ADVANCED HOUSING DESIGN GRADUATION STUDIO 2025 / 2026

ECOLOGIES OF INCLUSION

AR4AD150

“INDUSTRIAL STRUCTURES AS RESOURCE FRAMEWORKS FOR CIRCULAR HOUSING.”

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CONTENT

0.1 FOREWORD

This graduation project has provided me with the opportunity to explore a topic that I consider increasingly important within contemporary architecture: the reuse of existing buildings as valuable resources for future development. Throughout the process, I became ever more convinced that the construction sector must move beyond the traditional cycle of demolition and new construction. Existing buildings hold significant amounts of embodied energy, materials, and spatial potential that should not be overlooked.

The project challenged me to combine architectural design with structural analysis, circular construction principles, and housing design. Working within the limitations of an existing industrial framework required a different way of thinking about architecture, not as the creation of an entirely new object, but as the transformation and continuation of an existing one. This perspective has greatly influenced my understanding of sustainability and the role of the architect in the transition towards a circular built environment.

Beyond the technical and environmental ambitions of the project, I aimed to demonstrate that circular architecture can also create attractive, inclusive, and high-quality living environments. The integration of collective spaces, diverse housing typologies, and a strong relationship with landscape became essential themes throughout the design process.

Through this report, I would like to express my sincere gratitude to Robbert Guis, Ruurd Kuijlenburg, and Olv Klijn for their guidance throughout my graduation project. Their support, insights, and specialist advice have been very valuable during both the research and design process.

0.2 ABSTRACT

This graduation project investigates how existing industrial structures can be reused as the foundation for a circular housing system that supports liveable residential environments. The research responds to two contemporary challenges: the environmental impact of the construction sector and the growing demand for housing in Dutch cities.

The project focuses on the transformation of an existing industrial hall at Sydneystraat 37 in Rotterdam. Rather than demolishing the building, the existing foundation, ground floor slab, and steel structure are preserved and reused as the primary load-bearing framework for new housing. Building upon this framework, additional residential volumes are introduced using lightweight timber construction, reused steel elements, and biobased materials. The design incorporates reversible construction methods and demountable connections to maximize future adaptability and material reuse.

The final proposal consists of approximately 120 dwellings organized around a large communal courtyard and roof garden. A diverse mix of housing typologies, collective spaces, and green infrastructure creates a socially inclusive and high-quality residential environment. Environmental analysis demonstrates that retaining the existing structure and combining it with timber construction provides the most sustainable solution, preserving approximately 553 tons of embodied CO_2 while significantly reducing the need for new construction materials.

The research concludes that industrial structures should not be viewed as outdated buildings awaiting demolition, but as valuable resource frameworks capable of supporting future urban development. By reusing existing structures and applying circular design principles, the project demonstrates how sustainable housing can be created while reducing environmental impact and responding to the growing demand for homes.

01 INTRODUCTION

1.1 PROBLEM STATEMENT

The construction sector is one of the largest contributors to global environmental impact. According to the United Nations Environment Programme, buildings and construction account for nearly 37% of global energy-related CO_2 emissions and consume a large share of global raw materials. A substantial portion of this impact results from the extraction of new resources and the demolition of existing buildings that still contain structurally viable components (UNEP, 2022). Despite increasing attention to circular construction, demolition and new construction remain dominant development practices in most urban contexts.

Within the Netherlands this issue is particularly visible in post-war industrial areas. Many industrial buildings constructed during the second half of the twentieth century are approaching a moment of transition due to changing economic activities and spatial pressures in cities. Although these buildings are often structurally robust, they are frequently demolished to allow new development. As Stewart Brand (1994) argues, buildings should be understood as evolving systems capable of adaptation rather than static objects with a fixed lifespan. The early demolition of structurally intact buildings represents a loss of embodied energy, material value, and spatial potential. At the same time Dutch cities face a significant housing shortage. Rotterdam has identified the need for a large increase in housing production in the coming decades. Municipal policies aim to significantly expand the housing stock while ensuring a mix of social housing, mid-range housing, and private sector dwellings (Gemeente Rotterdam, 2023). This need for additional housing must be addressed while simultaneously reducing environmental impacts and limiting the consumption of new resources.

Industrial areas present a potential opportunity in this context. Many contain large buildings with strong structural systems, generous spans, and flexible layouts. These qualities can provide a spatial framework for transformation into new programs such as housing. Brand (1994) argues that buildings evolve over time and should be designed to accommodate changing uses. Rather than demolishing existing structures, architects can reinterpret them as frameworks for new programs. In the context of industrial buildings, large spans and strong structural systems provide opportunities for transformation into housing. However, converting industrial structures into residential environments presents several architectural challenges. Industrial buildings are typically designed for production or storage rather than habitation. Structural grids, floor depths, daylight conditions, and spatial hierarchies often differ significantly from those typically associated with housing environment. Furthermore, the integration of reused materials and circular construction strategies requires new design approaches. Circular construction does not only involve the reuse of existing materials but also the development of building systems that allow components to be disassembled and reused in the future. Durmisevic (2019) describes this as reversible building design, in which buildings are conceived as assemblies of components that can be separated and reused rather than permanently fixed together.

1.2 RELEVANCE

The relevance of this research lies at the intersection of environmental sustainability, housing production, and architectural innovation. First, reducing the environmental impact of the construction sector has become a major objective in European and Dutch climate policy. Circular construction strategies aim to minimize waste, reduce material extraction, and extend the lifespan of building components by reusing them in new projects (Ellen MacArthur Foundation, 2019). The current system, in which materials are extracted, processed, used, and discarded as waste at the end of their lifespan, is no longer sustainable. In the Netherlands, the construction sector accounts for approximately 50% of raw material use, 40% of energy consumption, 40% of waste production, and 30% of water use (Dirkse & Smit, 2024). With ongoing urban growth and housing shortages, this pressure continues to increase. At the same time, ecological consequences are becoming increasingly visible in the form of climate change, resource scarcity, and landscape degradation (IPCC, 2022).

Second, the transformation of industrial areas into mixed-use or residential environments is becoming an increasingly important urban strategy. Many cities contain extensive industrial zones that are increasingly changing due to economic shifts and spatial pressures. Developing architectural approaches that allow these areas to accommodate housing while maintaining structural resources can support more sustainable patterns of urban development.

Third, the project contributes to architectural knowledge regarding adaptive reuse and circular building systems. While adaptive reuse is often associated with historic preservation, ordinary industrial buildings represent a vast and largely underexplored resource for transformation. By investigating how a standardized structural grid can accommodate multiple housing typologies, the project demonstrates how architectural design can mediate between existing structures and new residential requirements.

1.3 OBJECTIVE AND MOTIVATION

The project explores whether existing industrial structures can function as long-term resource frameworks. By retaining the foundation, ground floor slab, and steel structure of the existing building, the project aims to significantly reduce material consumption while enabling new residential development. The main objective is to achieve maximum improvement with minimal intervention by increasing and strategically using building resources that are already present.

This graduation project addresses these challenges through the design of two residential buildings on an existing industrial site located at Sydneystraat 37 in Rotterdam. The current site contains a factory hall used for industrial production and storage. The building consists of a steel structural frame with two grids of approximately 7,8 by 6,0 and 5,6 by 5,4 meters, combined with a reinforced concrete ground floor slab and foundation. Rather than demolishing this structure, the project proposes to retain the existing foundation, ground floor slab, and steel frame as the structural base for new housing development.

A large portion of the ground floor will serve as parking for 76 cars and 300 bicycles. This plan is highly efficient, utilizing the existing heavy-duty concrete floor and the wide structural grid of the columns for car parking. Additional floors are introduced above the existing structure using reused steel elements sourced from donor buildings. These new layers create a stepped residential volume with varying heights, reaching up to approximately five floors. The flooring utilizes timber structures and lightweight assemblies, while the façade and secondary components incorporate materials salvaged from nearby industrial buildings. Prioritizing sustainability, the project emphasizes locally biobased materials as the primary choice, followed by reused or highly circular, low-impact alternatives. Furthermore, the integration of demountable connections minimizes the building's carbon footprint and ensures high future reuse potential. Through this approach the project investigates how existing industrial structures can function as long-term resource frameworks for housing development. Instead of treating existing buildings as obstacles to redevelopment, they are approached as material reservoirs and spatial structures capable of supporting new programs. By combining structural reuse, circular building systems, and diverse housing typologies, the project explores a design strategy for transforming industrial areas into liveable residential environments.

Finally, the project aims to create not only a sustainable and future-proof environment but also a liveable residential setting within an industrial structural grid. The design incorporates a variety of housing typologies, including ground-related apartments, maisonettes, gallery-access units, and corridor apartments. These come in a wide range of sizes to cater to all target groups. Additionally, collective spaces, such as roof gardens, wide access galleries, and shared circulation areas, are introduced to encourage social interaction and strengthen community formation.

1.4 RESEARCH QUESTIONS

Main research question:

How can existing industrial structures be reused as the basis for a circular housing system that enables liveable residential environments?

Sub-questions:

1. What is required to effectively use the existing industrial structure, foundation, ground floor slab, and steel frame, as a structural framework for new housing?
2. What characteristics of a modular and demountable building system are necessary to enable the seamless integration of reused and biobased materials?
3. What design approaches support the conversion of an industrial structural grid into a livable residential environment?

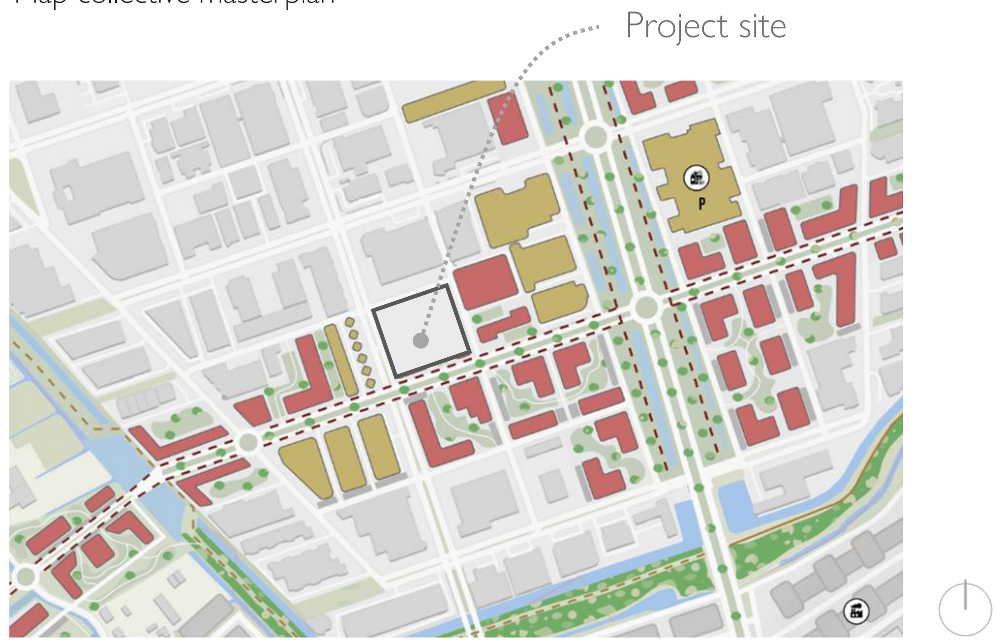
1.5 SCOPE

The research focuses on the adaptive reuse of an industrial site located at Sydneystraat 37 in Rotterdam. The total area of the plot is 10,115 m^2 and forms a square of approximately 100 × 100 meters. Currently, the project site is situated within a monofunctional industrial area characterized by large-scale buildings. The plot is located along one of the main access roads of the district, making it particularly attractive due to its excellent accessibility and logistical advantages for future residents and visitors.

Furthermore, this prominent location allows the project to serve as a catalyst for the redevelopment of the wider area, establishing a transition zone between industrial activity and residential life. What makes the site particularly interesting is its position at the intersection of three distinct urban conditions. On one side, it faces a busy access road that provides visibility and connectivity. On another side, it is bordered by existing residential and urban developments, while the remaining edges are directly adjacent to active industrial functions. This unique combination of infrastructure, housing, and industry creates a complex urban context in which the building must simultaneously act as a landmark, a residential environment, and a buffer between contrasting land uses. As a result, the project has the potential to mediate between these different conditions and demonstrate how industrial areas can gradually evolve into mixed and liveable urban districts.

Map Midden Delfland

Map collective masterplan



Map collective masterplan

Current situation

02 APPROACH

2.1 RESEARCH STRATEGY AND METHODS

The research is conducted through a research-by-design methodology, in which architectural design functions as a primary tool for generating knowledge. Rather than separating design from research, the two are continuously linked. The design process is used to explore spatial, structural, and material possibilities, while theoretical investigation ensures these explorations remain grounded in technical, environmental, and regulatory realities. According to Cross (2006), this approach allows complex spatial problems to be investigated through the iterative development, testing, and evaluation of design proposals.

Within this framework, the research operates on two parallel tracks:

- Exploratory design studies: This track focuses on the relationship between structural reuse and spatial quality. Through iterative studies, various forms, massing configurations, housing and access typologies are tested to determine which solutions best align with the architectural vision and the constraints of the industrial grid.
- Targeted theoretical research: These design explorations are continuously validated through technical analysis. This includes investigating material performance, environmental impact, and structural feasibility, such as achievable spans and load-bearing capacities. Furthermore, Dutch building regulations and municipal housing policies in Rotterdam are analysed to ensure compliance with requirements for unit sizes, program distribution, and social housing proportions.

By moving back and forth between experimentation and analysis, the project develops proposals that are not only conceptually and spatially innovative but also technically feasible and realistic within the given urban context.

Several additional research methods are used throughout the project.

Construction and material research.

A second research method focuses on investigating the existing structure and circular material strategies. To ensure an accurate assessment, original construction drawings were obtained and studied at the Rotterdam City Archives (Stadsarchief Rotterdam). These documents provide the essential data needed to structurally evaluate the load-bearing capacity of the existing concrete ground floor and steel frame. This analysis is crucial to define the maximum number of floors that can be added and the required structural spans. Building on this data, the project explores the potential for reusing steel components, both from the site itself and from nearby donor buildings, to create additional structural layers above the existing hall. Additionally, timber floor systems, prefabricated façade elements, and biobased materials are explored as lightweight alternatives to minimize structural loads and environmental impact. In parallel, theoretical research is conducted into the environmental performance of materials and their suitability for reuse. Specific attention is given to demountable connections, ensuring that components can be easily disassembled and reused in future building cycles.

Case study analysis

Precedent projects are analysed to understand how similar architectural challenges have been addressed. Case studies include projects that focus on adaptive reuse, circular construction, and the transformation of industrial buildings into residential environments. These examples provide insight into structural strategies, spatial organization, and material reuse practices that inform and support the design decisions.

2.2 THEORETICAL FRAMEWORK

The foundation of the transformation strategy lies in recognizing that a building is not a static object, but a dynamic system. Stewart Brand (1994) introduced this idea through the concept of the "Shearing Layers of Change." (fig 1.) He argues that buildings consist of multiple layers, each with its own lifespan and rate of change. The most permanent layers, the "Site" and the "Structure" , form the industrial foundation in this project: the steel frame and the concrete floor. By treating these layers as fixed and designing the "Skin" (facade) and the "Space Plan" (interior) as replaceable elements, the lifespan of existing materials is maximized. This layered approach allows the industrial structure to be reinterpreted as a framework capable of supporting different forms of housing over generations.

To translate this theoretical layering into a technical approach to circularity, the theory of "Reversible Building Design" by Elma Durmisevic (2019) is applied (fig 2.). Circularity in construction goes beyond simply using recycled materials; it requires a design that anticipates future change. Durmisevic emphasizes that buildings should be conceived as "material banks." A key principle here is the reversibility of connections. In this project, this means that added elements, such as timber floor systems and bio-based facade components, should not be permanently bonded to the existing steel structure. By using dry, demountable connections, the value of materials is preserved, allowing the building to be adapted or dismantled in the future without loss of quality.

The challenge of transforming a rigid industrial grid into a humane and livable residential environment is theoretically supported by the "Open Building" philosophy of N.J. Habraken. Habraken makes a clear distinction between the "Support" (the base structure) and the "Infill" (the interior fit-out). The support provides the collective framework, while the infill allows for individual variation in housing types. In this design, the existing grid of 7.8 by 6.0 meters functions as the support. Habraken's theory provides the basis for introducing a range of housing types, from maisonettes to corridor apartments, within this rational grid. It enables the design to combine the collective efficiency of industrial construction with the individual needs of residents, resulting in a socially sustainable living environment.

Together, these three perspectives form an integrated framework. Brand defines the long-term value of the structure, Durmisevic establishes the technical conditions for reuse, and Habraken enables the translation into flexible and livable architecture. This theoretical framework makes it possible to view Rotterdam's existing industrial resources not as waste, but as the essential backbone for a circular city of the future.

2.3 EXPECTED OUTPUT

The outcome of this research consists of three main components.

First, the project develops a circular building system based on the reuse of an existing industrial structure. This system demonstrates how foundations, structural frames, and new modular components can form a flexible architectural framework.

Second, the project proposes two residential buildings containing approximately 120 dwellings. The design explores a variety of housing typologies within the existing structural grid while integrating collective spaces such as roof gardens and wide circulation galleries.

Third, the research contributes to architectural knowledge about the transformation of industrial structures into residential environments through circular design strategies. The project therefore functions both as an architectural proposal and as an exploration of new design methods for circular housing development. Furthermore, it serves as a valuable practical framework for contractors and commercial developers, offering actionable insights into the complexities of adaptive reuse. By bridging the gap between theory and practice, this study provides a complete source of information to speed up the industry's transition toward sustainable, circular construction methods.

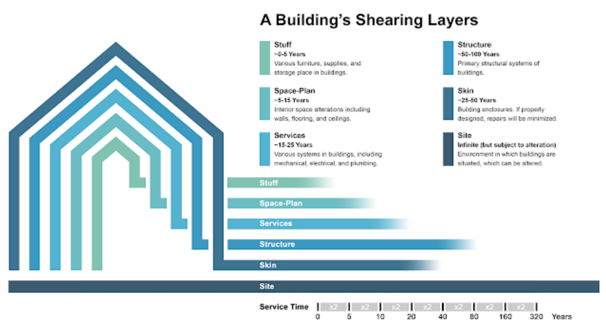


Fig. 1

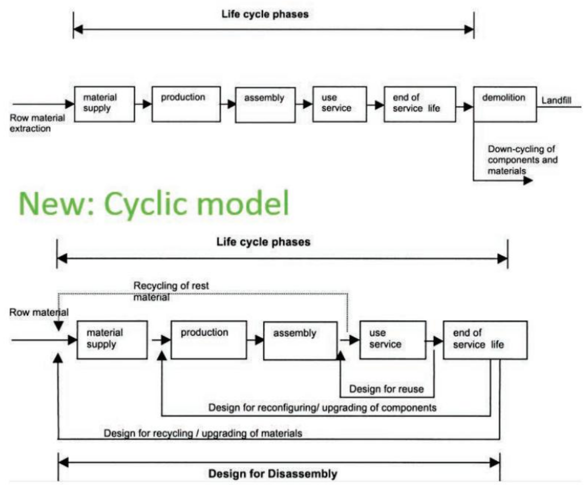


Fig. 2

2.4.1 DESIGN BRIEF

This project is part of a larger urban masterplan in which the concept of building resources plays a central role. Within this masterplan, the landscape of Midden-Delfland is approached as a productive system capable of supplying materials for the built environment. While the masterplan focuses on the development of new material flows, this project takes a complementary position by exploring how existing building materials and structures can be reused to the greatest extent possible. Instead of constructing a building entirely from newly produced materials, the design starts from the existing industrial hall. The foundation, ground floor slab and steel structure are retained and form the basis for further development. On top of this structure, new building volumes are added using reused steel elements sourced from donor buildings, combined with lightweight timber floors and biobased insulation materials. Where possible, façade elements and additional components are also composed of reused materials from the surrounding area.

This approach is directly linked to principles of sustainability and circular construction. By preserving existing structural elements, the embodied energy of the building is maintained and the demand for new raw materials is significantly reduced. In addition, the project focuses on demountability, allowing the building to be adapted, disassembled and reused in the future. In this way, the building becomes part of an ongoing material cycle rather than a final product. Although the project is developed for two buildings on a single site, its ambition extends beyond this specific location. The proposed building system and design principles are not site-specific and can be applied to similar industrial structures in Rotterdam and elsewhere. Industrial buildings with robust structural systems are found worldwide and represent a large, often underused resource. The concept of maximum reuse and demountable construction therefore has the potential to contribute to a broader transition within the construction sector, in which buildings are understood as temporary configurations of materials that can be continuously reused. In the future, this approach will become increasingly important to reduce environmental impact and respond to the growing scarcity of resources.

An important aspect of the design is the integration of collective spaces that support social interaction and improve overall living quality. At the center of the project is a large collective roof garden, positioned above the parking level. All apartments are organized around this space, allowing it to function as the social core of the building. The roof garden provides space for meeting, relaxation and informal activities. In addition, wide access galleries are introduced. These galleries function not only as circulation routes but also as semi-public spaces where residents can spend time and encounter each other. This increases the potential for informal interaction and contributes to a sense of community. This is essential for establishing a livable and inclusive residential environment within an industrial context. Lastly, a shared living area is centered around the main stairs and elevator to optimize connectivity. By placing this social rooms at the heart of the daily commute, maximum visibility and community engagement is ensured.

2.4.2 TARGET GROUP AND HOUSING TYPES

Target group

The project is designed for a broad and inclusive group of residents. Rather than focusing on a single user group, the aim is to accommodate a diverse population, including:

- single occupants and starters
- couples
- small and medium-sized families
- elderly residents

This diversity supports the ambition to create an inclusive living environment in which different household types can coexist. By offering a range of dwelling sizes and categories, the project includes both social housing and mid-range and free sector housing, in line with municipal housing policies in Rotterdam.

Housing types

To support this diversity, a wide range of housing typologies is introduced:

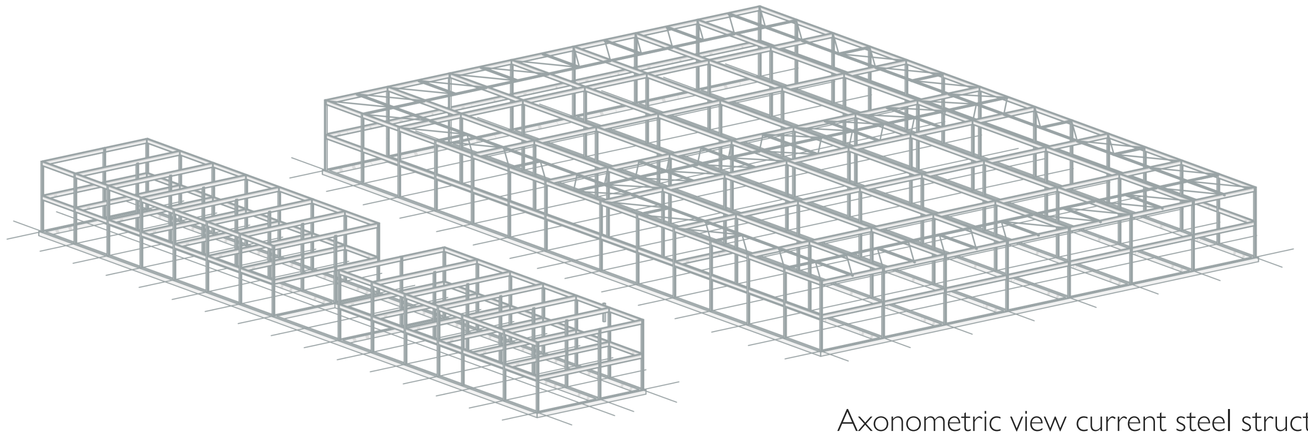
- studios and compact apartments (social housing)
- mid-sized apartments
- larger family dwellings (maisonettes)
- ground-related units on the lower levels

This variation allows the project to respond to different living needs and life stages within a single building. At the same time, the existing industrial grid of 7.8 by 6 meters is used as the organizing principle.

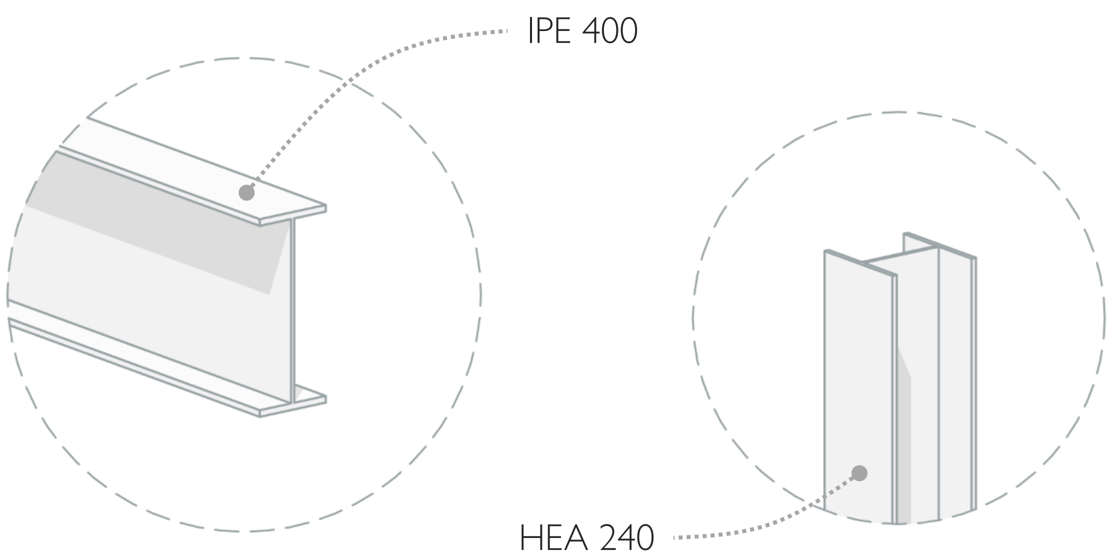
03 RESULTS

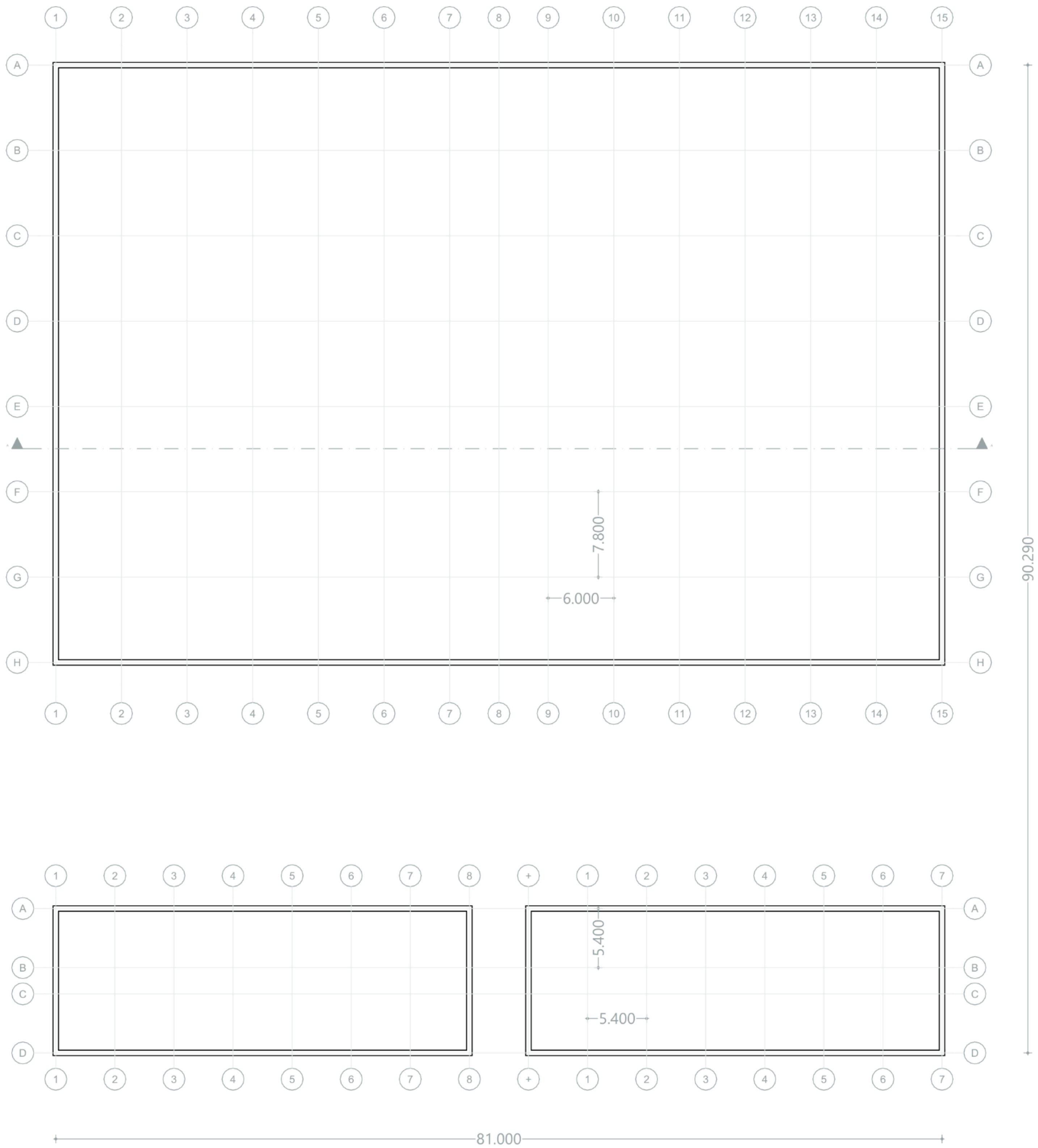
3.1 PRELIMINARY SITE ANALYSIS

The initial phase of this research focused on gathering comprehensive data regarding the existing state of the buildings on the plot. This information serves as the foundation for calculating the load-bearing capacity of the structure and identifying suitable residential functions that fit within the existing grid. Although the project consists of two separate buildings, they were constructed simultaneously using a similar construction methodology. This consistency allows for a combined structural approach across the site. The following section illustrates the fundamental data concerning the primary load-bearing structures.

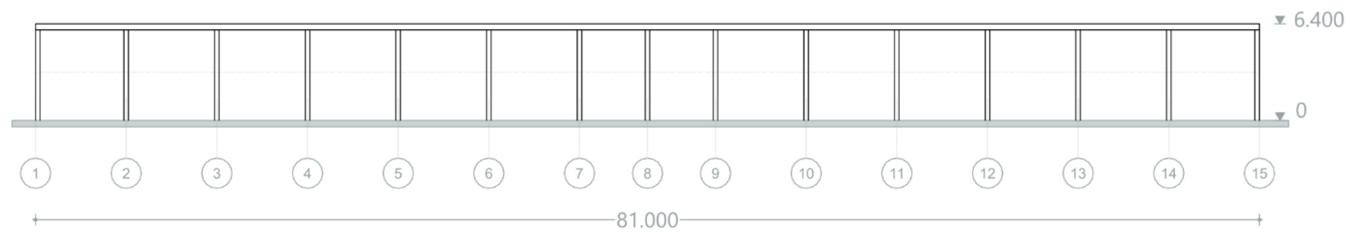


Axonometric view current steel structure





Current floorplan | 1:500

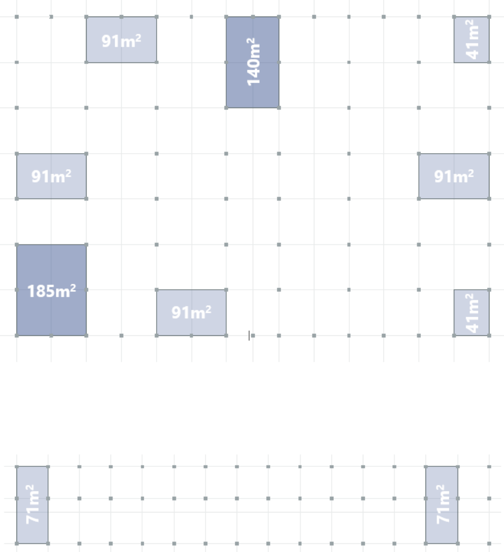


Current section | 1:500

3.2 SPATIAL CONFIGURATION STUDY

A step-by-step spatial analysis testing various typologies, from separate blocks to an open perimeter layout, to find the ideal balance between urban density and shared outdoor living.

1. The design process begins by exploring the most effective spatial configurations within the existing column-and-beam grid. The dimension of the grid limits the design options drastically resulting in only a handful apartment sizes.
2. A familiar Dutch gallery-access typology is tested. While highly efficient within the grid, it offers limited residential quality and outdoor space.
3. The buildings remain independent entities, resulting in a fragmented urban composition with little collective identity.
4. A perimeter block is explored, although the block provided clear urban edges, it resulted in insufficient daylight and limited courtyard dimensions.
5. A central courtyard accessible to all three buildings is introduced, significantly improving residential quality and social interaction. Nevertheless, the three buildings remain distinct and do not form a single entity which is needed to improve living quality,
6. The courtyard evolves into a communal garden embraced by two building wings, creating a strong sense of enclosure and tranquility. The top building is now closed and therefore visually blocks access to the courtyard for bottom building.
7. Opening the perimeter block connects the bottom building to the garden and allows the three volumes to function as one coherent residential ensemble. This is the best layout choice for balancing density, communal living, and residential quality because it breaks open a rigid perimeter block to let light and views in, while still maintaining enough enclosure to create a safe, intimate courtyard
8. An additional residential level is added to increase density while maintaining the compact footprint of the development.
9. Unused structural capacity is activated through an elevated parking deck, with a communal garden above, combining parking and high-quality outdoor space in a single intervention.



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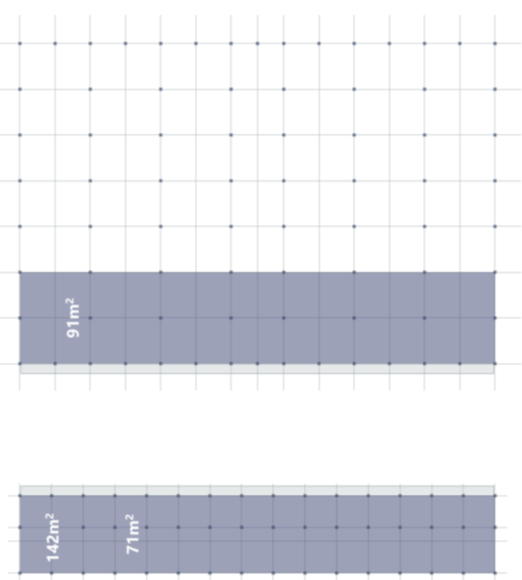

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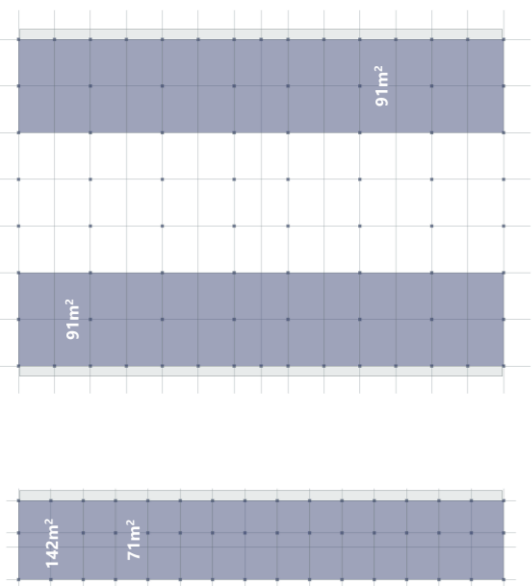

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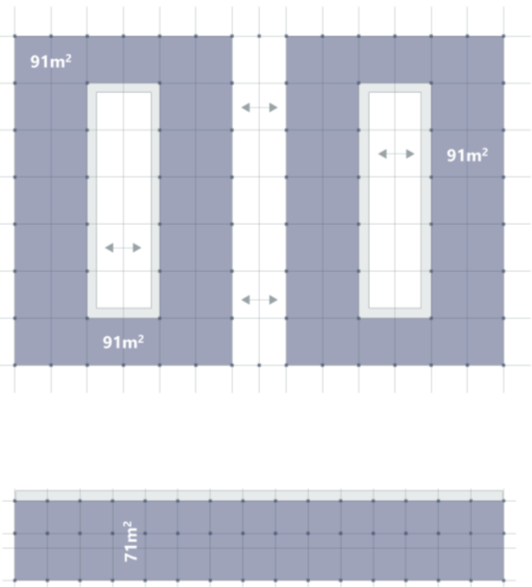

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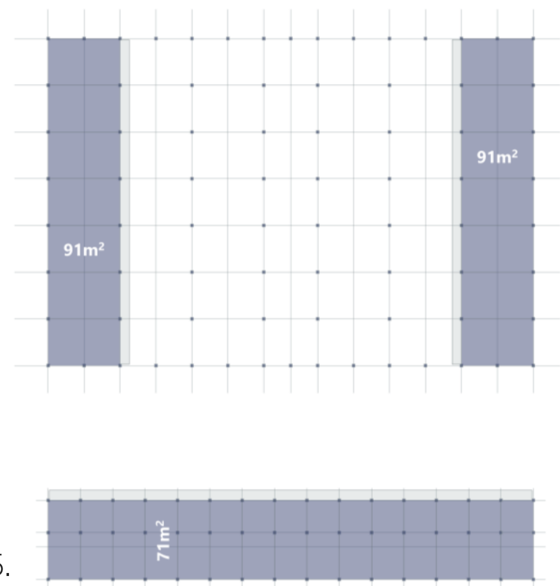

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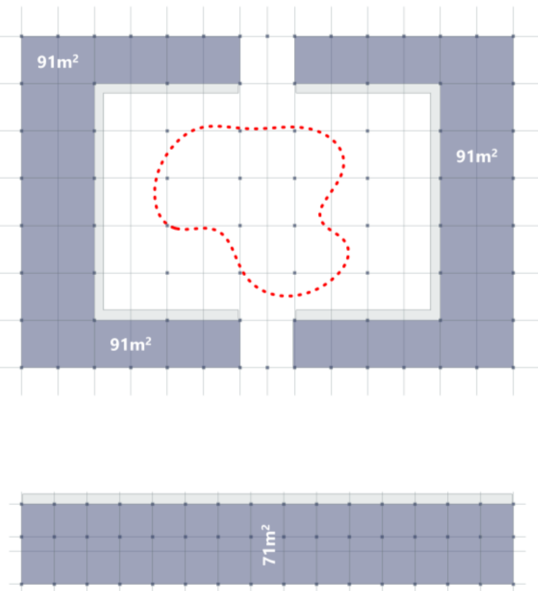

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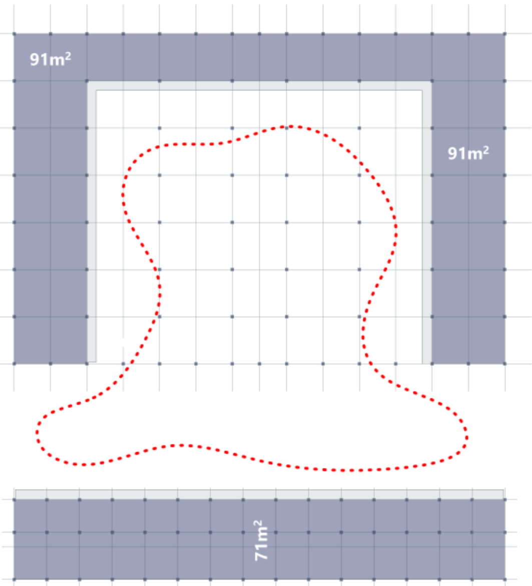

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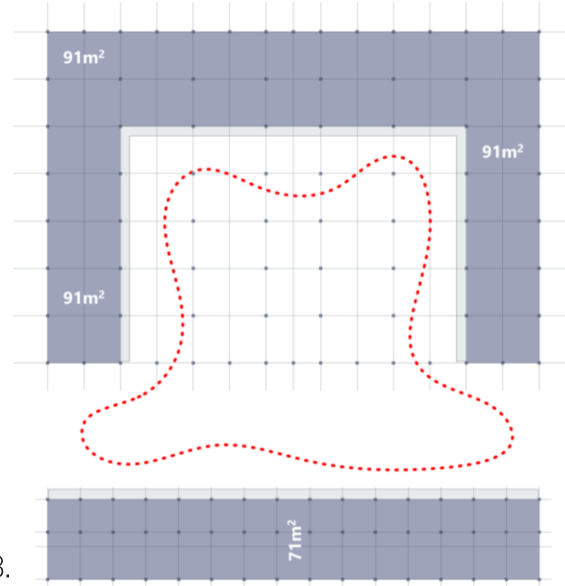

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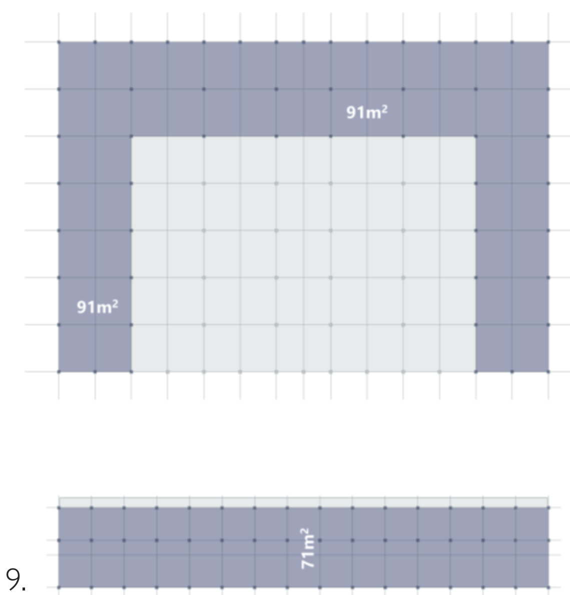

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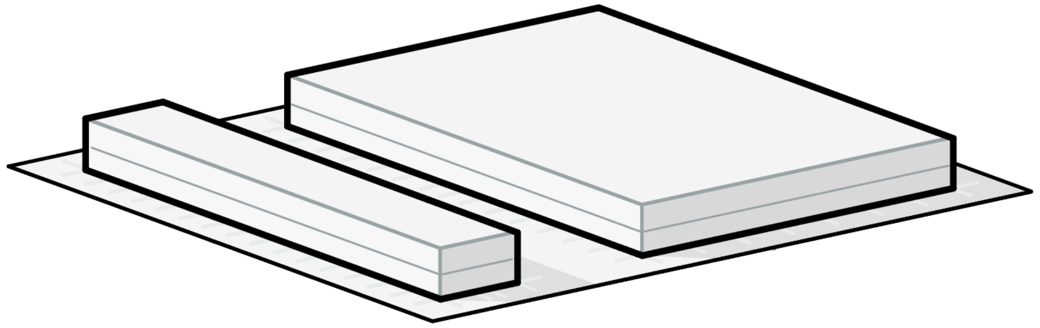
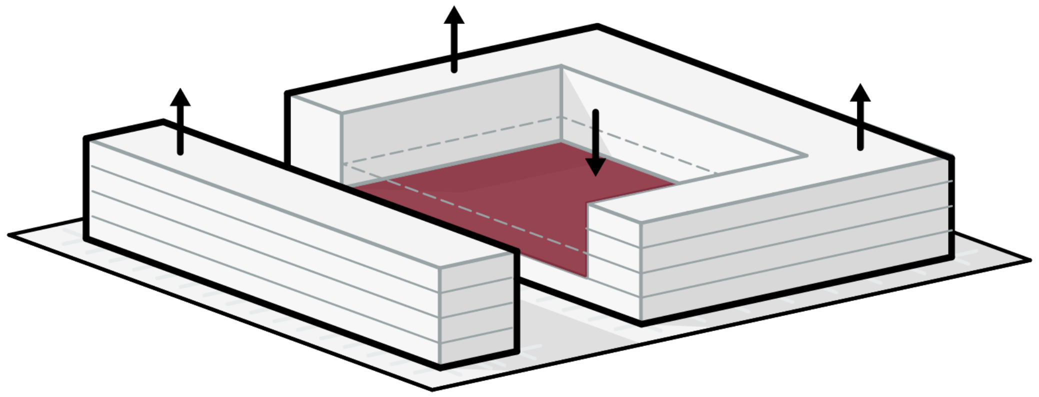
3.3 DESIGN FRAMEWORK

The design is based on the following six steps and principles:



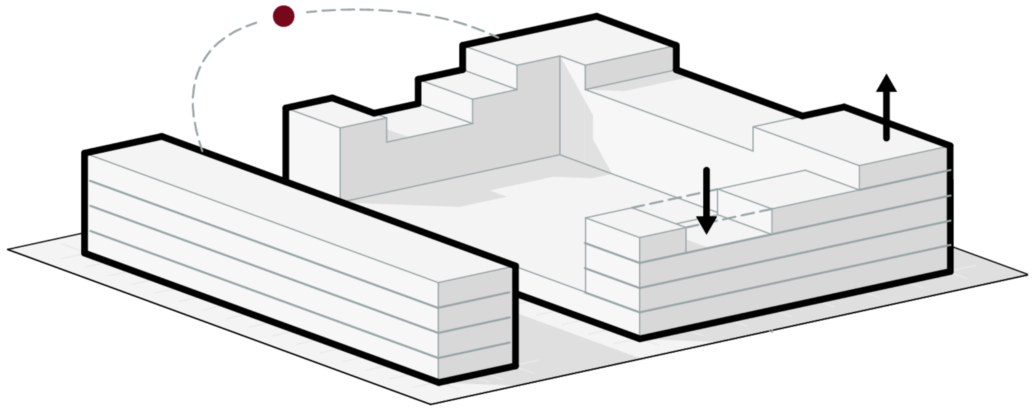
01 Current situation

The existing industrial buildings provide a robust structural framework that forms the foundation for the transformation. By retaining these elements, the project preserves valuable material resource.



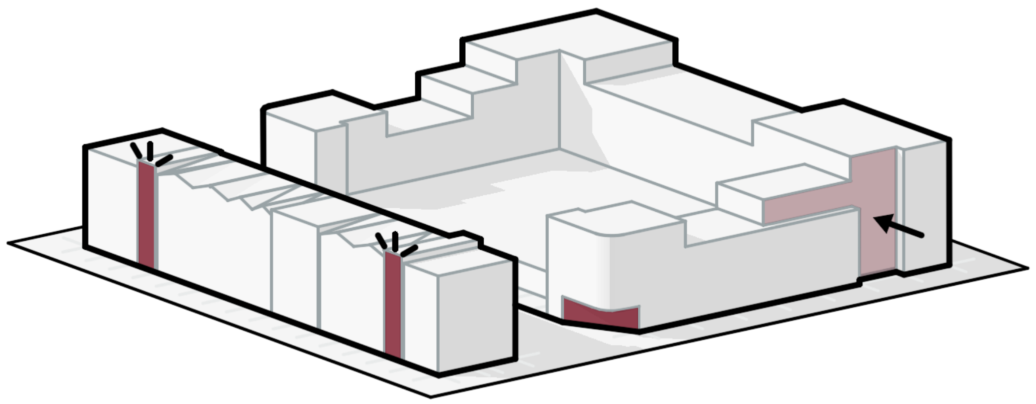
02 Transformation

The project adds two to three new layers to the existing structure. The centre of the building will be lowered by one level to create parking spaces with a green plaza on top. This intervention maximizes the use of the existing structure, minimizes the need for new construction materials while seamlessly integrating parking.



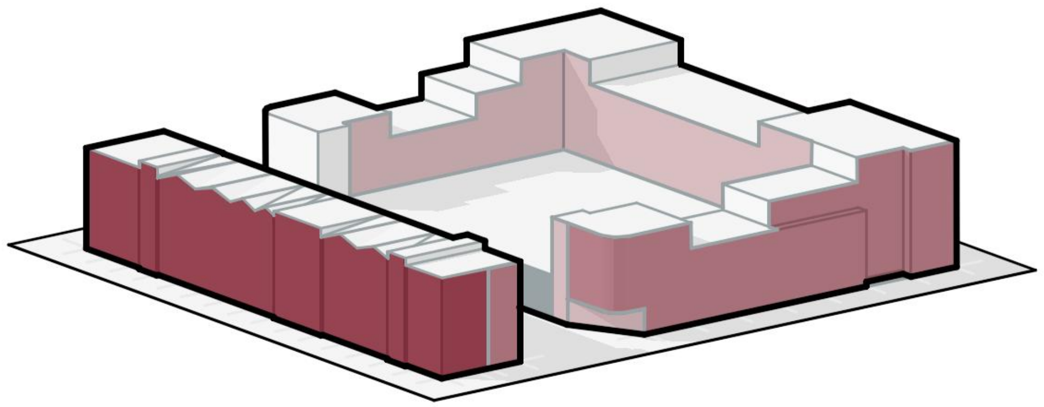
03 Layering

Variations in building height improve daylight access, create spatial diversity, and reduce the perceived scale of the development, contributing to a more comfortable residential environment.



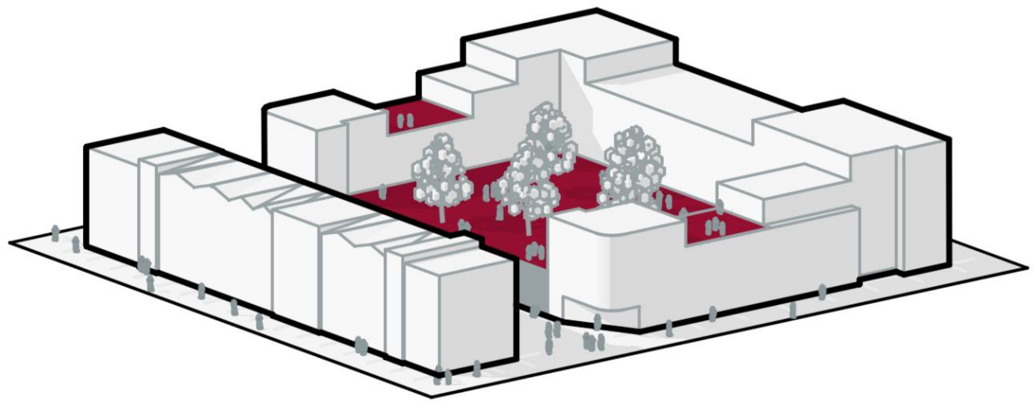
04 Articulation

Entrances, façade setbacks, and subtle curves are introduced to break down the scale of the large industrial volume and create a more legible residential environment. These interventions improve orientation and wayfinding, clearly marking access points and transitions between public and private spaces. By softening the rigid geometry of the existing structure, the design creates a more human scale and enhances the overall residential character of the development.



05 Dualism

A clear distinction between the urban exterior and the residential interior strengthens both the identity and functionality of the project. The outer façades maintain a robust and industrial appearance that reflects the character of the surrounding context and the existing structure. In contrast, the courtyard façades are designed with a softer architectural expression, incorporating balconies, greenery, and communal spaces. This contrast creates a gradual transition from the public city to the private living environment



06 Community

Collective gardens, roof terraces, and shared circulation spaces encourage social interaction and transform the former industrial site into a vibrant residential community.

3.4 AXONOMETRY

This holistic view illustrates how the building integrates into its urban context, highlighting the contrast between the intimate courtyard and the robust exterior of the block. To the north, the design connects with the industrial zone, establishing a natural boundary formed by greenery and trees. Additionally, the eastern street features an intimate green axis designed with a strong focus on the human scale.

3.5.0 GROUND FLOOR

The ground floor maximizes the reuse of the existing industrial structure by accommodating parking, storage, and bicycle facilities within the original building footprint. By concentrating these supporting functions at ground level, the upper floors can be fully dedicated to housing and collective outdoor spaces.

Both buildings feature four main entrances connected by a central corridor, which provides direct access to the stairwells and elevators (vertical circulation points). To enhance the quality of this central hallway, it is equipped with several skylights.

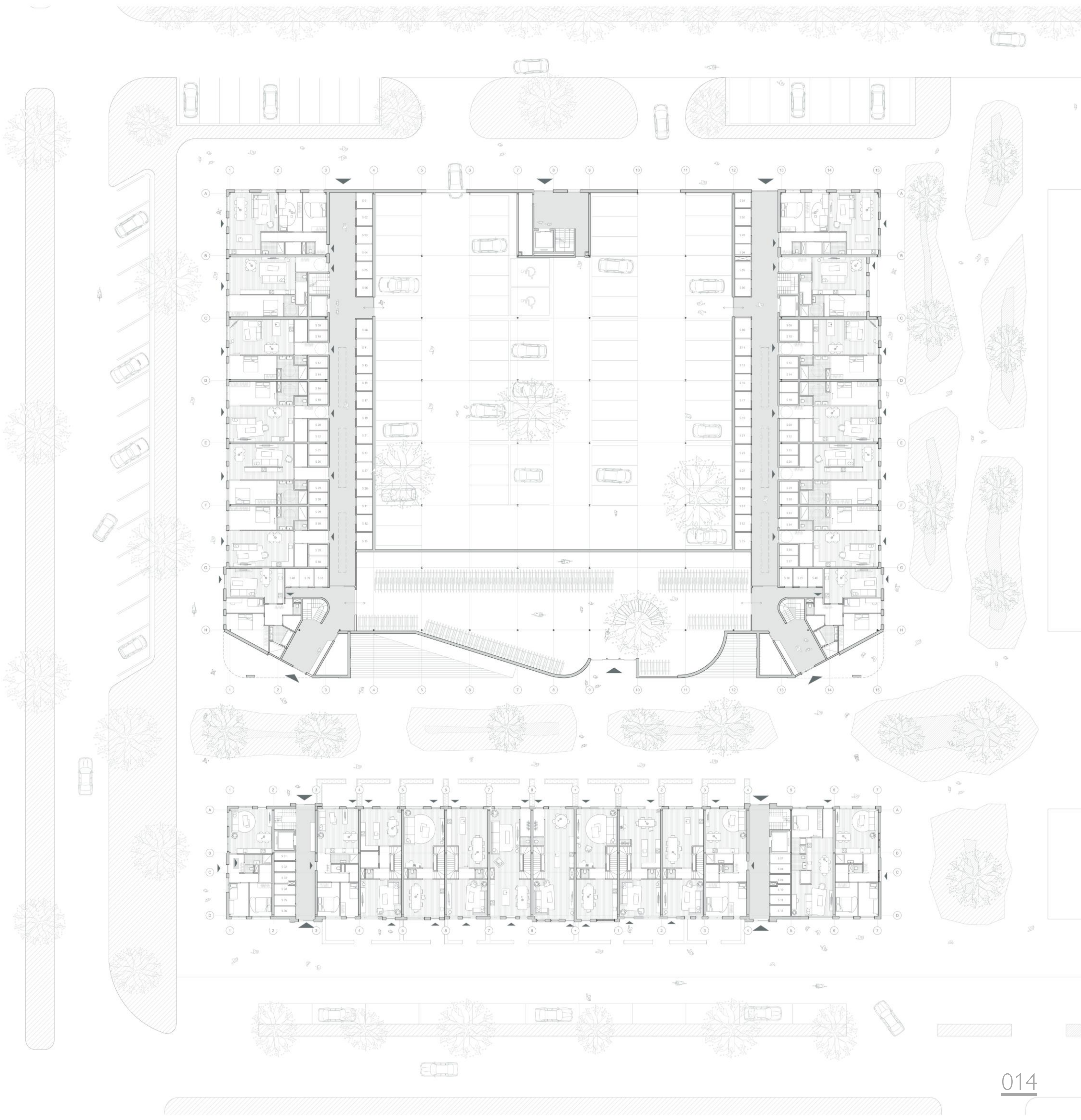
The surrounding area offers plenty outdoor parking spaces, beautifully complemented by rich green zones and mature trees around both buildings.

North Building

- Includes 68 internal parking spaces (including 2 wheelchair-accessible spots), 76 storage units, and 312 bicycle parking spaces, which are shared between both buildings. The parking garage itself features ceiling openings designed to let in natural daylight and allow trees to grow through.

The South Building

- Features 12 external storage units.
- The units located in the middle are multi-story maisonettes, whereas the units on the sides consist of standard single-level apartments.



Entrance

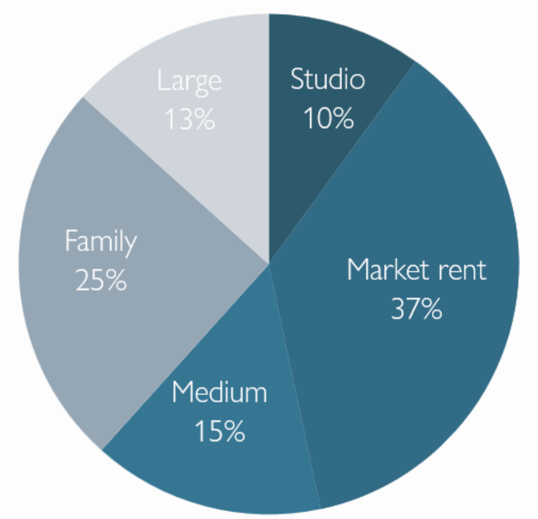
Circulation space

Green zones

3.5.1 FIRST FLOOR

The first floor forms the social heart of the development. A large collective courtyard is positioned above the parking level, providing residents with a safe and green outdoor environment. Social spaces located around the circulation cores encourage daily encounters and strengthen community formation while ensuring easy access for all residents. Since these areas serve as high-traffic hubs, they are designed as gathering points to foster interaction and enhance social cohesion among residents.

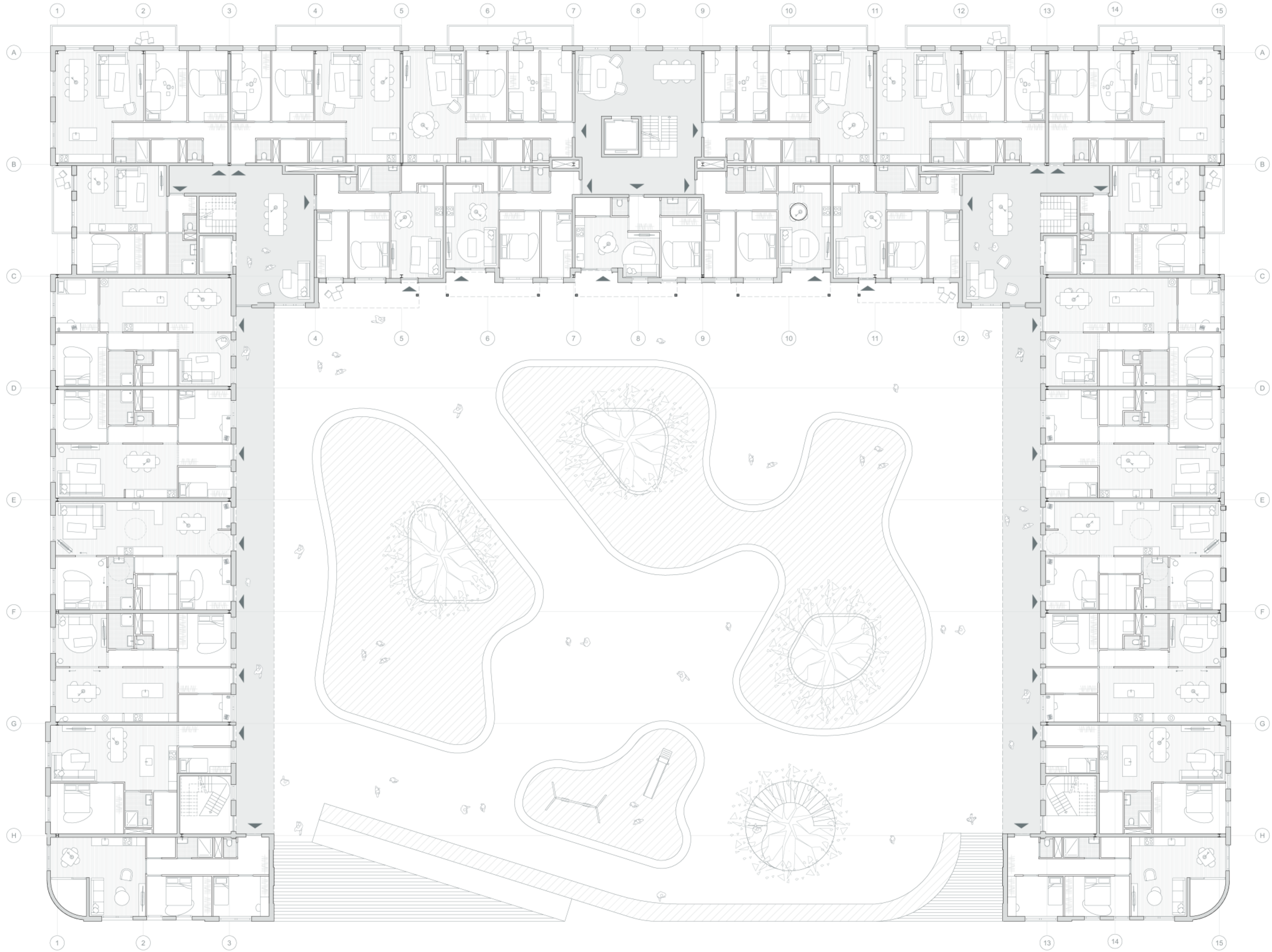
Type	m^2	Amount
Studio	45-50	12
Market rent	65	44
Medium	80	18
Family	95	30
Large	110-140	16
		120

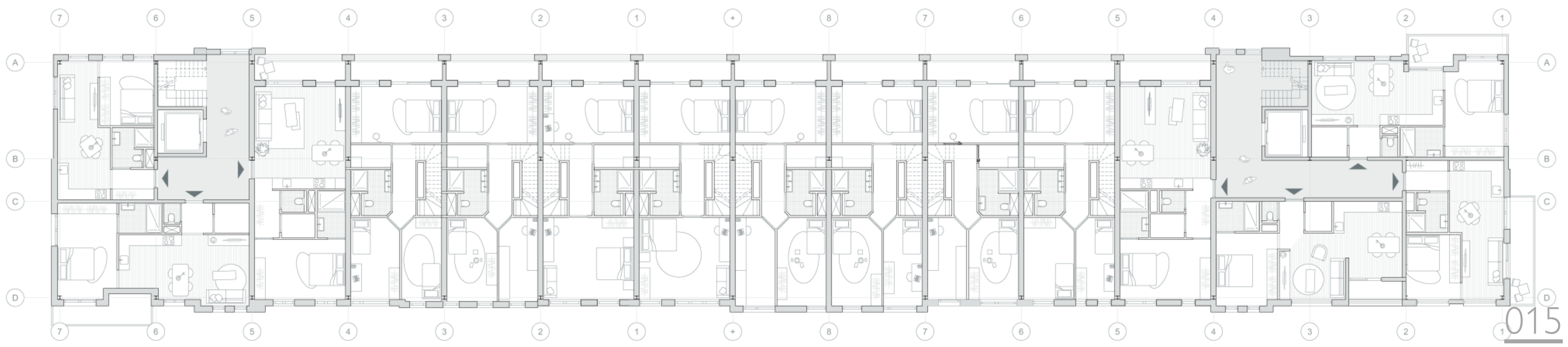


Entrance

Circulation space

Green zones

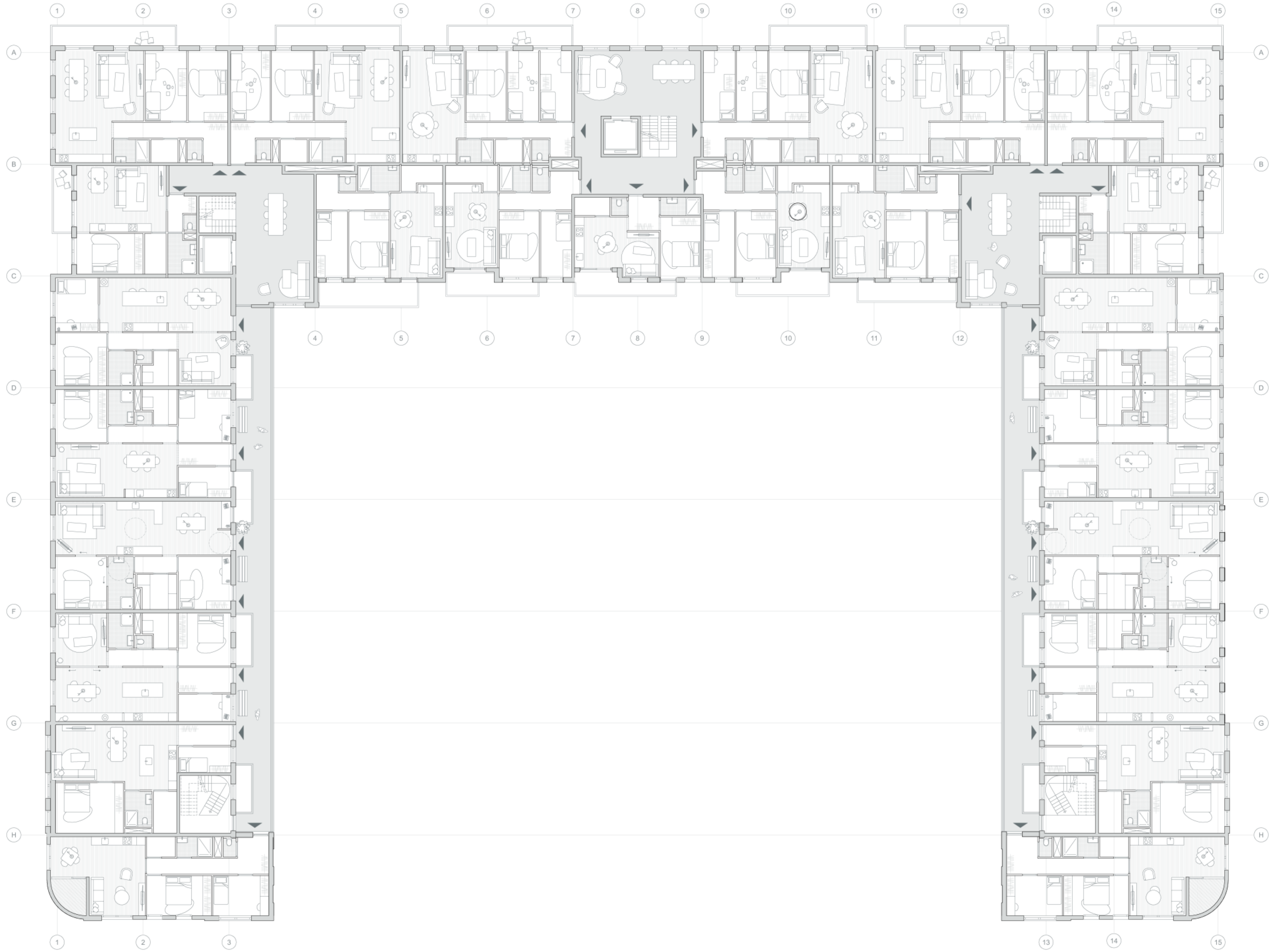


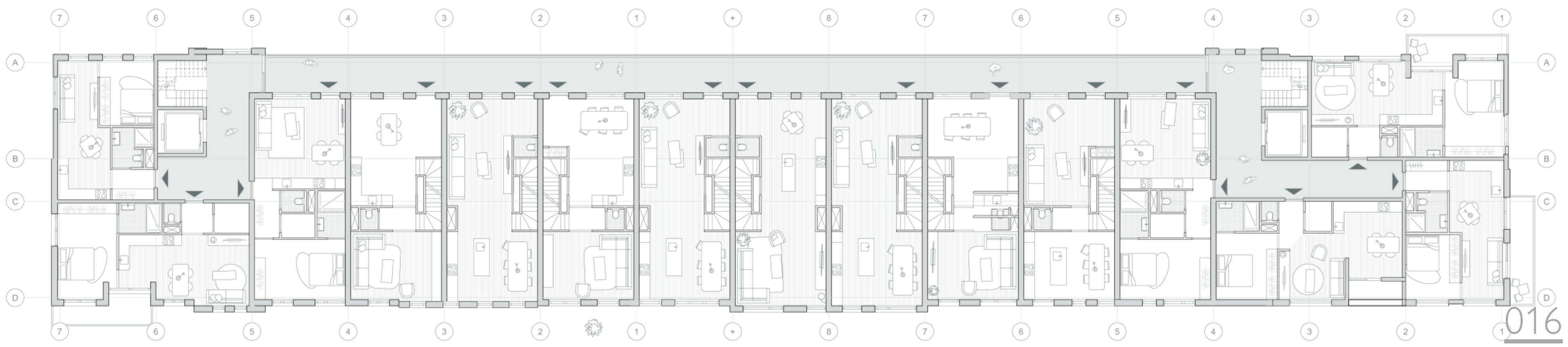


3.5.2 SECOND FLOOR

The second floor introduces the main residential access system through wide living galleries. These galleries function as both circulation routes and semi-private outdoor spaces, encouraging informal social interaction between residents. Floor openings improve daylight infiltration and visual connections throughout the building, enhancing the spatial quality of the shared circulation areas.

The South Building provides the access level to the second floor of the multi-story maisonettes.





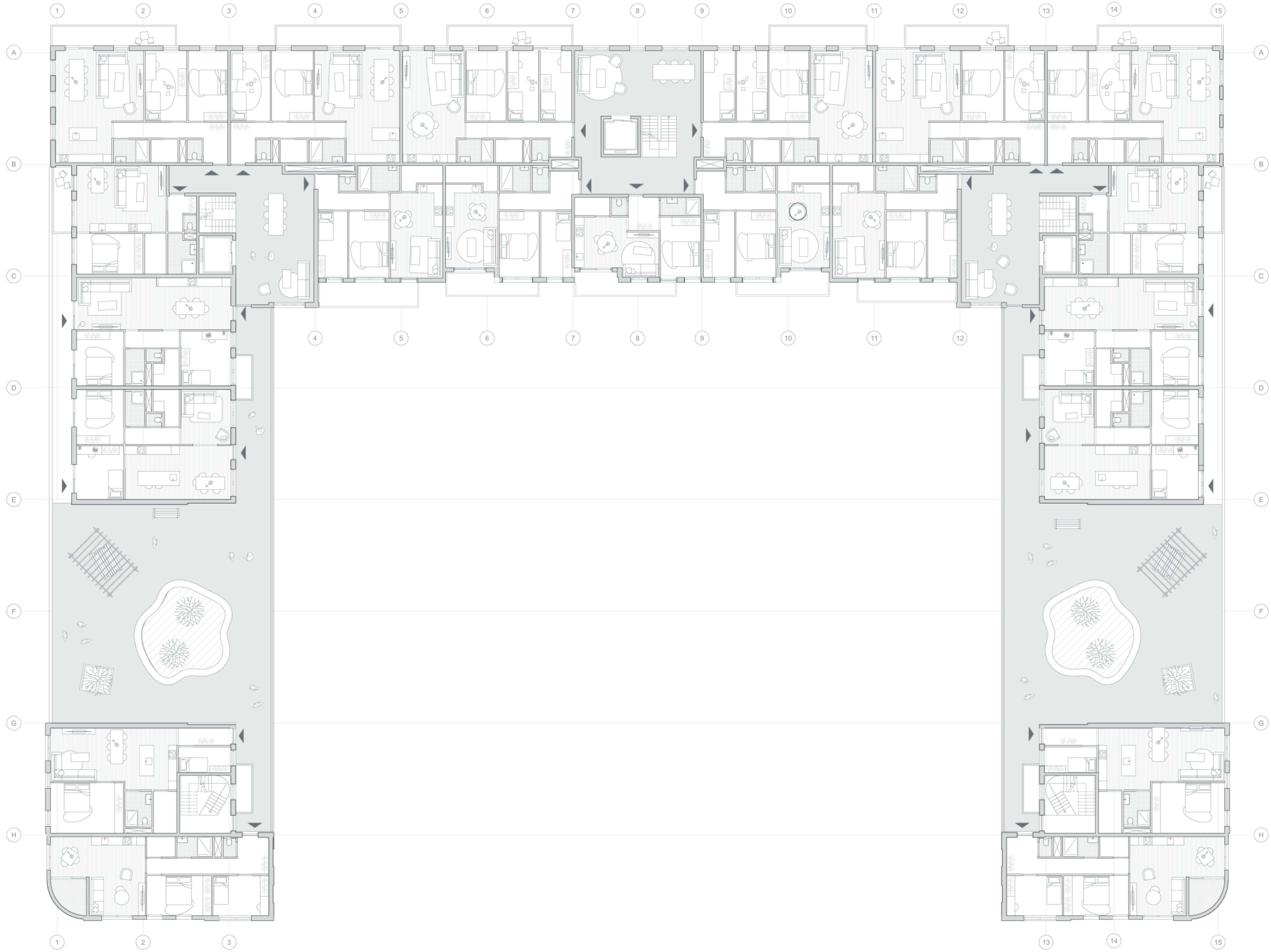
Entrance

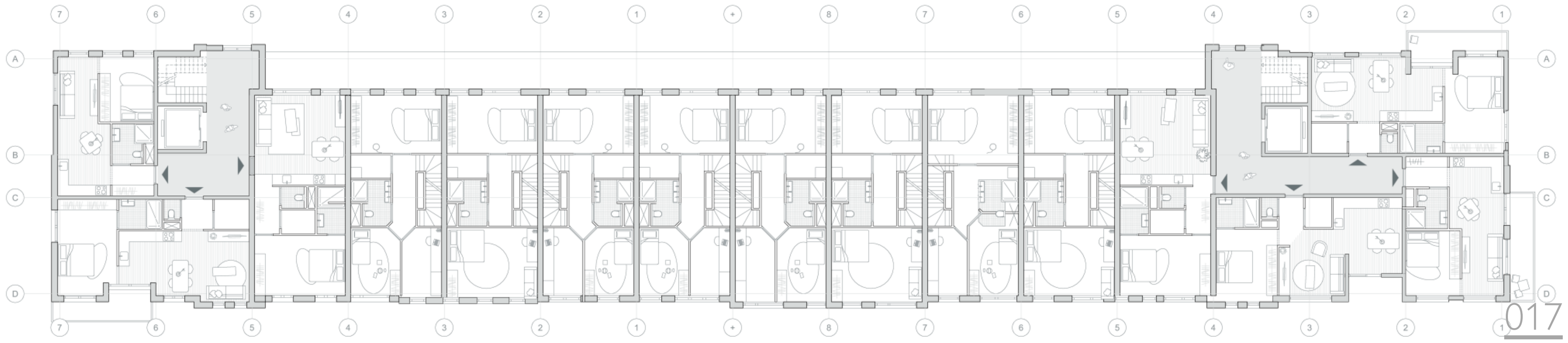
Circulation space

Green zones

3.5.3 THIRD FLOOR

The third floor incorporates additional communal outdoor spaces in the form of roof terraces. By distributing collective amenities throughout the building, residents gain access to a variety of shared environments that support recreation, relaxation, and social interaction while strengthening the sense of community.





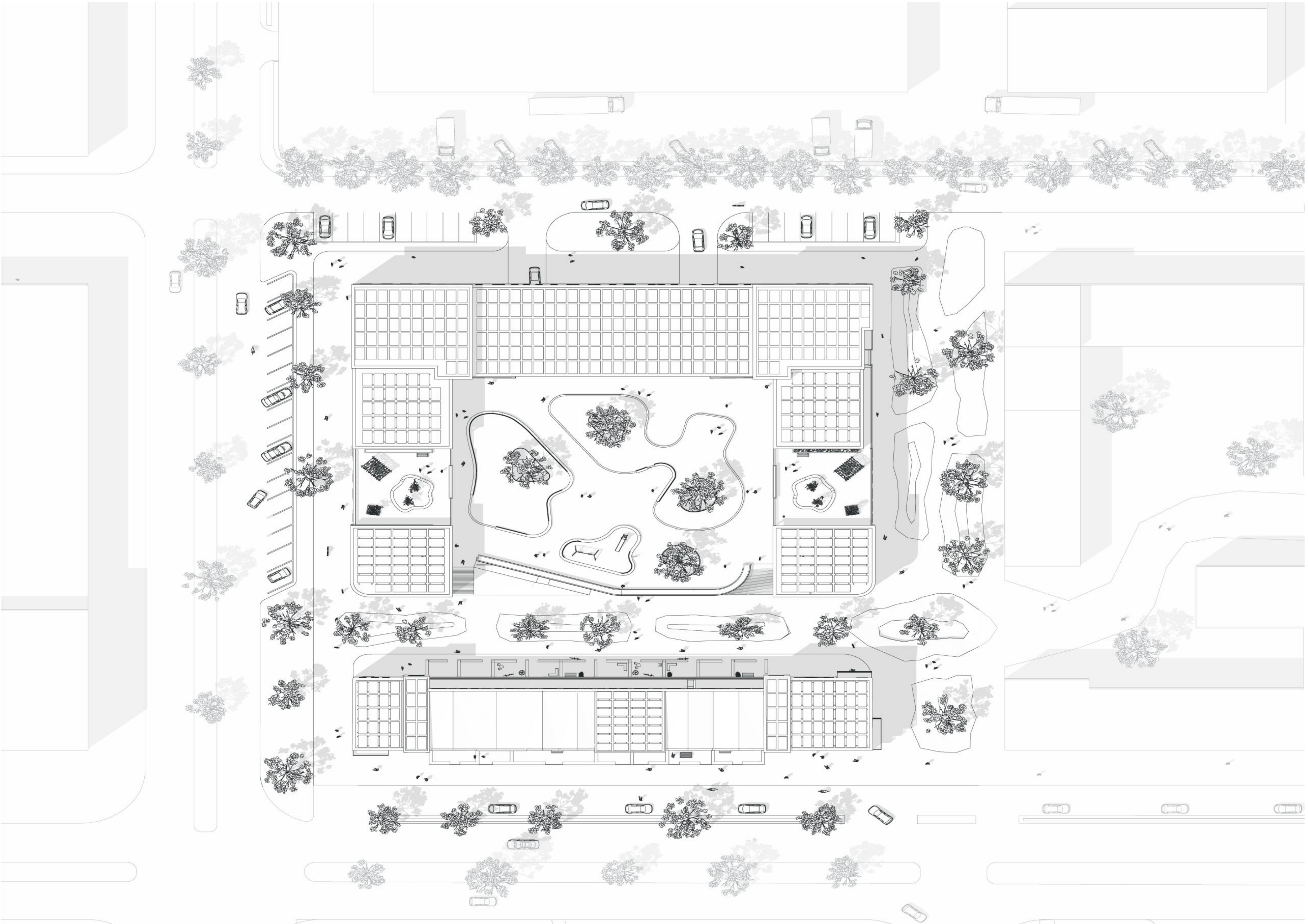
Entrance

Circulation space

Green zones

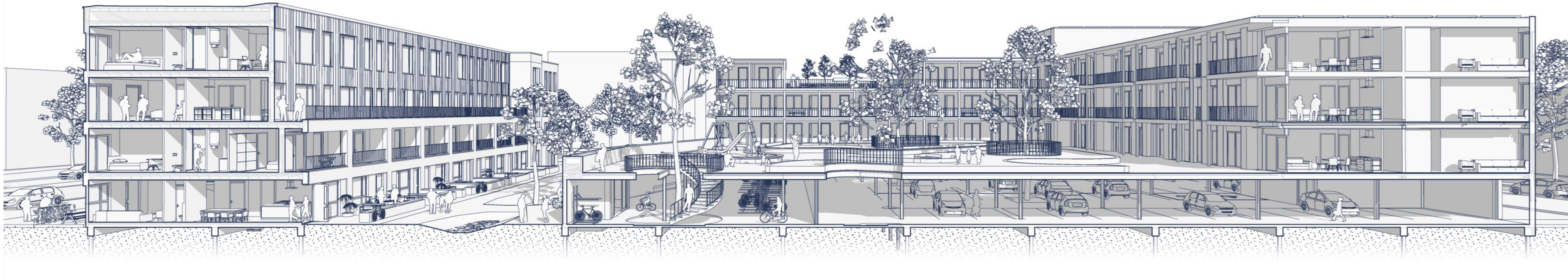
3.5.4 TOP PERSPECTIVE

The roof level demonstrates how environmental performance and residential quality are integrated within the design. Solar panels contribute to renewable energy generation, while the surrounding landscape and green buffer zones create a clear transition between the residential development and the adjacent industrial area. Together, these interventions improve both sustainability and liveability.



3.6 SECTIONS

This top-down view illustrates how the building integrates into its urban context. A dense row of trees acts as a clear, robust buffer, establishing a definitive boundary between the residential area and the neighboring industrial zone. Additionally, the roof is equipped with 402 solar panels.



3.7 ENVIRONMENTAL IMPACT AND METHODOLOGY

To determine the ecological impact of this design, a CO_2 emission calculation is performed. The starting point is that reusing large structural elements helps reduce the environmental load. This is mainly because it avoids the energy-intensive production of new materials and reduces the amount of construction waste.

The calculation focuses specifically on the main load-bearing structure. Secondary elements, such as floors, roofs, and facades, are not included because they are expected to be similar in every version of the design. The reinforcement ratios applied to the concrete volumes and densities of CLT and steel e.g., are derived from standard engineering benchmarks, ensuring the material quantities reflect realistic structural requirements. Finally, four different scenarios are compared to identify which construction or reuse method is the most sustainable choice.

Concrete and rebar

Foundation beams (strip foundations)
Total length= 1134m
1.134m 0,6m * 0,5m = 340,2 m^3
Reinforcement ratio = 80 kg / m^3
340,2 m^3 * 80 kg / m^3 = 27,2 ton

Driven piles
Total units (420 + 64) * (0,3m * 0,3m * 15m) = 653,4 m^3
Reinforcement ratio = 120 kg / m^3
653,4 m^3 * 120 kg / m^3 = 78,4 ton

Concrete ground slab
81m * 54,6m * 0,18m = 796,1 m^3
81m * 14,6m * 0,18m = 212,9 m^3
1.009 m^3

Reinforcement ratio = 100kg / m^3
1.009 m^3 * 100 kg / m^3 = 109,9 ton

Rebar total = 229,1 ton
Concrete total = 1.925,2m^3

Structural steel

Existing

IPE 400 (beams)
Total length ≈ 1.356m
Unit weight = 66,3 kg / m
Total weight = 1.356 * 66,3 ≈ 89.903 kg

HEA 240 (columns)
Total length ≈ 510m
Unit weight = 60,3 kg / m
Total weight 510 * 60,3 ≈ 30.753 kg
Total existing status = 120.656 kg

Added

IPE 400 (beams)
Total length ≈ 2.115m
Unit weight = 66,3 kg / m
Total weight = 1.356 * 66,3 ≈ 140.225 kg

HEA 240 (columns)
Total length ≈ 608m
Unit weight = 60,3 kg / m
Total weight 510 * 60,3 ≈ 36.662 kg
Total finished status = 176.887 kg

Cross Laminated Timber elements

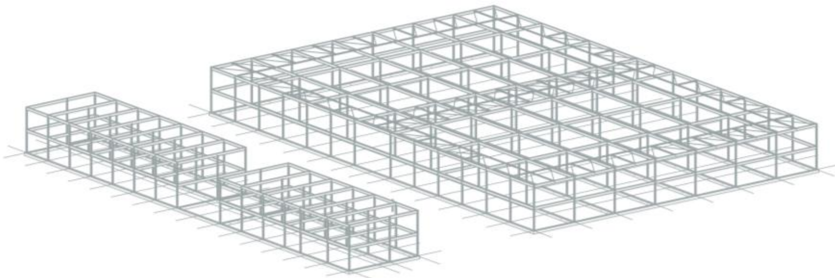
CLT elements
Volume per wall = 12,4m * 12,9m * 0,16m = 25,6 m^3
Total volume = 42 * 159,9 m^3 = 1074,9 m^3
Density CLT 475 kg / m^3 → 1074,9 m^3 * 475 = 510.577,5 kg

CLT elements
Volume per wall = 6,2m * 12,9m * 0,16m = 12,8 m^3
Total volume = 42 * 12,8 m^3 = 537,6 m^3
Density CLT 475 kg / m^3 → 537,6 m^3 * 475 = 255.360 kg

Scenario 1: New build *New construction with steel load-bearing structure.*

Element	Mass/volume	CO_2 per unit	Embodied carbon	Total CO_2 (ton)
Reinforcing steel	229.100 kg	0,80kg / kg	-	183,3
Concrete	1.925,2m^3	120,0 / m^3	-	231
Structural steel	120.656 kg	1,15kg / kg	-	138,8

553,1-ton CO_2

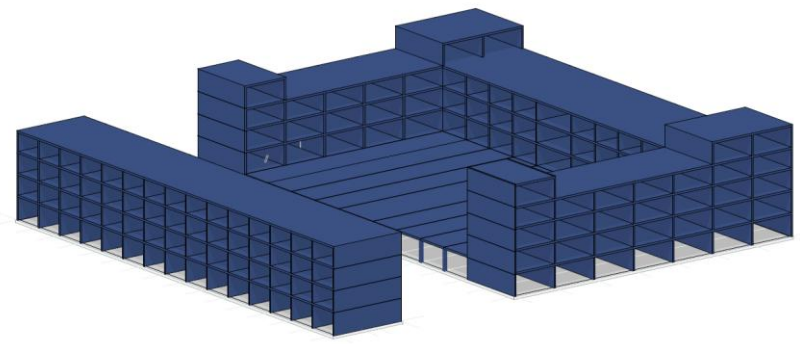


The environmental cost already incurred to construct the building's original load-bearing frame.

Scenario 2: New build *New construction with timber load-bearing structure.*

Element	Mass/volume	CO_2 per unit	Embodied carbon	Total CO_2 (ton)
Reinforcing steel	229.100 kg	0,80kg / kg	-	183,3
Concrete	1.925,2m^3	120,0 / m^3	-	231
CLT	510.577,5 kg	0,15kg / kg	-1,64 kg / kg	-760.7

-346,4 + 553,1 = 206,7-ton CO_2

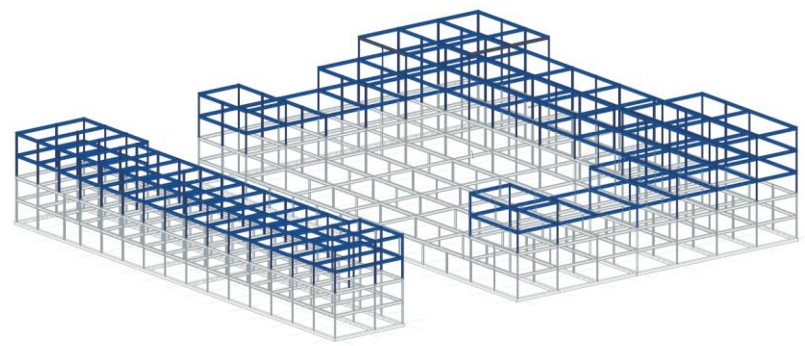


Choosing a complete reconstruction would result in the total loss of the existing structure. The original framework already contains 553.1 tons of embodied CO_2, representing environmental impacts that have already occurred. Demolishing the building would effectively discard this invested carbon. In a lifecycle carbon assessment, retaining the existing structure allows this embodied carbon to be preserved and contributes to the overall carbon savings of the project

Scenario 3 Transformation *Renovation with additional structural steel.*

Element	Mass/volume	CO_2 per unit	Embodied carbon	Total CO_2 (ton)
Reinforcing steel	229.100 kg	0,80kg / kg	-	0
Concrete	1.925,2m^3	120,0 / m^3	-	0
Structural steel	176.887	1,55kg / kg	-	274

274-ton CO_2

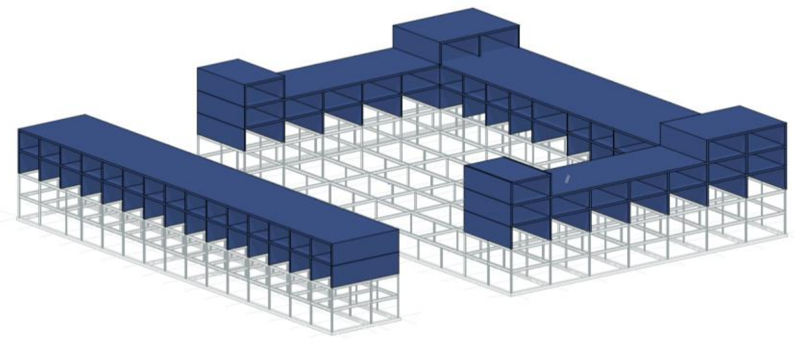


The projected carbon expenditure required to vertically extend (top up) the building utilizing new structural steel profiles.

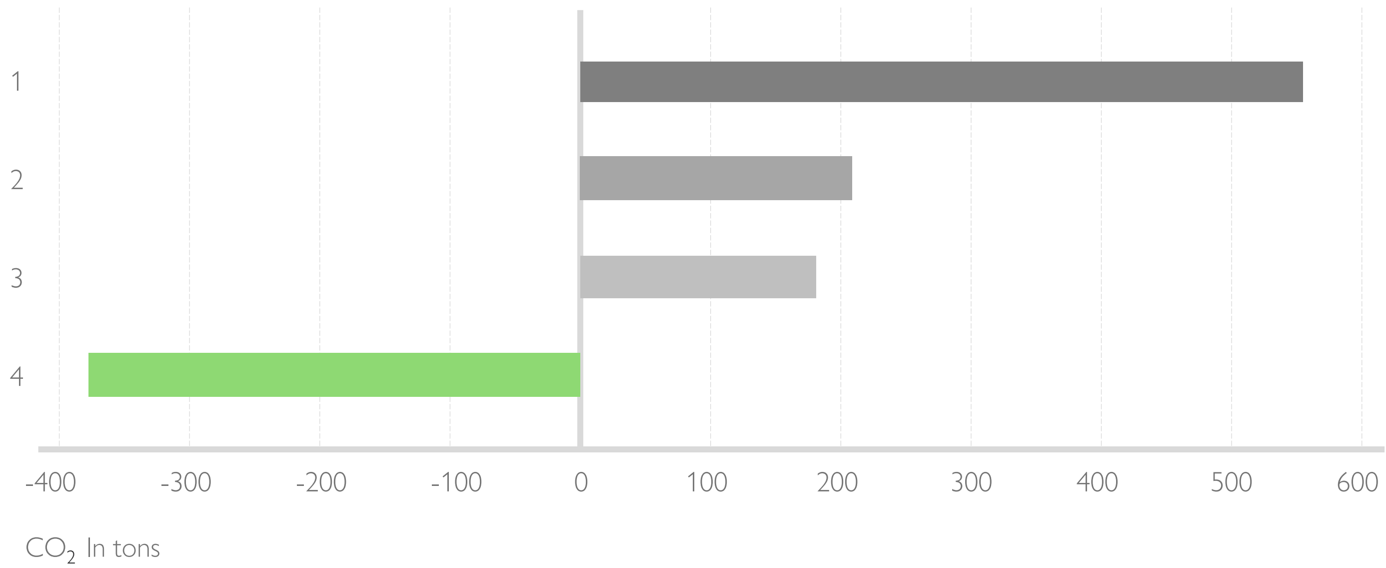
Scenario 4: Transformation *Renovation with CLT and structural preservation.*

Element	Mass/volume	CO_2 per unit	Embodied carbon	Total CO_2 (ton)
Reinforcing steel	229.100 kg	0,80kg / kg	-	0
Concrete	1.925,2m^3	120,0 / m^3	-	0
CLT	255.336,9 kg	0,15kg / kg	-1,64 kg / kg	-380,5

-380,5-ton CO_2



The most ecologically responsible strategy is to combine the existing support structure with a new vertical extension constructed from structural timber. This approach yields a dual environmental benefit: It successfully retains and protects the already emitted carbon within the existing structure. It significantly minimizes future emissions by leveraging the natural carbon properties and low embodied energy of timber.

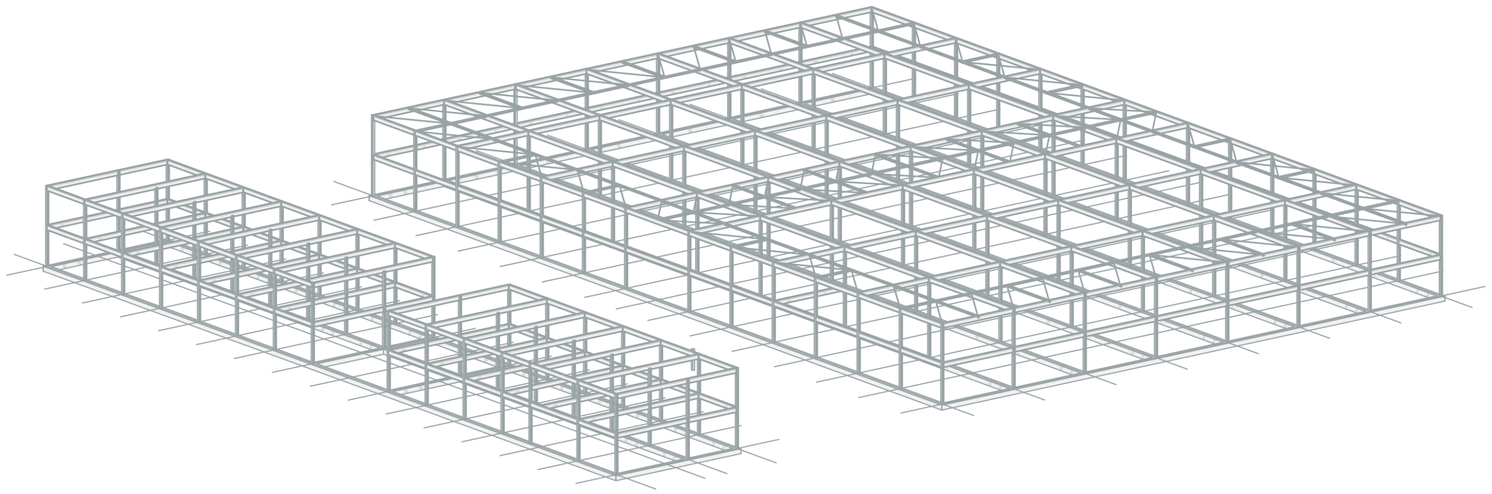


The analysis indicates that the most sustainable solution is the preservation of the existing structure combined with a vertical extension constructed from Cross-Laminated Timber (CLT). This approach retains the 553.1 tons of embodied CO_2 already invested in the existing frame while minimizing additional emissions using a low-carbon, carbon-storing material. By avoiding demolition and reducing the demand for new construction materials, this strategy delivers the greatest overall environmental benefit and represents the most responsible option from a lifecycle carbon perspective.

3.8 EXISTING AND NEW STRUCTURE

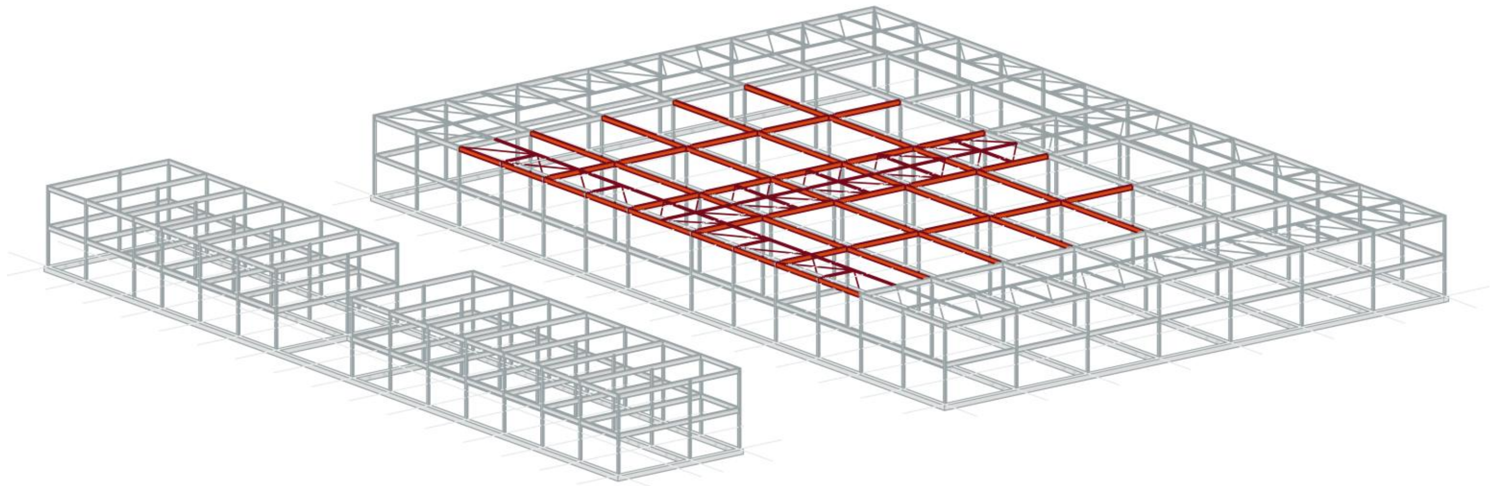
The existing industrial buildings form the foundation of the proposed transformation strategy and are approached as valuable resource frameworks rather than obstacles to redevelopment. The structure consists of a reinforced concrete foundation, a concrete ground floor slab, and a steel frame composed primarily of HEA columns and IPE beams.

Reusing the foundation and steel frame reduces the demand for new materials, preserves embodied carbon, and provides a rational structural grid for organizing housing and collective spaces. The existing structure therefore serves as the permanent support system of the project, while new lightweight and adaptable building layers are added in accordance with the principles of circular construction and long-term flexibility.



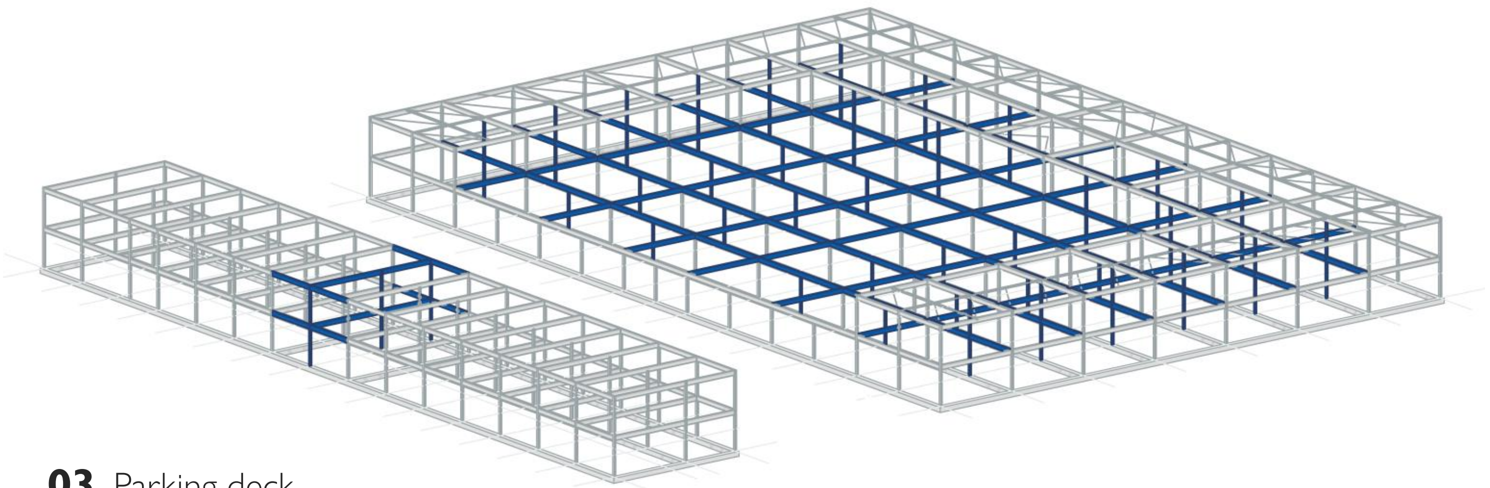
01 Current situation

Current situation consisting out of two separate buildings.



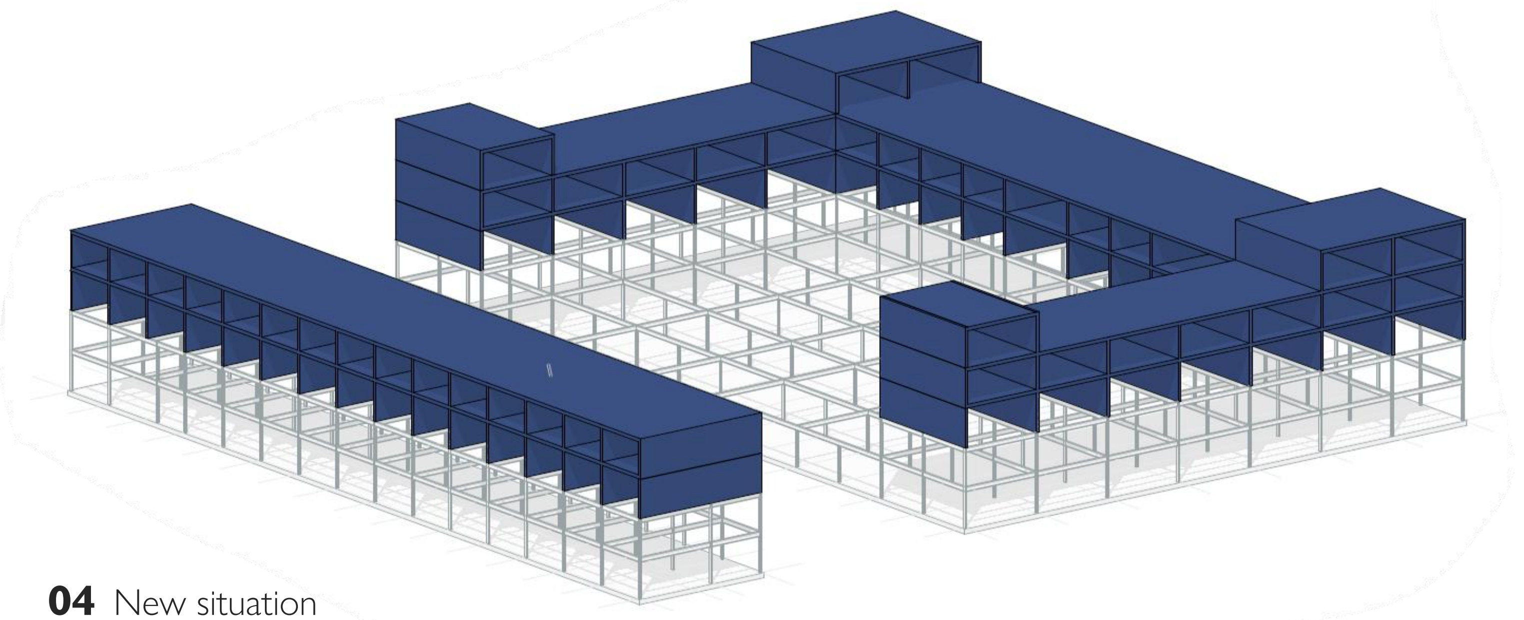
02 Structural replacement

Marked in red is how the existing structure will be dismantled and reused one level below.



03 Parking deck

The structural elements are now repositioned one level below their original location. This approach eliminates the need for new materials by taking full advantage of the existing components. New columns are added to support the added forces.

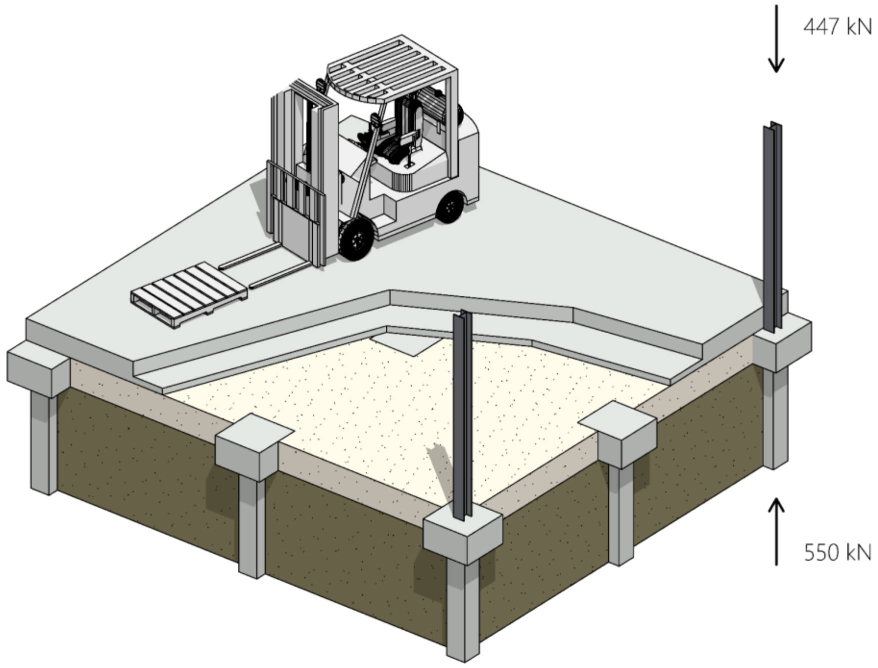


04 New situation

A new load-bearing structure is placed on top of the existing steel frame and foundation, enabling a taller building volume and an increased number of apartments. This extension consists of a Cross-Laminated Timber (CLT) structure, serving as a sustainable and bio-based alternative to traditional construction materials.

3.9 STRUCTURAL CAPACITY ANALYSIS

To determine the potential for new construction on the existing foundation and steel frame, a structural analysis was performed. The original structure was designed to support an industrial live load of 2,000 kg/m² to accommodate heavy machinery and storage. Therefore, the existing foundation, despite the building's modest height of 6 meters, can absorb significant forces. By repurposing the building for residential use, this heavy industrial load requirement is largely eliminated. Furthermore, the new design utilizes timber frame construction (HSB) and biobased materials, which are significantly lighter than traditional concrete and steel. These calculations compare the average weight of a new floor level against the residual capacity of the foundation. This comparison allows us to determine the maximum number of additional floors possible without requiring additional foundation reinforcement.



Calculations current situation

Dead Load (G_k) - Permanent loads

Concrete slab:	25 kN/m³ * 0,23m * 16m²	= 92,0 kN
Concrete layer:	20 kN/m³ * (16m² * 0,1m)	= 32 kN
Existing structure:	Estimated weight	= 11,0 kN
Total:l		= 127,0 kN per pile

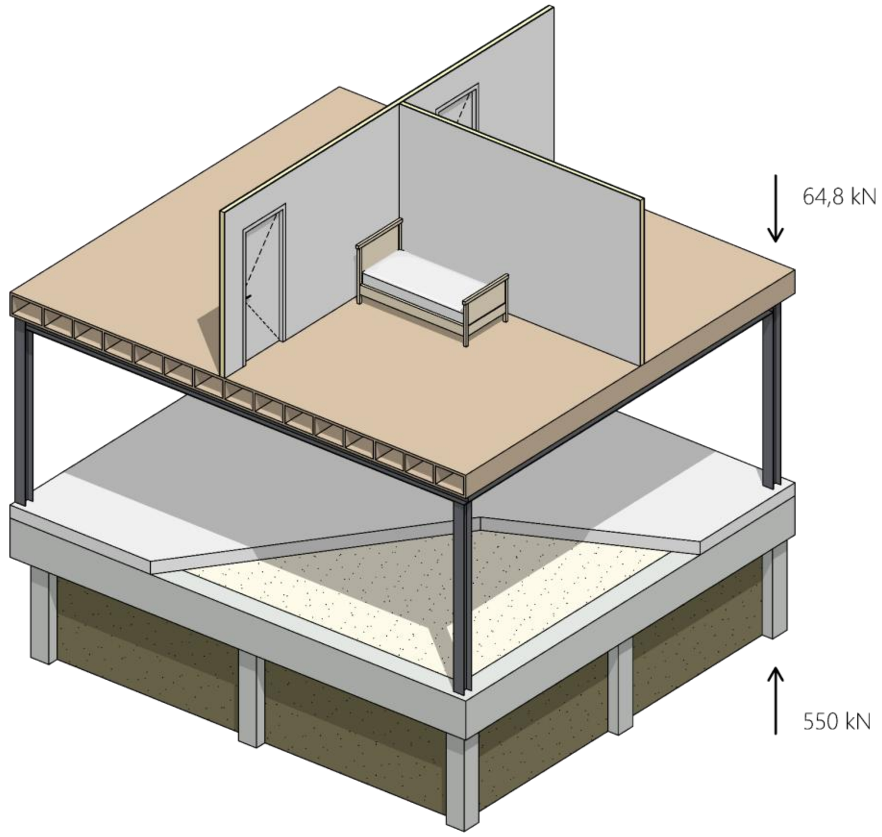
Note: 2500kg/m³ is standard reinforced concrete density, which equals 25kN/m³

Live load (Q_k) - Variable loads

Industrial load:	20kN/m² * 16m²	= 320,0kN

$(G + Q)$ = 127,0 + 320,0 = 447.0 kN

Pile capacity (550,0 kN)
550 / 447 ≈ 1,25 safety margin



Calculations new situation

<u>Total load existing structure:</u>

Dead Load (G_k) - Permanent loads

Concrete slab:	25 kN/m³ * 0,23m * 16m²	= 92,0 kN
Concrete beam:	25 kN/m³ * (0,4m * 0,6m) * 4m	= 24,0 kN
Existing structure:	Estimated weight	= 11,0 kN
Total		= 127,0 kN per pile

<u>Total load per added floor:</u>

Dead Load (G_k) - Permanent loads

Steel Structure:	New columns HEA and IPE	= 7,2 kN
Timber floor:	Lignatur and wooden joist	= 9,6 kN
HSB walls:	Partition + facade walls	= 8,0 kN
Finishes:	Ceiling and floor finishes	= 4,0 kN

Variable loads (Q_k)

Usage:	Occupants and furniture	= 36,0 kN
Total		= 64,8 kN per pile

550 - 127 = 423kN
423 / 64,8 ≈ 6,5 floors

Conclusion

The structural calculations indicate that the existing load-bearing system can support a maximum of 6.5 additional floors. To ensure structural safety and stability, this figure is rounded down, establishing a maximum height of 6 floors (approximately 24 meters) for the new residential development.

3.10.1 CONSTRUCTION TECHNOLOGY

The project utilizes timber as the primary construction material. A high-performance alternative to traditional concrete hollow-core slabs is the use of Cross-Laminated Timber (CLT) or Laminated Veneer Lumber (LVL) floor elements. These engineered wood products offer a high strength-to-weight ratio, allowing for large spans while significantly reducing the carbon footprint of the building. Furthermore, timber acts as a carbon sink, sequestering CO_2 throughout the building's lifespan.

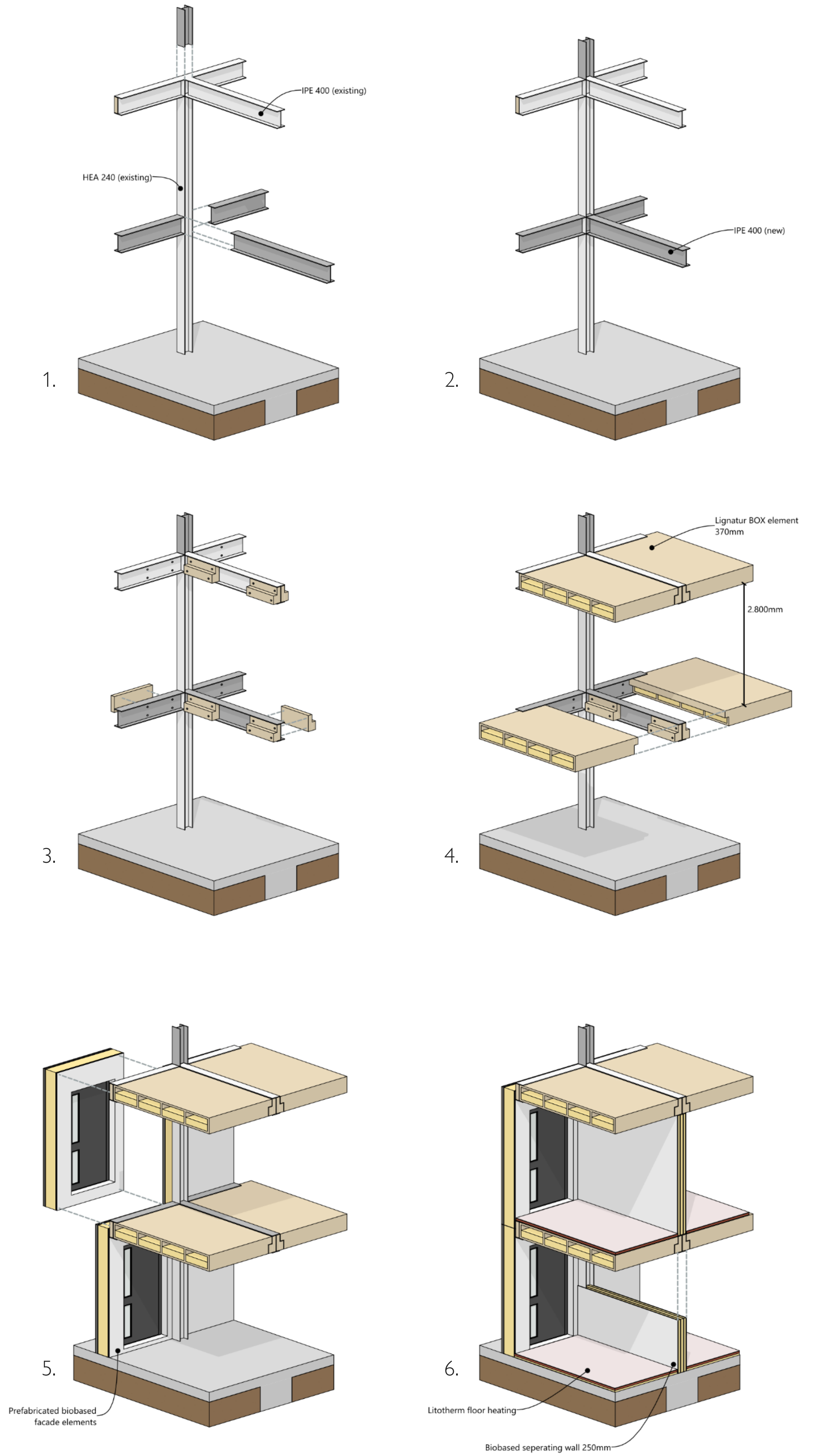
In addition to the timber structure, the façade elements are prefabricated and assembled on-site. Prefabrication is highly advantageous as it ensures superior quality control, significantly reduces construction time, and minimizes on-site waste and noise pollution. This controlled manufacturing process is essential for achieving the high tolerances required for circular building systems.

Circularity and demountability are the core priorities of the design. To support this, a smart connection system has been developed using the existing IPE profiles and timber blocking (klossen) to create mounting points for both the floors and walls. This method ensures that components are not only easily installed but can also be fully disassembled without damage, making them ready for future reuse.

The project utilizes a floor thickness of 360mm. This dimension allows the floors to fit precisely between the IPE 400 beams, leaving sufficient space for integrated floor heating and final finishes.

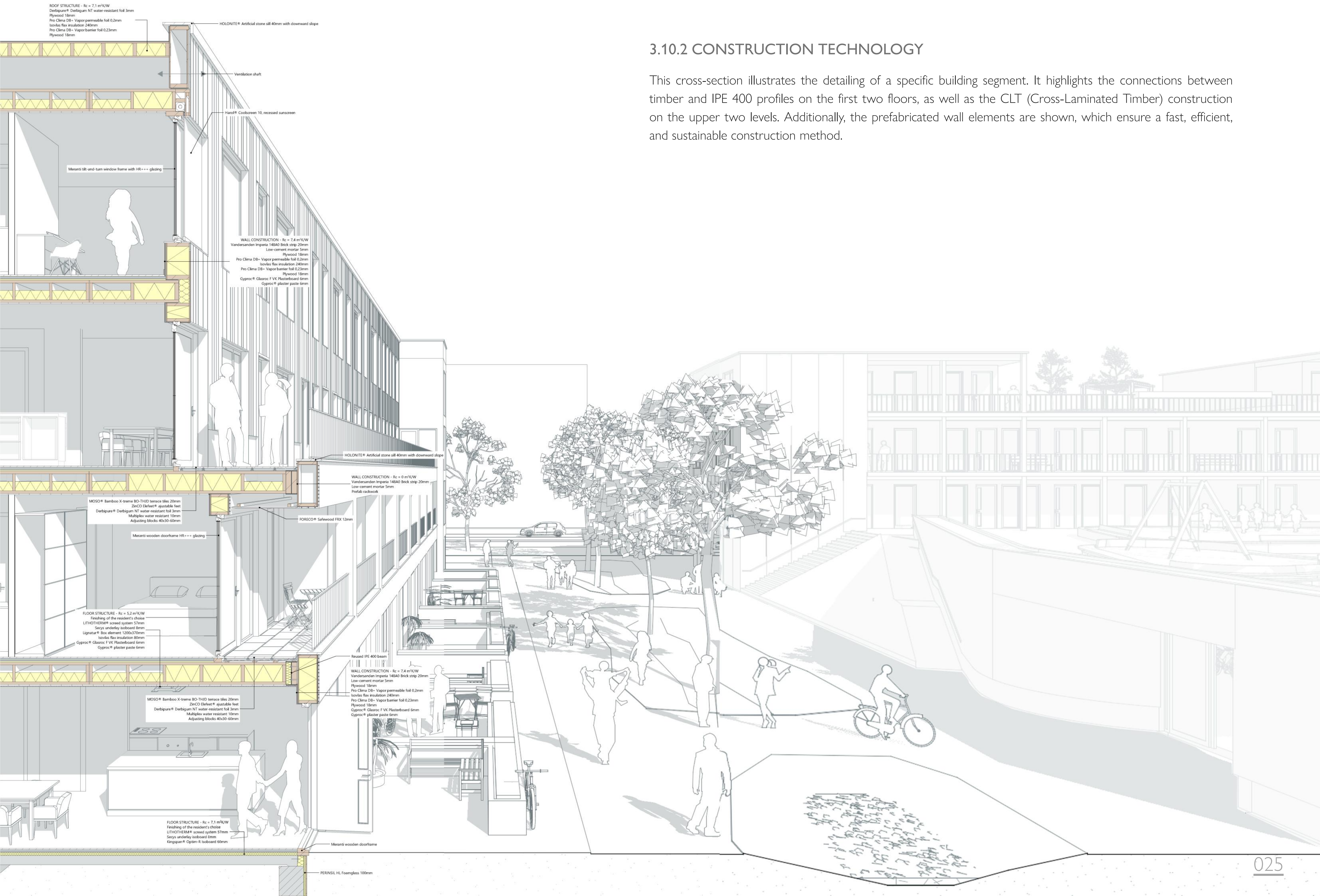
Span table LIGNATUR Box (LKE)

Loads	l (m)	4.5	5	5.5	6	6.5	7	7.5	8	8.5	10
q = 200kg/m^2; q = 0kg/m^2; g = 47kg/m^2	h [mm]	120	140	160	180	200	220	280	320	320	-
	w [mm]	8	8	9	9	10	11	7	9	9	-
q = 200kg/m^2; q = 36kg/m^2; g = 89kg/m^2	h [mm]	140	180	200	220	280	280	320	360	360	440
	w [mm]	8	9	10	10	7	10	10	8	10	9
q = 200kg/m^2; q = 181kg/m^2; g = 39kg/m^2	h [mm]	180	180	200	240	280	280	320	360	360	360
	w [mm]	9	10	11	10	9	12	12	10	13	17



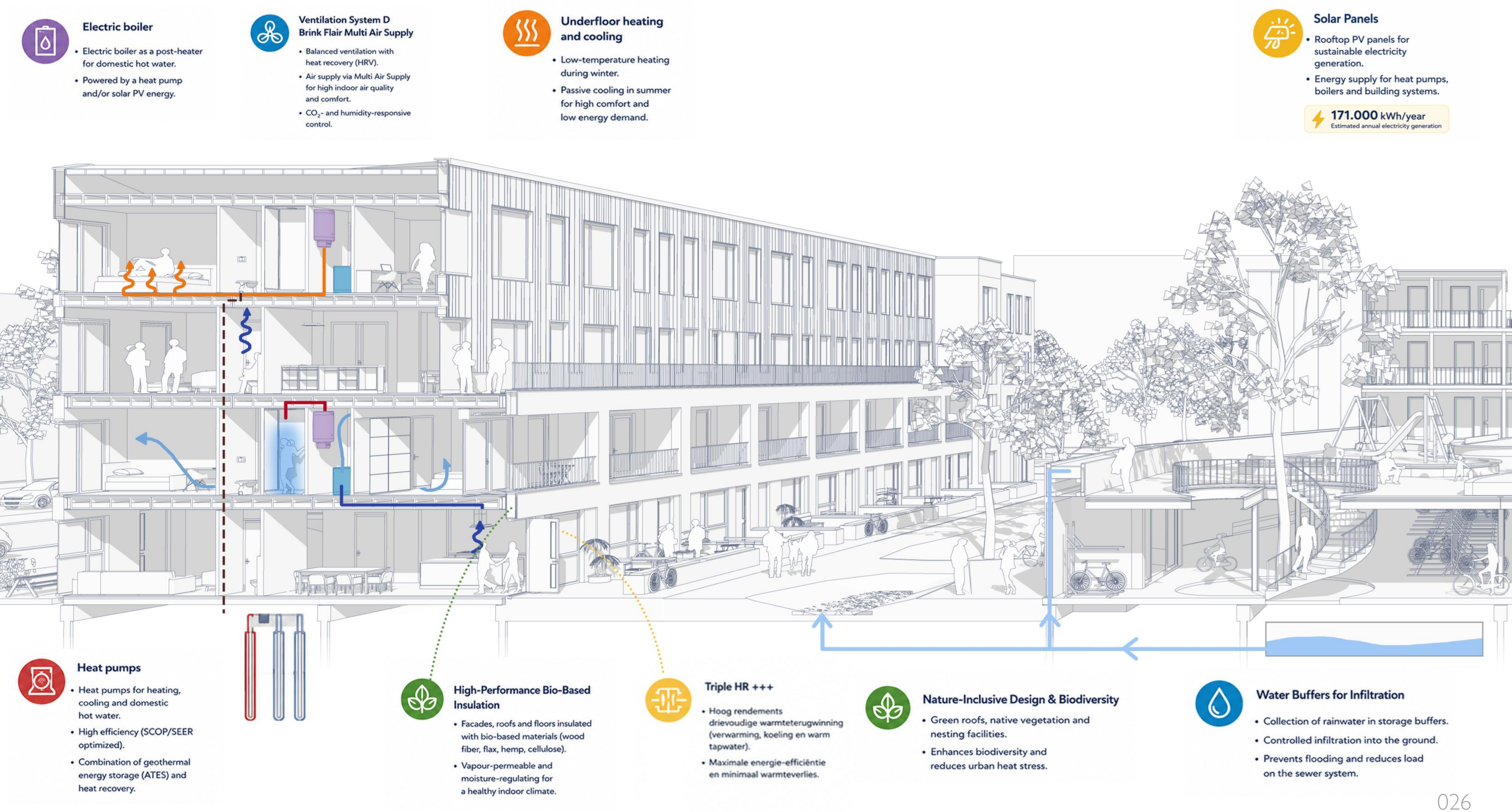
3.10.2 CONSTRUCTION TECHNOLOGY

This cross-section illustrates the detailing of a specific building segment. It highlights the connections between timber and IPE 400 profiles on the first two floors, as well as the CLT (Cross-Laminated Timber) construction on the upper two levels. Additionally, the prefabricated wall elements are shown, which ensure a fast, efficient, and sustainable construction method.



3.11 CLIMATE

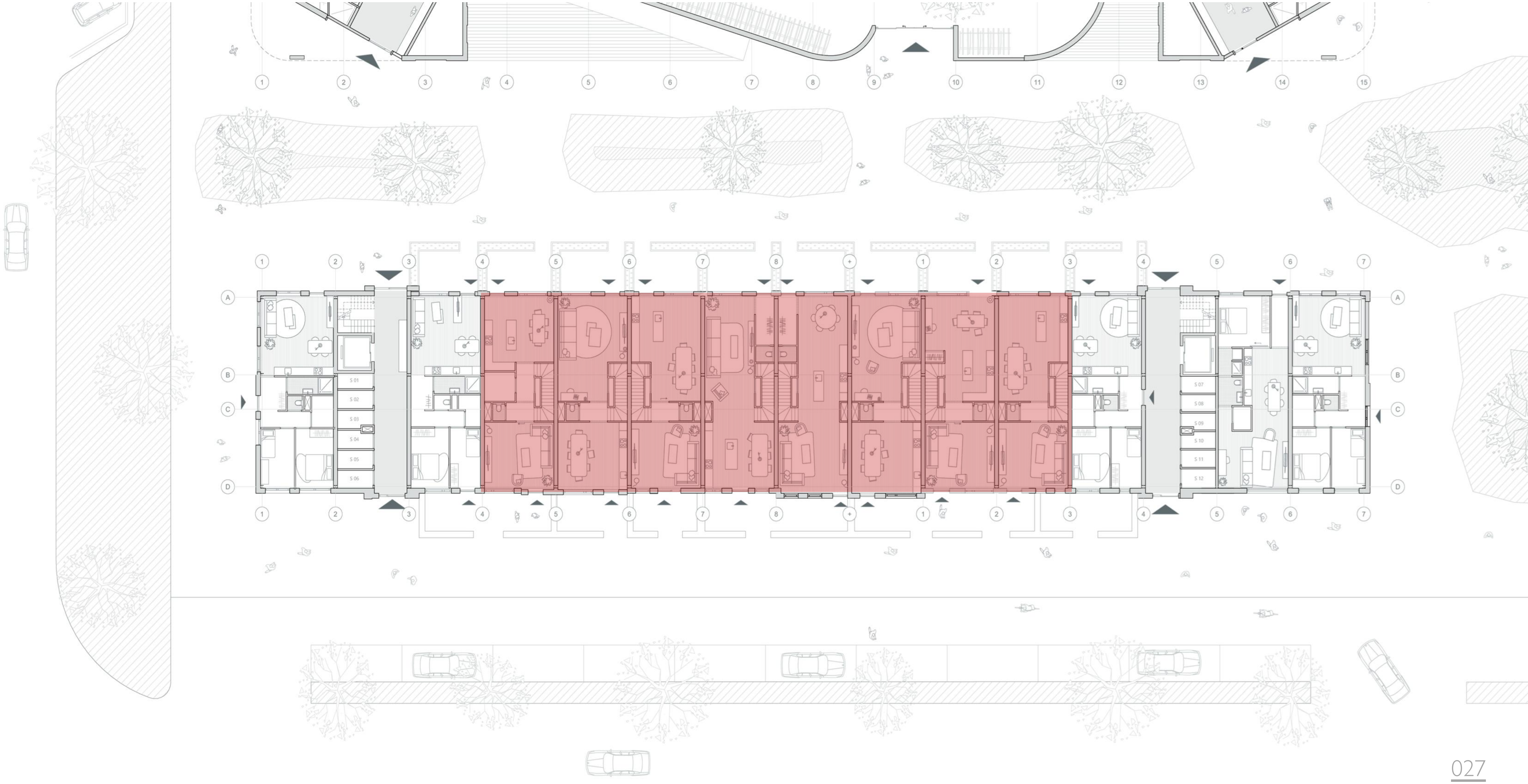
A modern climate concept shows that high-quality living and environmental care go hand in hand. By using smart, energy-efficient systems, like low-temperature heating and solar power, the design significantly lowers energy use. This smart approach to energy not only reduces the building's environmental impact but also creates a much healthier and more comfortable home for its residents.



3.12.1 MAISONETTES

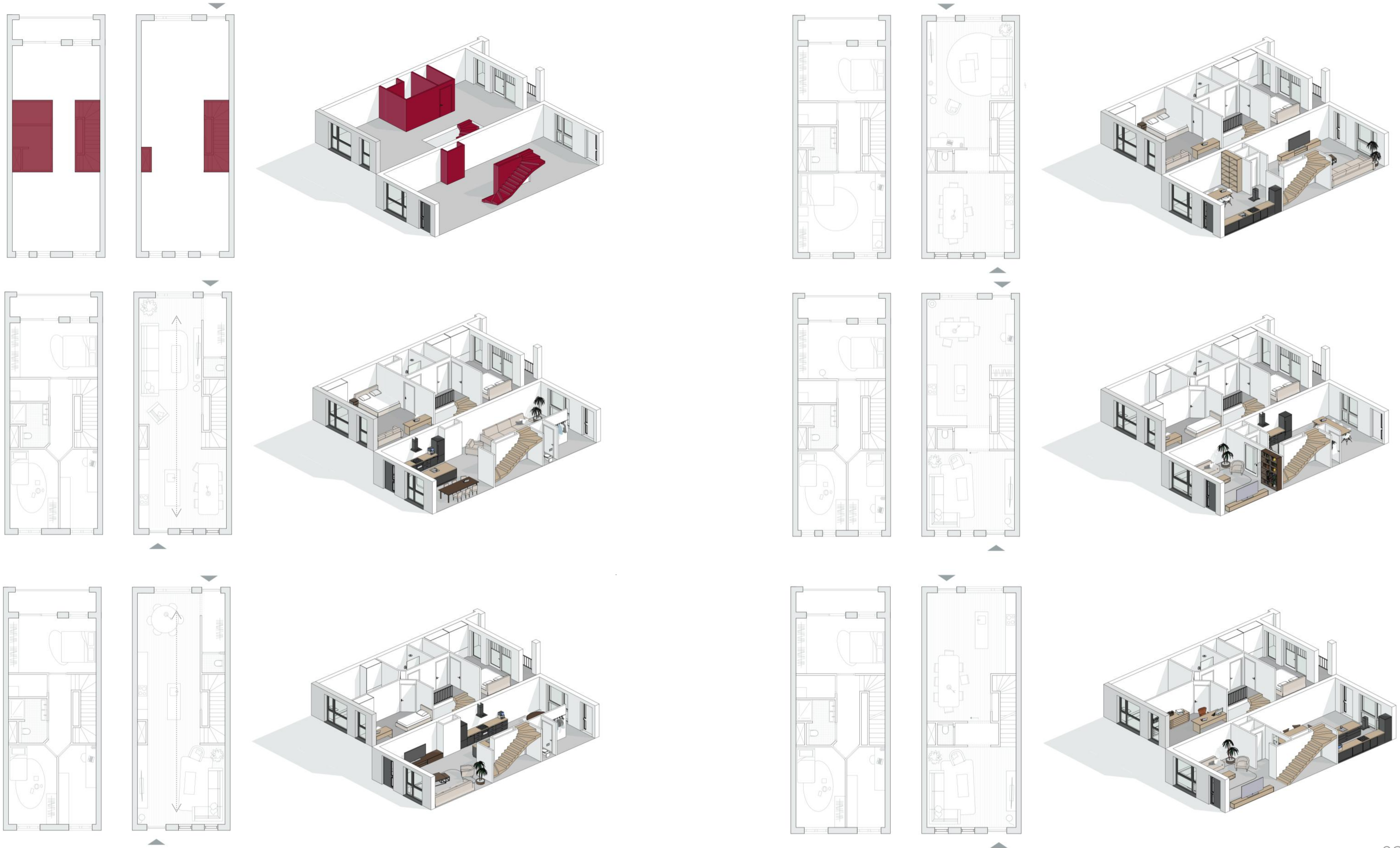
This section compares and showcases different apartment types, reflecting the project's concept of delivering units as a 'shell' (casco). This means only a few core elements are fixed, such as the stairs and the plumbing infrastructure for the toilet and bathroom, while the surrounding space remains completely flexible. The units in the lower block feature a unique typology with two separate entrances.

This layout raises interesting design questions: do you want the main entrance to open into the living room or the kitchen, and which entry point feels most intuitive? These choices make a shell-only delivery ideal, as it grants residents maximum freedom to customize their own living layout.



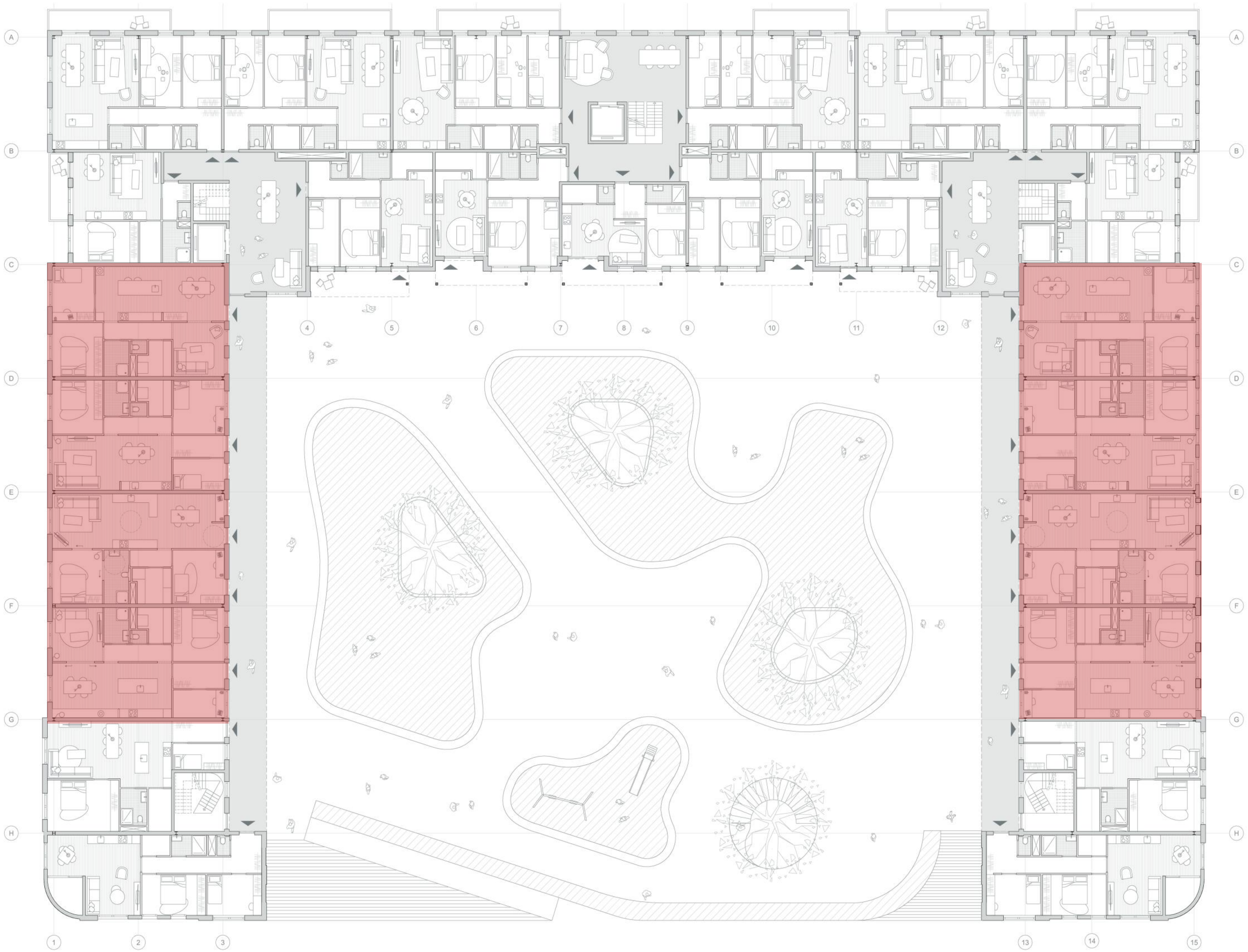
3.12.2 MAISONETTES

This series of floor plans demonstrates a wide variety of layouts on the ground floor. The primary variation lies in the placement of the toilet. Positioning the bathroom core in the center of the unit naturally divides the living space into two distinct zones. Alternatively, moving this core allows the living space to open entirely, creating a continuous, elongated open-plan layout.



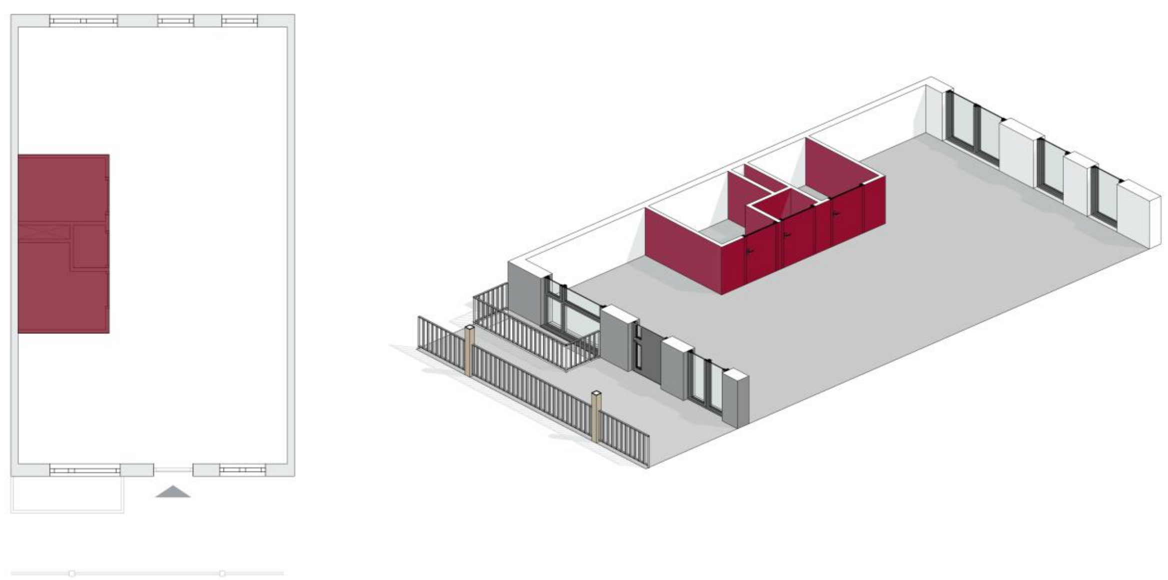
3.12.3 90m² DWELLINGS

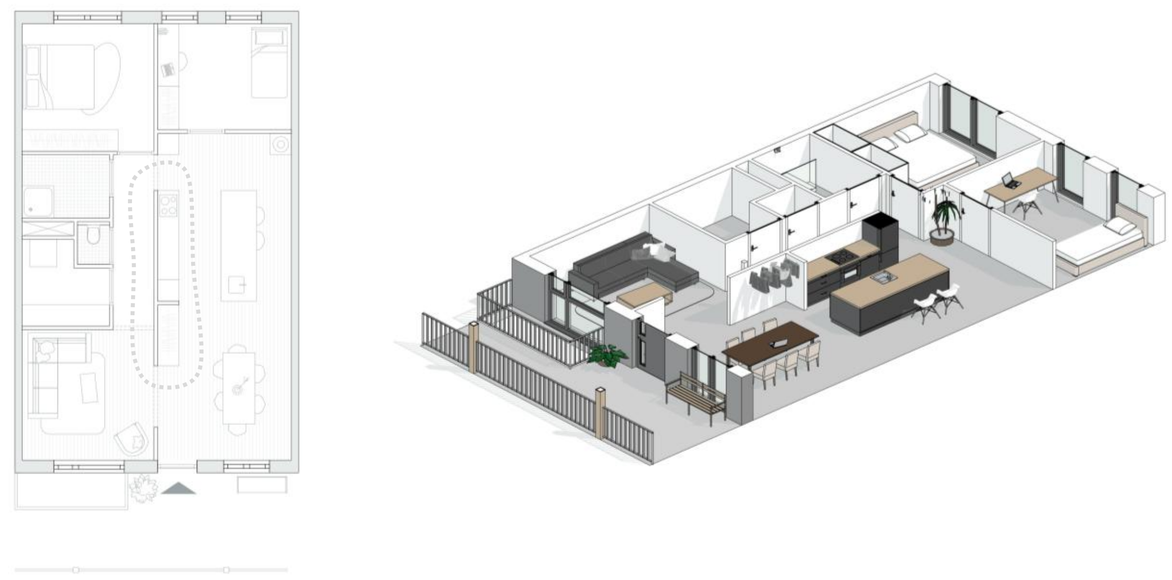
This is the most common apartment type within the design, fitting precisely within the industrial 7.8m x 12m grid. While it follows the same 'shell' principle as the other units, this specific apartment type consists of only a single level. The highly flexible typology can be configured into a one-, two- or three-room layout, making it perfectly suited for a diverse range of residents. This apartment type is situated along a 'living gallery.' Instead of a traditional private outdoor space like a balcony, inhabitants share an exceptionally wide gallery. While this space is normally used strictly for circulation, this design transforms the gallery into an active, usable outdoor living space.

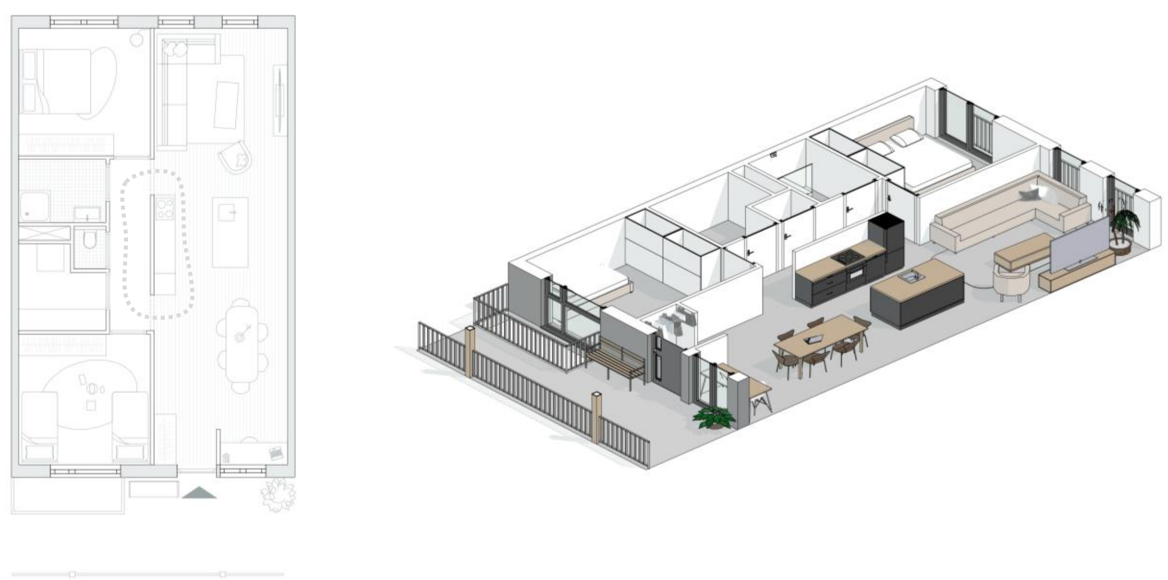


3.12.3 90m² DWELLINGS

The key principle of this apartment is that the hallway is not a closed, dark space. Instead, the layout allows for a continuous loop through the apartment, which optimizes sightlines, maximizes natural light, and eliminates wasted corridor space. While the hallway can still be closed off with a door if desired, the use of lightweight partition walls ensures that the entire layout of the apartment can be adapted quickly and effortlessly.

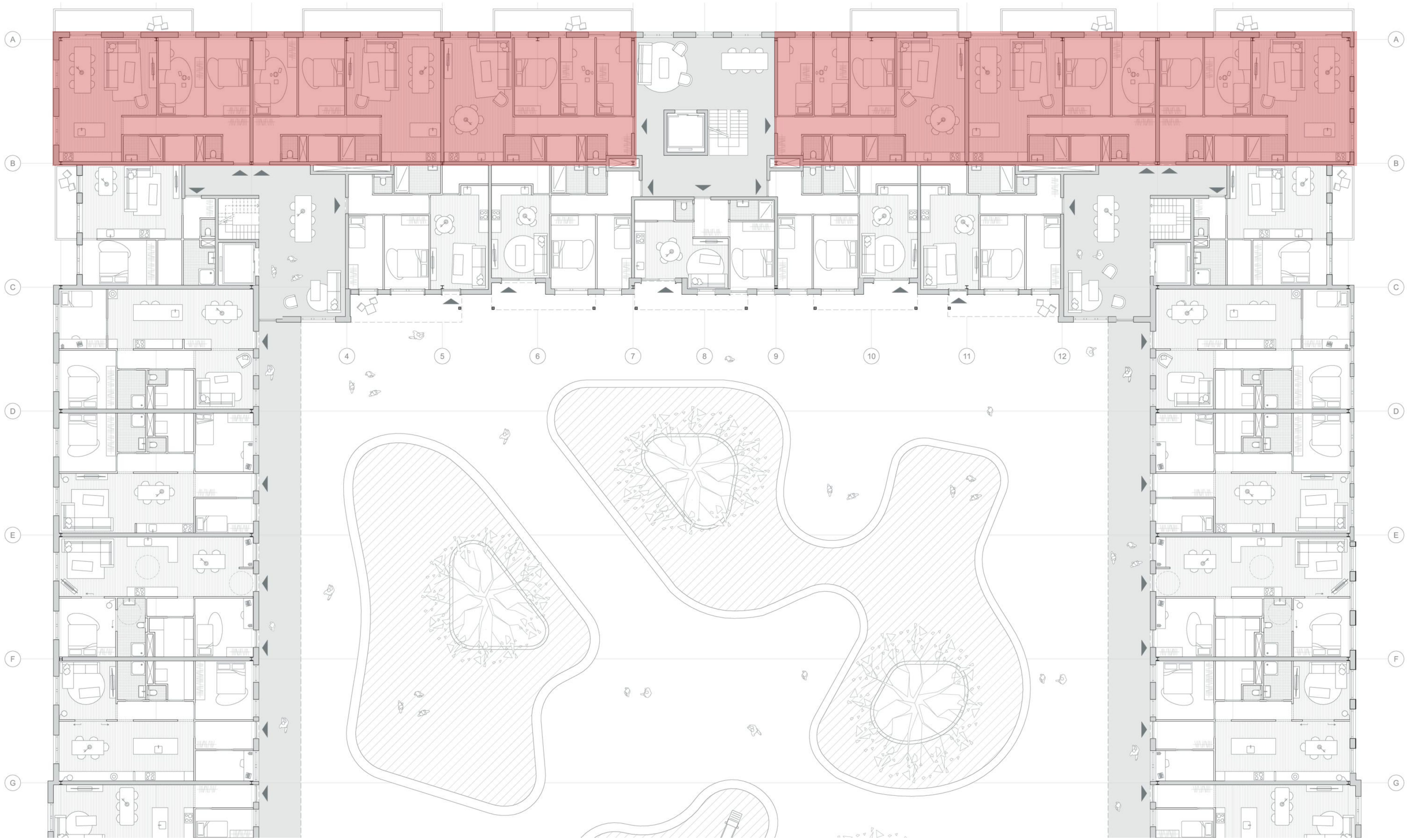






3.12.4 90m² DWELLINGS

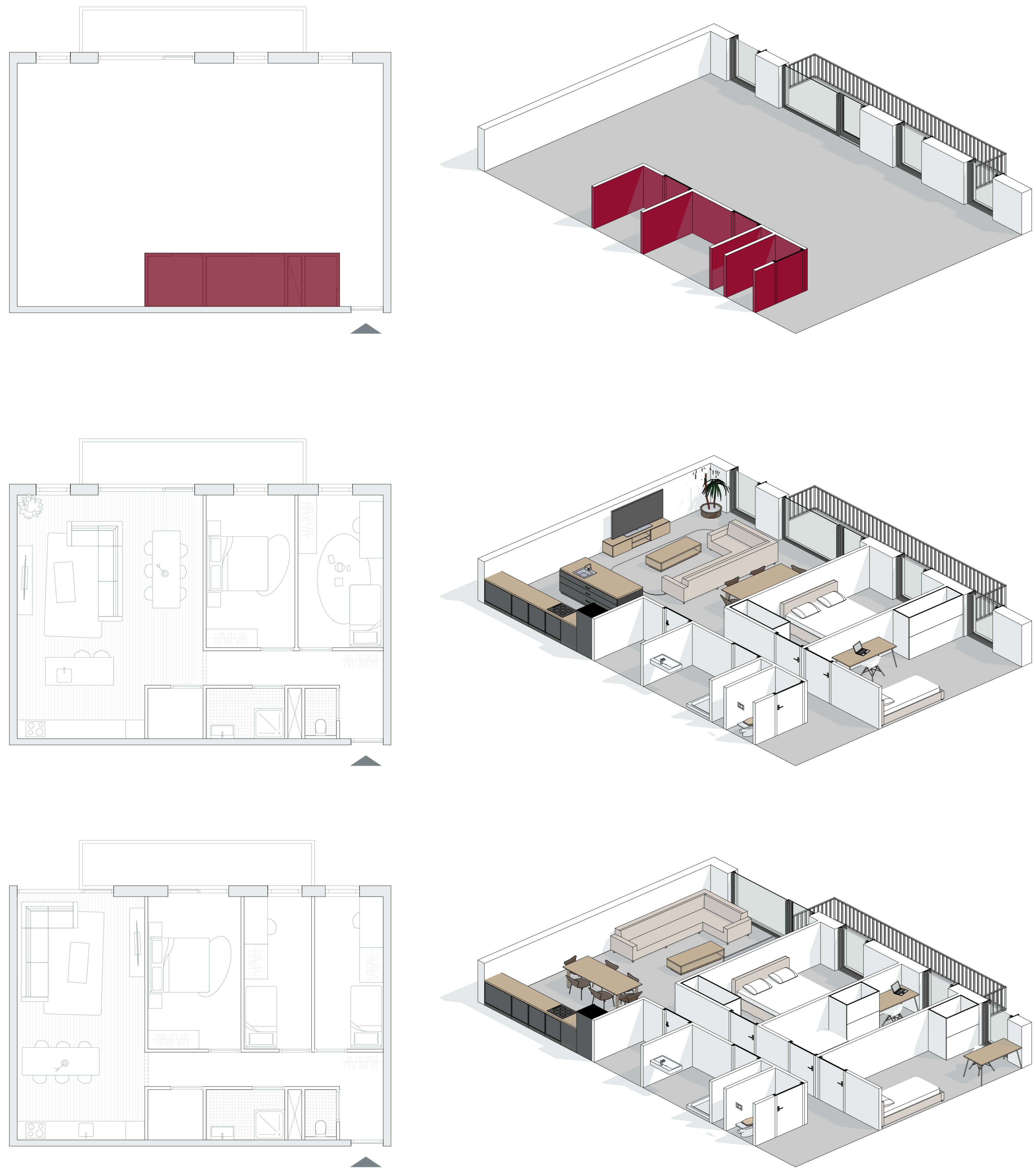
Because this apartment type is single-aspect, receiving daylight from only one side, it naturally offers fewer layout configurations. However, the typology fits perfectly within the building's rigid structural grid. By integrating deep balconies and large expanses of glazing, the design maximizes natural daylight, ensuring that the overall living quality remains exceptionally high.



3.12.5 90m² DWELLINGS

This visual presents two distinct configurations for these apartments, showing both a two-bedroom and a three-bedroom layout.

This typological research demonstrates that, even within a rigid structural grid, it is entirely possible to generate high-quality, completely flexible housing. This loose-fit capability allows residents to fully customize their environment, turning a standardized apartment into a personal living space. By giving users agency over their floor plan, the design not only maximizes immediate living quality but also ensures long-term adaptability as residents' needs change over time.



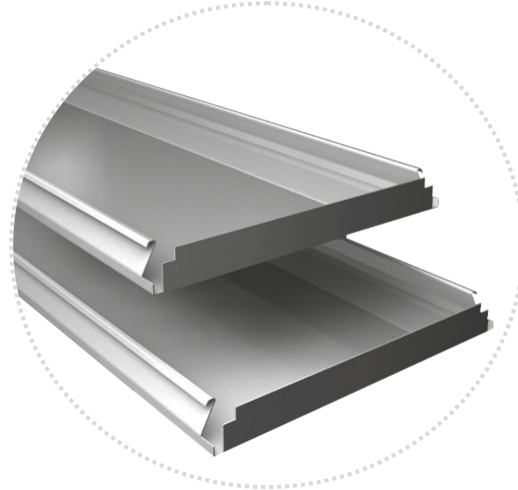
3.13 MATERIALISATION

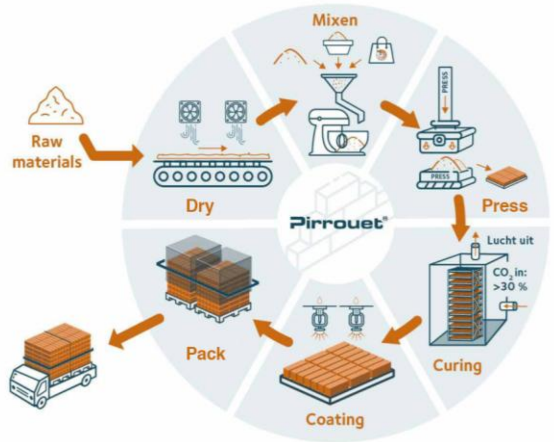
Vandersanden Pirrouet®

Brick plays a central role in the aesthetic of this project. While traditional masonry is often energy-intensive, this design utilizes Vandersanden Pirrouet®, a CO2-negative facing brick. Unlike conventional bricks, these are not fired in a kiln but are created through a carbonation-based pressing process that captures and stores CO2. To further optimize material efficiency, the bricks are applied as brick slips rather than full-sized bricks. Since the primary structure consists of a Timber Frame (HSB) system, the slips function as a lightweight outer skin, significantly reducing the total volume of material required. Furthermore, the project employs a dry-stack click system instead of traditional mortar. This mortarless approach ensures that the façade is fully demountable, allowing the bricks to be removed and reused at the end of the building's life cycle. While not a biobased material, the Pirrouet® system represents a highly sustainable, circular, and low-impact alternative to traditional masonry.

Luxalon® 300L [1]

The existing 300mm-wide ceiling panels will be reclaimed and reused, preserving their distinct and robust aesthetic. Made of high-quality aluminium, these panels are exceptionally well-suited for circularity; they can be easily refurbished with a new coating to match the new interior design without losing their structural integrity. Furthermore, the original mounting system is designed for easy disassembly, which actively facilitates efficient removal and high-quality reuse in the new project.





Source: Vandersanden®.

Platowood Platonium 01

The exterior is finished with Platowood Fraké Weathered, a choice that perfectly aligns with the project's circular and aesthetic goals. This wood undergoes a sustainable hydro-thermal finishing process, making it exceptionally durable and dimensionally stable without the use of harmful chemicals. A key feature of the 'Weathered' finish is that it is delivered with a pre-applied, uniform grey coating. Because the wood is already "pre-greyed," it eliminates the phase of uneven discoloration typically seen in natural timber.

04 CONCLUSION

4.1 SUB-QUESTIONS AND CONCLUSIONS

4.1.1 Requirements for structural reuse

To answer Sub-question 1, *What is required to effectively use the existing industrial structure, foundation, ground floor slab, and steel frame as a structural framework for new housing?,* a thorough investigation of the existing structure is essential.

This process began with archival research and the analysis of original construction drawings, which were then converted into a set of usable digital drawings. Through this investigation, detailed knowledge was obtained regarding the structural system, including the materials used, the dimensions of the various elements, and their structural characteristics. In addition to documenting the existing conditions, structural assessments are required to determine whether the current structure can accommodate the loads associated with its new residential function. This involves evaluating both the foundation system and the steel structure to verify their capacity to support new or increased loads and to identify any necessary interventions or reinforcements.

Once the existing structural conditions and load-bearing capacities have been established, enough information is available to develop design proposals that effectively integrate and reuse the existing structure. This understanding forms the basis for making informed design decisions and maximizing the potential of the industrial framework for residential transformation.

4.1.2 Requirements for a Modular and Demountable Building System

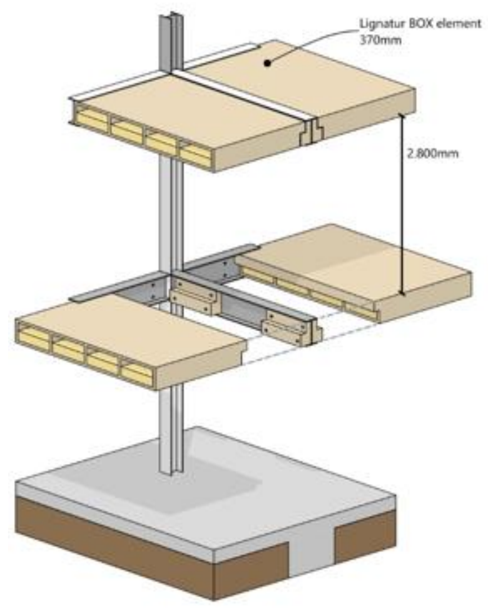
Sub-question 2 addresses the following question: *What characteristics are required for a modular and demountable building system to support circular housing within an existing industrial structure?*

To support circular housing within an existing industrial structure, a building system must be designed not only for construction, but also for adaptation, disassembly, and future reuse. Circularity therefore extends beyond material selection and requires a building system that can accommodate change over time.

A first requirement is the use of reversible connections. Structural elements, façade components, and interior systems should be mechanically fixed rather than permanently bonded. This allows components to be removed, replaced, repaired, or reused without damage, preserving their value for future building cycles.

A second requirement is modular coordination through standardized dimensions and a consistent structural grid. Repetition in dimensions reduces the number of unique components and increases opportunities for reuse. Within this project, the existing industrial grid forms the basis for the modular organization of floors, walls, and façade elements, allowing many components to share identical dimensions and connection details.

A third essential requirement for this transformation is a lightweight prefabricated construction systems. The load-bearing capacity of the existing structure limits the weight of new additions, making timber and other lightweight materials particularly suitable. Prefabricated floor and wall elements improve construction quality, reduce material waste, and simplify future disassembly. To connect these elements to the existing steel frame, timber infill blocks are introduced between the steel beams, creating a simple and reversible connection system. Biobased materials, including timber, flax insulation, and façade components, further support the circular ambitions of the project due to their low environmental impact and compatibility with demountable construction methods.



A fourth characteristic is the separation of building layers according to their expected lifespan. Following Brand's concept of the Shearing Layers of Change, different building components should be designed and managed according to the rate at which they change. While the primary structure may remain functional for more than a century, other elements such as façades, building services, and interior finishes typically require replacement much sooner. In this project, the existing foundation, ground floor slab, and steel structure are therefore treated as long-life elements that form the permanent framework of the building. New additions, including façades, floor systems, services, and interior layouts, are designed as independent layers that can be maintained, upgraded, or replaced without affecting the structural system.

Finally, adaptability is an important factor. A circular building should be capable of accommodating changing user requirements and future functions. Building on Habraken's Open Building principles, the existing industrial structure acts as a permanent support system, while the residential units function as infill. This distinction allows dwellings to be modified, combined, or reconfigured over time. In the proposed design, apartments are delivered as flexible shells that can be customized by residents and adapted throughout their lifespan, extending both the functional and social longevity of the building.

4.1.3 Design Strategies for a Liveable Residential Environment

Sub-question 3 addresses the following question: *What design approaches support the conversion of an industrial structural grid into a livable residential environment?*

Transforming an industrial structure into a liveable residential environment requires more than the introduction of housing units within an existing framework. While the structural grid provides an efficient basis for development, architectural interventions are necessary to create a comfortable, attractive, and socially connected living environment. The design therefore focuses on improving residential quality through collective spaces, spatial variation, greenery, materialization, and flexibility.

A key strategy is the introduction of a hierarchy of collective spaces throughout the building. At the heart of the project is a large communal roof garden, accessible to all residents and designed as the primary social space of the development. This green courtyard provides opportunities for recreation, informal encounters, and community building. Additional collective spaces are integrated at different scales, including two communal roof terraces and shared gathering spaces located adjacent to the stair cores on every floor. By distributing these communal areas throughout the building, social interaction is encouraged while ensuring that shared facilities remain easily accessible.

Residential quality is further enhanced through the provision of generous supporting facilities. Wide access galleries function not only as circulation routes but also as semi-private outdoor living spaces. Each dwelling includes a private storage room, complemented by additional storage facilities on the ground floor. Parking is accommodated beneath the communal roof garden, providing approximately 76 parking spaces while minimizing the visual impact of vehicles on the residential environment. In addition, more than 300 covered bicycle parking spaces promote sustainable mobility and contribute to the convenience of daily life.

Landscape design plays an important role in creating a healthy and attractive living environment. Extensive greenery is incorporated both around the buildings and within the communal courtyard. Trees, planting beds, and natural water-management systems such as wadi landscapes contribute to biodiversity, improve the microclimate, and help manage rainwater runoff. These green interventions soften the industrial character of the site and strengthen the connection between residents and nature.


Living gallery and collective courtyard


Collective space for inhabitants


Collective courtyard

External storages for inhabitants


Collective bike parking


Green zones

Materialization is used to reinforce the identity of the development. The exterior façades adopt a more robust and urban architectural language that reflects the industrial context of the site. In contrast, the courtyard façades utilize warmer and more natural materials, creating a welcoming residential atmosphere. This duality establishes a clear distinction between the public urban edge and the more intimate communal interior.

The project also places strong emphasis on flexibility and social diversity. A variety of apartment sizes are distributed throughout the building rather than concentrated in specific zones. This creates a mixed residential community and supports social cohesion between different household types. Furthermore, the modular housing layout allows apartments to be adapted, combined, or subdivided over time, enabling the building to respond to changing residential needs.

Finally, several architectural interventions are introduced to improve the human scale of the development. The large industrial volumes are broken down through variations in depth, curved façade elements, and a layered composition of building masses. These interventions reduce the perceived scale of the building, create visual diversity, and contribute to a more comfortable and engaging residential environment.

The analysis demonstrates that transforming an industrial structural grid into a liveable residential environment requires a combination of collective amenities, spatial flexibility, high-quality landscape design, thoughtful materialization, and architectural interventions that enhance human scale. Together, these strategies convert the efficiency of the industrial framework into a residential environment that supports comfort, social interaction, and long-term liveability.

4.2 MAIN RESEARCH QUESTION AND IMPLICATIONS

This research investigated how existing industrial structures can be reused as the basis for a circular housing system that enables liveable residential environments. The findings demonstrate that industrial buildings can successfully fulfil this role when their existing structural capacity is used as a permanent support framework and combined with lightweight, modular, and demountable building systems.

A key outcome of the research is that the existing foundation, ground floor slab, and steel structure can be retained and reused as the primary load-bearing framework for new housing. Through archival research, structural analysis, and load-bearing calculations, it was demonstrated that the existing industrial structure possesses sufficient capacity to accommodate multiple additional residential floors without requiring a new foundation or primary structural system. As a result, large quantities of embodied carbon, materials, and energy are preserved, while the need for new resource-intensive construction is significantly reduced. Rather than being treated as outdated buildings awaiting demolition, industrial structures can therefore be understood as valuable resource frameworks capable of supporting future urban development.

The research further demonstrates that circular housing within existing structures requires a modular and demountable building system. Lightweight prefabricated timber construction proved particularly suitable due to its low structural weight, high level of prefabrication, and compatibility with reversible construction methods. The use of dry connections, standardized components, and the separation of long-life and short-life building layers ensures that materials can be maintained, adapted, dismantled, and reused in future building cycles. Prefabrication also contributes to faster construction processes, improved quality control, reduced material waste, and greater efficiency during assembly. As a result, the proposed system is not only circular now of construction but remains adaptable and reusable throughout its entire lifespan.

The environmental analysis confirms that the combination of structural preservation and timber construction represents the most sustainable strategy. By retaining the existing structure, approximately 553 tons of embodied CO_2 remain preserved within the building instead of being lost through demolition. At the same time, the use of timber introduces a significant carbon storage capacity, as wood sequesters atmospheric carbon throughout its lifespan. Together, these strategies create a dual environmental benefit: preserving the environmental investment already present within the existing structure while minimizing future emissions using biobased materials. Furthermore, the reuse of the foundation, ground floor slab, and primary steel structure drastically reduces the quantity of new materials required, resulting in substantially lower environmental impact compared to conventional demolition and reconstruction.

However, the research demonstrates that circularity alone is not sufficient. To successfully transform industrial buildings into desirable residential environments, architectural interventions are equally important. The introduction of collective roof gardens, shared social spaces, wide living galleries, green courtyards, diverse housing typologies, and extensive landscape integration transforms the efficiency of the industrial grid into a comfortable, socially connected, and inclusive living environment. Through these interventions, the project proves that high residential quality can coexist with structural reuse and circular construction principles.

Beyond the architectural proposal itself, this research contributes to the growing body of knowledge surrounding adaptive reuse and circular construction. Within the Dutch construction sector, the reuse of existing structures is still relatively uncommon and often considered more complex and expensive than demolition and new construction. However, increasing environmental pressures, resource scarcity, and climate objectives will require the sector to shift towards the reuse of existing building stock in the coming decades. This research therefore provides practical insights for architects, contractors, developers, and policymakers by demonstrating not only what is possible, but also how existing industrial structures can be effectively transformed into circular housing.

The significance of this research extends far beyond the specific case study in Rotterdam. Although developed for a single industrial site, the underlying principles are highly transferable. Industrial buildings with robust structural systems exist in large numbers throughout the Netherlands and worldwide. However, the research is limited to a single case study and assumes that the structural condition of the existing building is suitable for reuse. In practice, detailed structural inspections and engineering assessments would be required to verify the feasibility of reuse before implementation. The strategy of retaining existing structural frameworks while adding lightweight, demountable, and biobased housing systems can therefore be applied on a much broader scale. As a result, the environmental and societal impact of this approach has the potential to extend far beyond a single project and contribute to a wider transition towards circular urban development.

In conclusion, existing industrial structures can be reused as the basis for circular housing by preserving their structural framework and combining it with lightweight, prefabricated, biobased, and demountable building systems. When supported by carefully designed collective spaces, flexible housing typologies, and high-quality residential environments, these structures can successfully accommodate contemporary housing needs while significantly reducing environmental impact. This research demonstrates that industrial buildings should not be viewed as the end of a building cycle, but as the starting point for new cycles of use, adaptation, and material reuse. The reuse of existing structures, combined with prefabricated timber construction and reversible building systems, is therefore not merely a sustainable alternative to conventional development, but a realistic, scalable, and necessary strategy for the future of housing and the transition towards a circular built environment.

4.3 REFLECTION

This graduation project has been one of the most valuable learning experiences of my architectural education. Throughout the project, I gained extensive knowledge about existing structures, structural reuse, and circular construction principles. In previous design projects, I almost exclusively worked with new-build developments, where the design process started with a blank canvas. Working within an existing industrial structure required a completely different approach. Instead of designing an entirely new building, I had to understand, analyse, and work with the opportunities and limitations of an existing framework. This proved to be both challenging and highly educational.

One of the most important lessons I learned is that existing buildings should not be viewed as obstacles to development, but as valuable resources that can form the basis for new architectural interventions. Through archival research, structural analysis, and design exploration, I developed a much deeper understanding of how existing structures can contribute to more sustainable forms of urban development.

Looking back, I am particularly satisfied with the outcome of the project. The transformation demonstrates how a former industrial building can be given a completely new purpose while preserving its structural value. What was once a large and relatively harsh industrial environment has been transformed into a residential complex that prioritizes liveability, social interaction, and environmental performance.

The project has strengthened my interest in adaptive reuse and circular architecture and has shown me the potential of working with existing buildings as a starting point for future design. I believe the knowledge and experience gained during this graduation project will continue to influence my approach to architecture and urban development in the future.

5.1 REFERENCES

Alexander, M., & Beushausen, H. (2019). Durability, service life prediction, and modelling for steel and reinforced concrete structures.

Brand, S. (1994). How Buildings Learn: What Happens After They're Built. Viking Press.

Cross, N. (2006). Designerly Ways of Knowing. Springer.

Durmisevic, E. (2019). Circular Economy in Construction: Design Strategies for Reversible Buildings. Delft University of Technology.

Ellen MacArthur Foundation. (2019). Completing the Picture: How the Circular Economy Tackles Climate Change.

Gemeente Rotterdam. (2023). Woonvisie Rotterdam.

Intergovernmental Panel on Climate Change. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Cambridge University Press.

United Nations Environment Programme. (2022). Global Status Report for Buildings and Construction.