation would be most effectively integrated into the building in terms of providing ecological compensation.

Void Area : 1037,9 m²
1st Iteration GnPR : 0,724

Void Area : 1075,3 m²
2nd Iteration GnPR : 0,75

35-42 1:20 scale study model of the three main building elements—facade, void, and communal balcony—with several iterations of vegetation placement, form, and type

Communal Balcony Area : 165,77 m²
1st Iteration GnPR : 0,116

Facade Area : 216,46 m²
1st Iteration GnPR : 0,151

Communal Balcony Area : 28,44 m²
2nd Iteration GnPR : 0,02

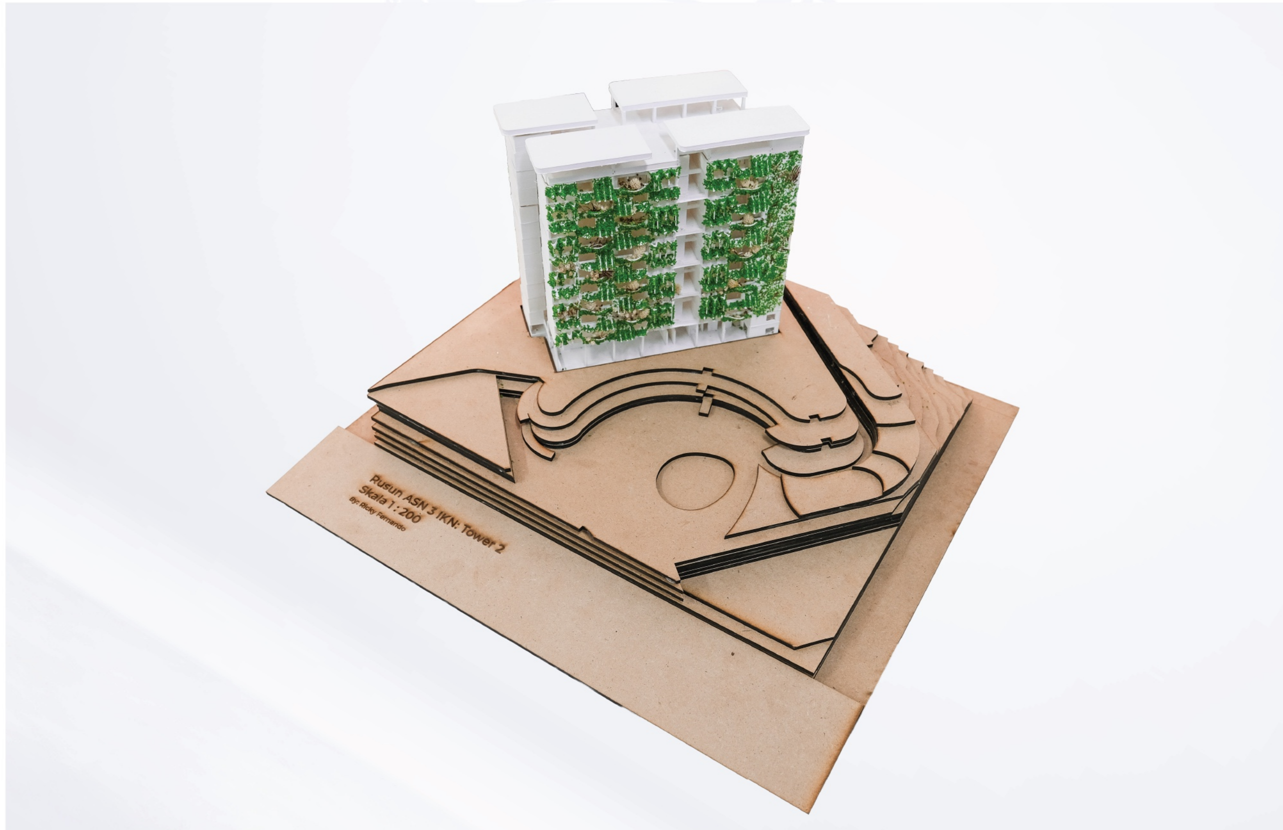
Facade Area : 234,18 m²
2nd Iteration GnPR : 0,163

Communal Balcony Area : 145,16 m²
3rd Iteration GnPR : 0,101

Facade Area : 226,32 m²
3rd Iteration GnPR : 0,158

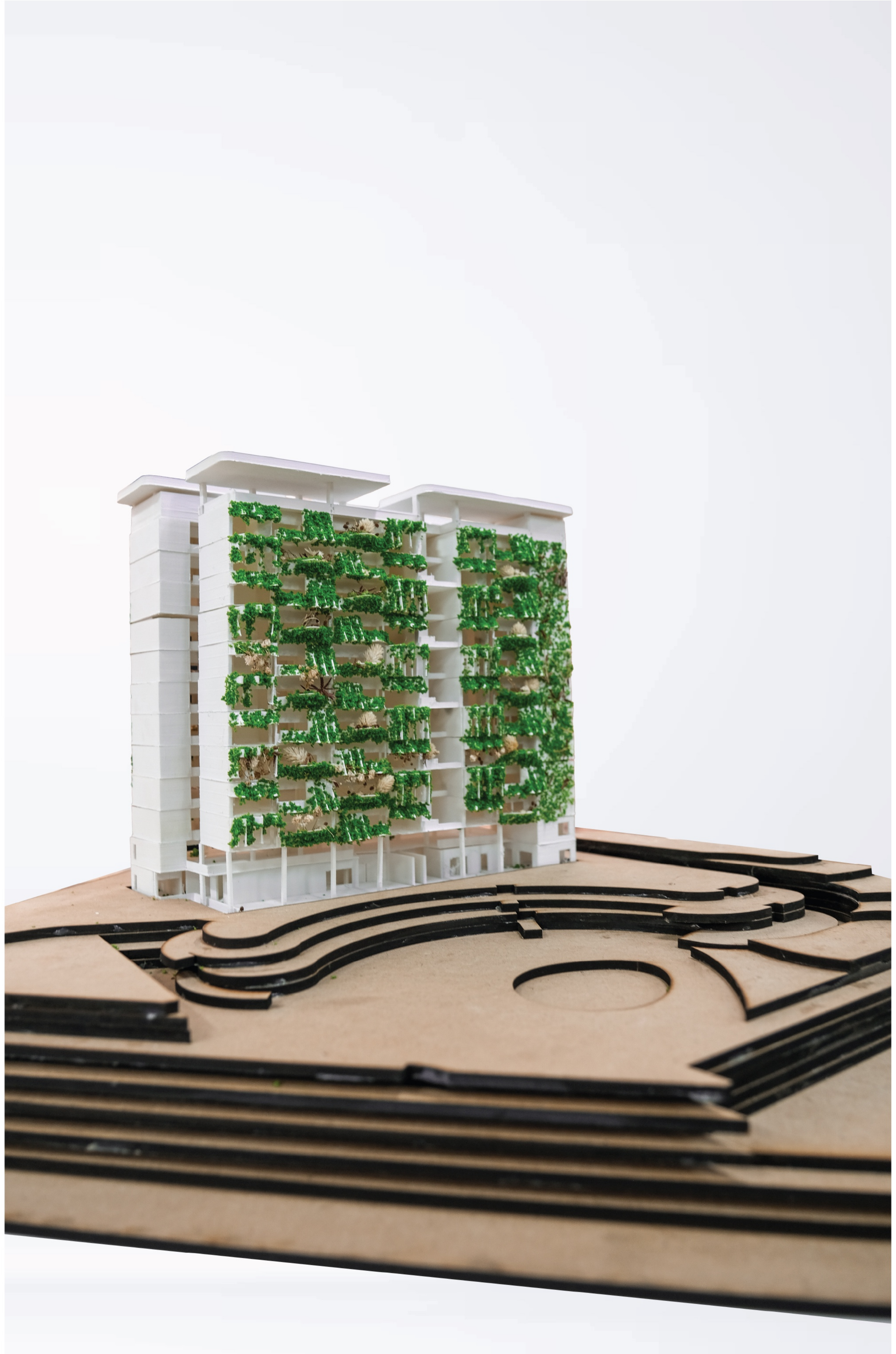
b. **Site model of the *ASN* 3 Apartment Complex in IKN.**
The site and site conditions described in the 'Context' section have several unique features that are easier to study in three dimensions. The creation of a 1:100 scale model of the *ASN* 3 Apartment Complex site in IKN serves as one of the prototyping processes carried out during the design phase.

c. **Building Element Prototype: Implementation on The Tower**
The building model, integrated with the green elements determined from previous design phases, is represented in a 1:200 model of Tower 2 of the *ASN* 3 Apartment in IKN. The building mass serves as a suitable medium to illustrate how the implementation of previous explorations can test the outcome of the design.

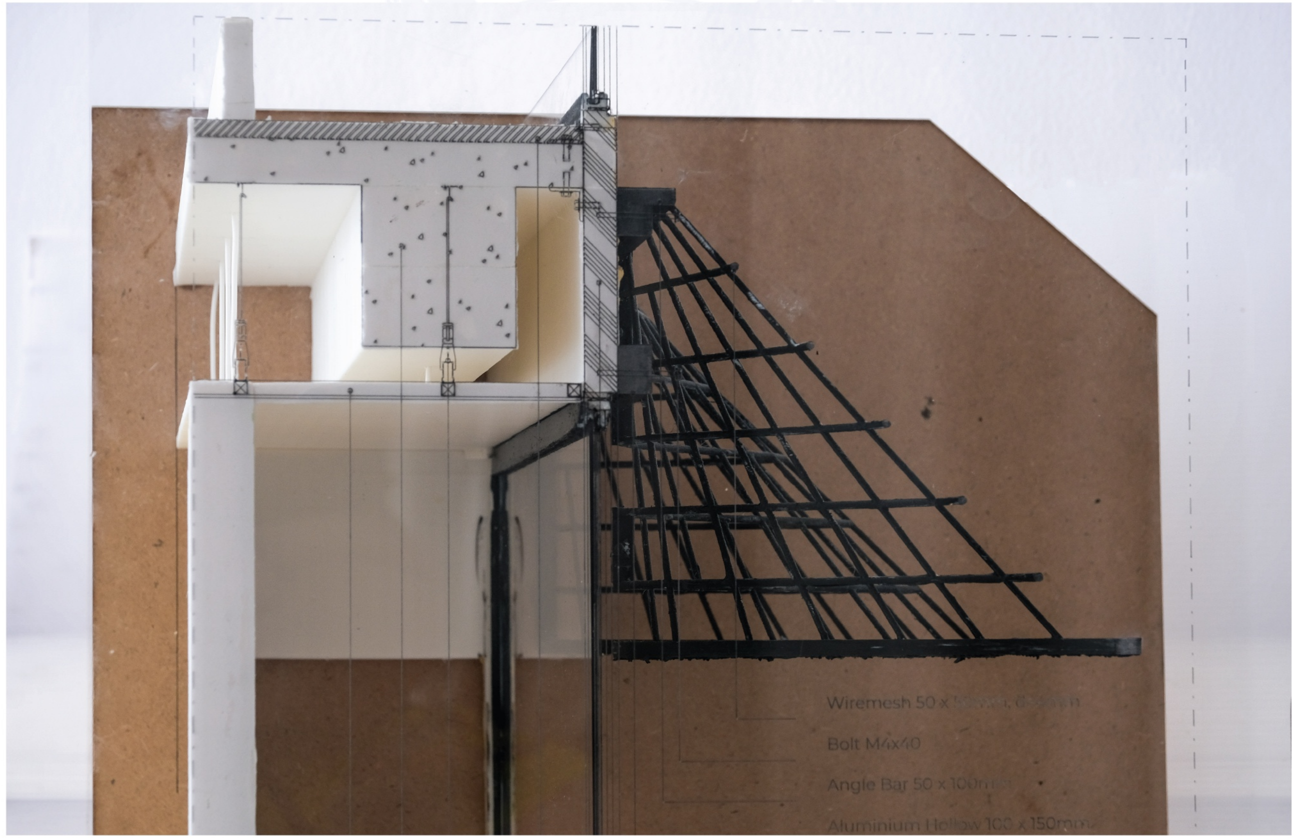


43 1:400Model of the *ASN* 3 Apartment Complex

44-45 Model 1:200 of the Tower 2 mass of ASN 3 Apartment in IKN with its surrounding

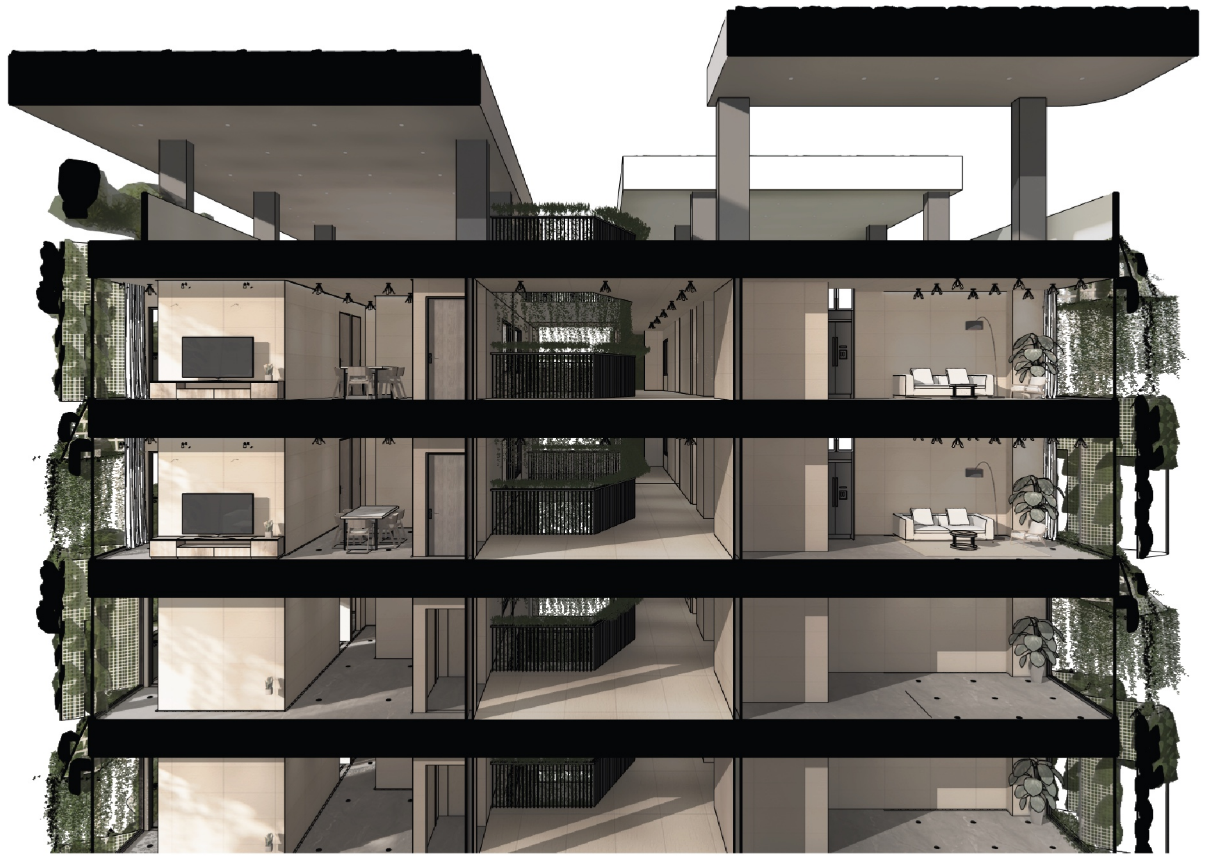


d. **ASN 3 Apartment Green Facade: In Detail**
The curved configuration chosen through the parametric exploration presented new challenges in the fabrication phase and construction-scale logic on site. A study of the green facade configuration, which was considered the most complex—specifically the non-green configuration on the windows—was ultimately developed through detailed prototypes at scales 1:5 and 1:10.



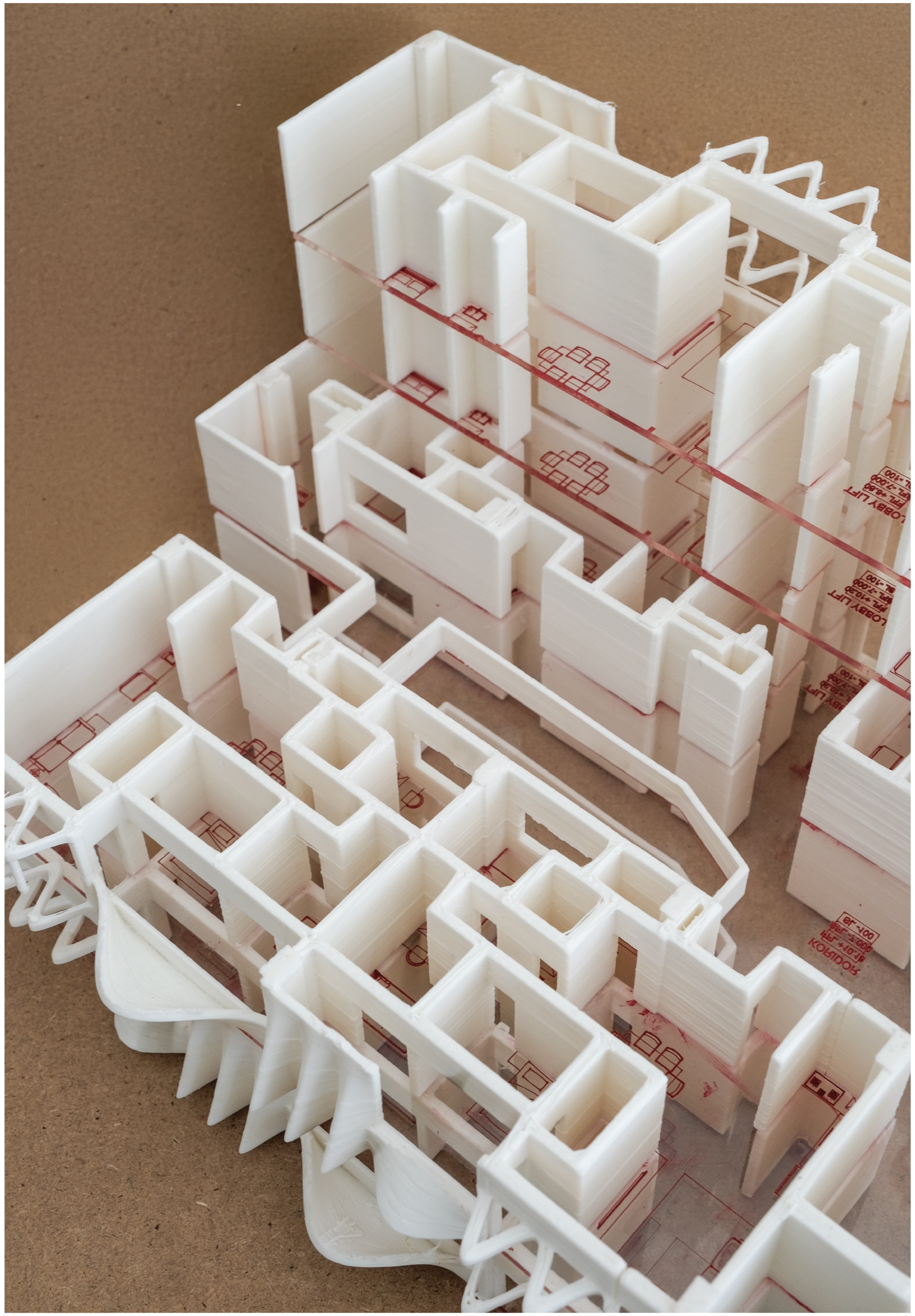
46-47 1:10 scale sectional detail, highlighting the relationship between the configuration and the

e. **Spatial Section Model**
The narrative that has been developed from the beginning, along with its interventions and solutions, requires a resolution in the form of a prototype to complete the desired information. The spatial section model serves as an effective medium for demonstrating the relationship between interior spaces and the implemented green facade elements



48 The perspective section serves as the basis for creating prototypes or spatial section models

49-50 [overleaf] The spatial section model developed from the perspective section



Result

Fulfillment of Ecological Metrics

The interventions implemented in Tower 2 of ASN 3 Apartment are divided into five main sections: the ground floor, mezzanine, odd floors (1st, 3rd, 5th, 7th, and 9th) - typical layout, even floors (2nd, 4th, 6th, 8th, and 10th) - typical layout, and roof floor. The interventions were carried out by calculating the GnPR for the following elements:

51 Vegetation elements in the design feature four facades as main components, with color notations for each element

52-56 [overleaf] Color notation of vegetation on each floor

Table 1-5 [overleaf] Table of green elements breakdown by floor for Green Plot Ratio Measurement

Main Elements

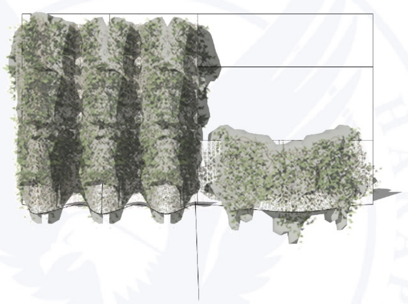
Green Column

Planter

Exterior / Interior
Green Walls

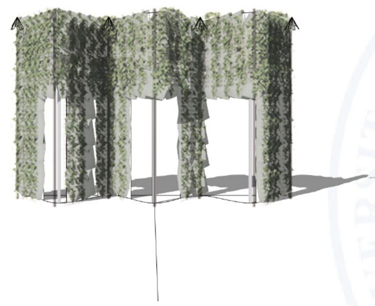
Vegetated Railings

Main Elements:
Green Configuration - Balcony

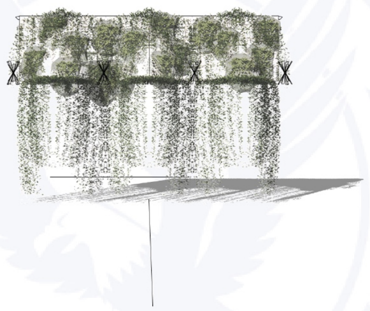


Main Elements:
White Configuration - Balcony

Main Elements:
Green Configuration - Window

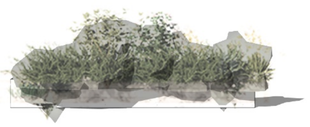


Main Elements:
White Configuration - Window

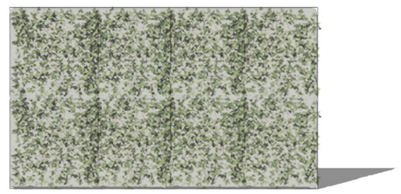


Green Column

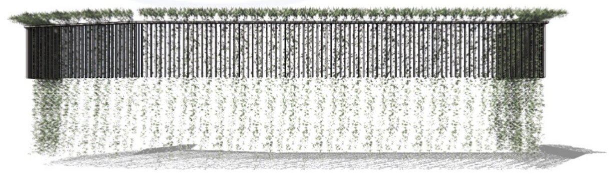
Planter



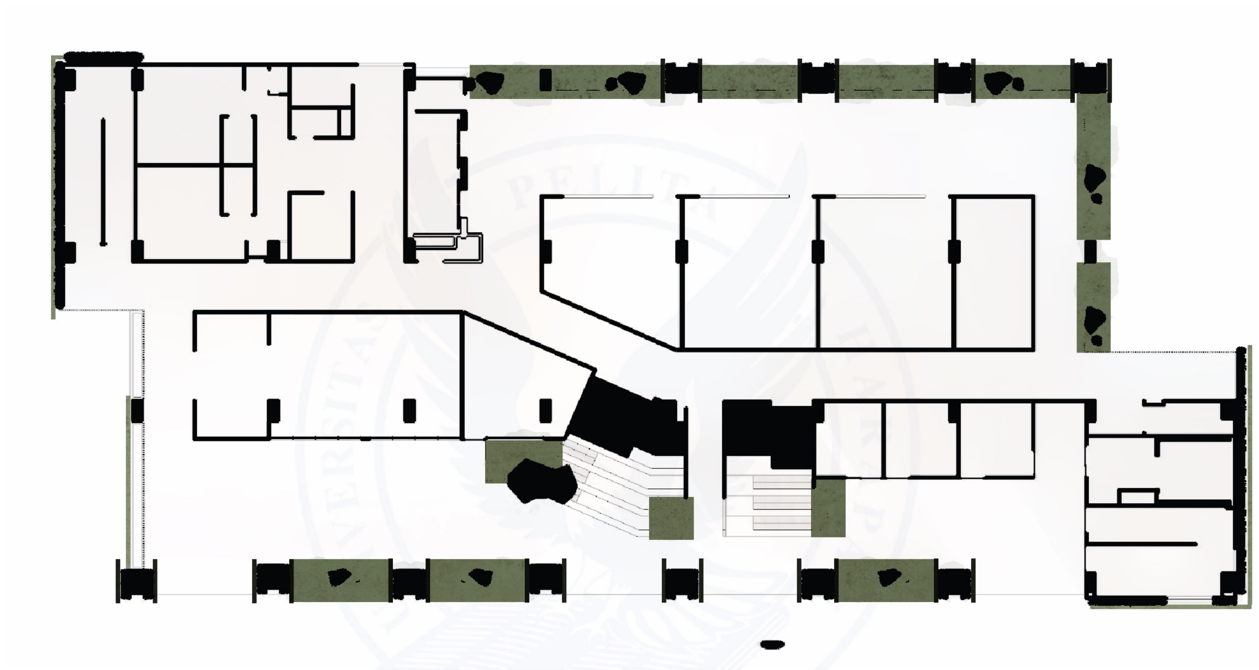
Green Walls



Vegetated Railings



Ground Floor

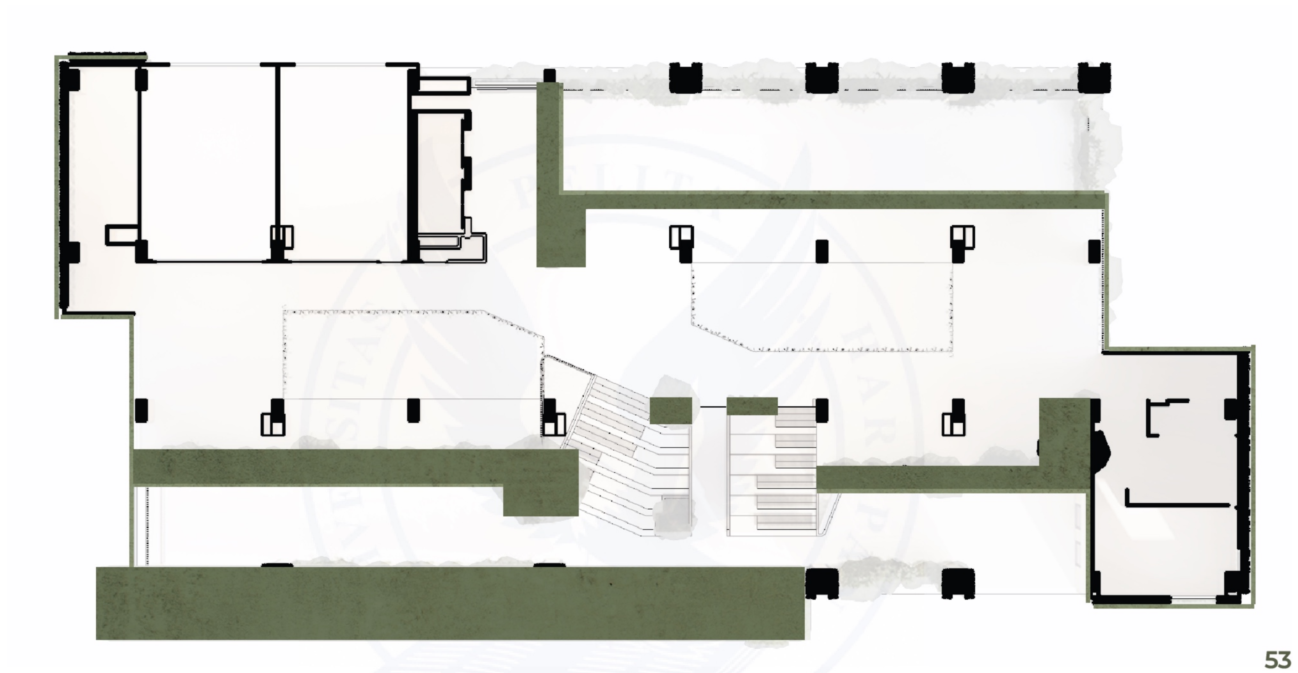


52

GF

Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Exterior Green Wall	Vertical Greeneries		1	22,78
			1	37,06
			1	27,285
			1	53,38
Green Column	Vertical Greeneries		11	63,8
			Total	**204,305**
Planter	Shrubs	Dicots	7	19,789
			1	2,145
			1	3,542
			1	1,74625
			1	4,61
			1	1,82
			1	1,51
			Total	**35,16225**
	Trees	Open Canopy	1	1

Mezzanine



53

MZ

Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Exterior Green Wall	Vertical Greeneries		1	21,44
			1	34,88
			1	25,68
			1	50,24
Interior Green Wall	Vertical Greeneries		1	3,2025
			1	7,14
			1	19,53
			1	12,6
			1	6,3525
			1	7,245
			1	25,3575
			1	4,83
			Total	**218,4975**
Planter	Shrubs	Dicots	1	93,02
			1	10,97
			1	7,31
			1	12,38
			Total	**123,68**
	Trees	Open Canopy	2	2

Typical Odd Floor

54

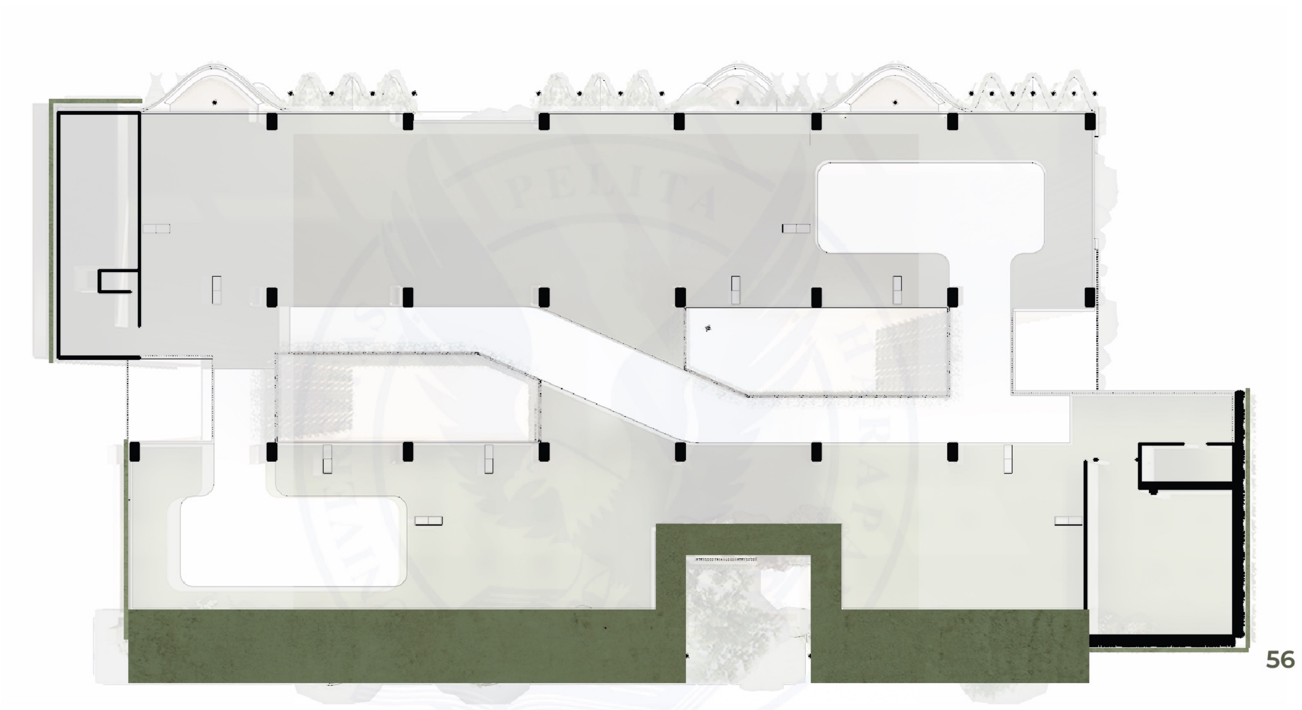
Odd		5		
Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Exterior Green Wall	Vertical Greeneries		1	24,12
			1	39,24
			1	28,89
			1	56,52
			1	31,14
			1	8,1
Railing	Vertical Greeneries		2	9,48
			2	21,444
			2	7,296
			2	6,564
Interior Green Wall	Vertical Greeneries		1	11,16
			Total	**243,954**
Planter	Shrubs	Dicots	1	0,5
	Trees	Open Canopy	1	1

Typical Even Floor

55

Even		5		
Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Exterior Green Wall	Vertical Greeneries		1	24,12
			1	39,24
			1	28,89
			1	56,52
			1	31,14
			1	8,1
Railing	Vertical Greeneries		2	9,48
			2	21,444
			2	7,296
			2	6,564
Interior Green Wall	Vertical Greeneries		1	11,16
			Total	**243,954**
Planter	Shrubs	Dicots	1	0,5

Roof Floor



RF

Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Exterior Green Wall	Vertical Greeneries		1	33,5
			1	54,5
			1	40,125
			1	78,5
			Total	**206,625**
Planter	Shrubs	Dicots	1	59,39

Composition of Main Elements in Fulfilling Green Plot Ratio (GPR) Calculation Requirements

Element	Category	Sub-Category	Q on Site	Quantity / Planted Area
Green Configuration - Balcony	Vertical Greeneries		3	66,66
			3	15,78
			3	15,12
			3	2,25
			Total	**99,81**
White Configuration - Balcony	Vertical Greeneries		3	12,75
			3	15,78
			3	15,12
			3	2,25
			Total	**45,9**
	Trees	Open Canopy	3	3
Green Configuration - Window	Vertical Greeneries		3	80,22
			Total	**131,37**
White Configuration - Window	Vertical Greeneries		3	34,2
			3	72,99
			Total	**318,78**

Table 6 Table of Green Element Breakdown from the Four Main Elements in the Design

Table 7 [overleaf] Final Green Plot Ratio Measurement

Final Green Plot Ratio Measurement

Category	Sub Category	Unit	Leaf Area Index (LAI) Value	Canopy Area /m^2	Quantity/ Planted Area		Leaf Area
			(A)	(B)	(C)		(A) x (B) x (C)
Trees	Open Canopy	No.	2,5	12,5	38	No.	1187,5
	Intermediate Canopy	No.	3	50	0	No.	0
	Dense Canopy	No.	4	80	0	No.	0
Shrubs	Monocot	m^2	3,5	NA	0	m^2	0
	Dicot	m^2	4,5	NA	395,7	m^2	1780,795125
Turf	Turf	m^2	2	NA	0	m^2	0
Vertical Greenery	-	m^2	2	NA	7030	m^2	14059,735
Total Potential Leaf Area							17028,03013
Total Site Area							43000
Potential GnPR (Total Potential Leaf Area x 6 / Total Site Area)							2,376004203
Existing GnPR							
	Ground GnPR						0,651482558
	Building GnPR						2,376004203
Total GnPR							3,027486762

Design Result

Integration of Parametric Tools in Green Facades of Vertical Housing as Ecological Compensation utilizes several parameters, with the primary parameter determining the fulfillment of ecological compensation—ecological metric—being the Green Plot Ratio (GnPR).

As the main parameter in this project, the Green Plot Ratio serves as a tool to test the effectiveness of the ecological compensation offered by the proposed design. This metric works by comparing the total amount of vegetation present on the site and building (Total Leaf Area) with the Site Area of the building.

In the exploration of green facade elements within the case study, alternative proposals were developed according to the division of the Green Plot Ratio matrix on the site (Ground GnPR) and the Green Plot Ratio of each tower of the *ASN* 3 Apartment Complex in IKN (Existing Building GnPR). Eventually, the GnPR value of the existing building is compared with the GnPR resulting from the design intervention (Potential GnPR).

At the *ASN* 3 apartment complex in IKN, the initial calculation of the existing design resulted in an Existing GnPR value of 0.73397. Meanwhile, the design proposal for the *ASN* 3 apartment complex in IKN achieved a GnPR value of approximately 3.0275. This indicates that the intervention produces four times more vegetation than the existing design. Moreover, the GnPR value of ~3.0275 signifies that the design—with a footprint of approximately 1,100 m² per tower—can provide ecological compensation equivalent to vegetation planted on a 130,182.5 m² area (43,000 m² x 3.0275).

Conclusion

Green facades present a promising solution to the issue of urban expansion, which has a detrimental impact on the environment, especially given the growing prevalence of vertical typologies in major cities. The ecological compensation offered by green facades serves as a form of reforestation or afforestation, mitigating the ecological degradation caused by development.

The case study of the Government Employee (*ASN*) 3 Apartment Complex in Ibu Kota Nusantara (IKN) is particularly relevant, considering that the site designated for this apartment complex was originally a green area. Therefore, development on this site requires ecological compensation efforts. Since the proposed development is of vertical typology, green facades can play a significant role in providing that compensation.

Various ecological compensation policies have indicated that green facades are recognized as a legitimate form of ecological mitigation. The Green Plot Ratio (GnPR), adapted from the Urban Redevelopment Authority's LUSH 3.0 policy in Singapore, is used as the primary parameter for measuring the success of ecological compensation in this research titled Parametric Tool Integration on Green Facades as Ecological Compensation.

Through a series of parametric explorations using digital tools and specific algorithms, the optimal placement and configuration of the green facades were determined. Spatial exploration during the design phase—supported by prototype fabrication—further promoted a more tangible implementation of the green facade proposal.

This exploration was based on literature review, a study of the *ASN* 3 Apartment Complex case, and a focus on the key parameter: Green Plot Ratio. The final result is a green facade design integrated into the *ASN* 3 Apartment Complex, achieving an ecological compensation value (GnPR) of 3.0275, which means the ecological benefit is four times greater than the existing design, or equivalent to vegetation planted on 130,182.5 m² of land (calculated as 43,000 m² × 3.0275).

Suggestions

Based on the research and design exploration conducted, several suggestions are proposed to provide insight and direction for future readers and researchers:

1. Design:
   The green facade configurations and algorithms developed in this study require a more focused investigation into the combinatory potential between facade elements, to enhance ecological effectiveness and visual integration.

2. Policy:
   Policies that include green facades should adopt clear and focused frameworks centered around ecological compensation needs. If policies like this are adapted into national regulations or building codes, their ecological effectiveness can be felt on a broader and more systematic scale.

3. Future Research:
   a. Ecological and Social Impact:
      Green facades, as a strategy for ecological compensation, provide diverse benefits for residents, including temperature regulation, air filtration, stress reduction, and opportunities for social interaction in vertical housing. These human-centered impacts deserve further research in future studies.

   b. Parametric and AI Integration:
      Parametric-based research offers novel opportunities at this stage of development. However, with the rise of AI integration, the author suggests further advancement in AI-assisted parametric tools, not only to optimize coverage and facade geometry but also to aid in selecting appropriate vegetation types for different conditions.

   c. Toolkit Development:
      The author also proposes the development of a dedicated plugin or toolkit in Grasshopper, specifically aimed at supporting the calculation and fulfillment of ecological metrics, such as the Green Plot Ratio (GnPR), to streamline the design process for ecological compensation in vertical architecture.

Figure Index

Table Index

Appendices

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Appendix 1 Existing Green Plot Ratio Measurement

Category	Sub Category	Unit	Leaf Area Index (LAI) Value (A)	Canopy Area /m^2 (B)	Quantity/ Planted Area (C)		Leaf Area (A) x (B) x (C)
Trees	Open Canopy	No.	2,5	12,5	139	No.	4343,75
Trees	Intermediate Canopy	No.	3	50	121	No.	18150
Trees	Dense Canopy	No.	4	80	11	No.	3520
Shrubs	Monocot	m^2	3,5	NA	0	m^2	0
Shrubs	Dicot	m^2	4,5	NA	0	m^2	0
Turf	Turf	m^2	2	NA	0	m^2	0
Vertical Greenery	-	m^2	2	NA	1000	m^2	2000
Total Ground Leaf Area							28013,8
Total Site Area							43000
Ground GnPR (Total Leaf Area / Total Site Area)							0,65148
Trees	Open Canopy	No.	2,5	12,5	5	No.	156,25
Trees	Intermediate Canopy	No.	3	50	0	No.	0
Trees	Dense Canopy	No.	4	80	0	No.	0
Shrubs	Monocot	m^2	3,5	NA	36,47	m^2	127,63756
Shrubs	Dicot	m^2	4,5	NA	36,47	m^2	164,10544
Turf	Turf	m^2	2	NA	71,6	m^2	143,2
Vertical Greenery	-	m^2	2	NA	0	m^2	0
Total Existing Building Leaf Area							591,193
Total Site Area							43000
Existing Building GnPR (Total Leaf Area * 6 / Total Site Area)							0,08249
Existing GnPR							0,73397

Appendix 2 Presentation Board of Ecological Parameter in Green Facades

Pelita Harapan Design Report: Ecological Parameter in Green Facade

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