

# MITIGATING WATER SCARCITY AND URBAN HEAT

Integrating Circular Water Metabolisms and Thermo-  
dynamic Architecture in the Barcelona Eixample



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**Architecture and  
the Built Environment**







# ABSTRACT

Our cities are getting hotter, drier, and more unlivable, yet we keep building the same static, heat-trapping architecture. I started the Lighthouse Block project because I wanted to prove that we don't have to rely on brute-force mechanical systems or waste massive amounts of water to survive the climate crisis. Instead of hiding technical infrastructure in the basement, this thesis elevates it, transforming a standard Barcelona city block into a living, visible eco-machine.

The core idea is pragmatic: water and heat are not waste; they are raw materials. By decentralizing the urban water cycle, separating greywater streams, and implementing structural blue roofs, the block creates its own circular metabolism. This guarantees a continuous, drought-proof water supply to fuel the "Green Engine" — the vegetation that actively and biologically cools the microclimate precisely when it is needed most.

Beneath the surface, the block plugs directly into the local geology. By integrating Managed Aquifer Recharge (MAR) and Aquifer Thermal Energy Storage (ATES), it builds a massive seasonal thermal battery that stores winter cold for summer cooling, and vice versa. Ultimately, the Lighthouse Block is about shifting the urban paradigm. It proves that architecture can stop being a passive consumer of resources and instead become an active, thermodynamic system that regenerates its own environment.



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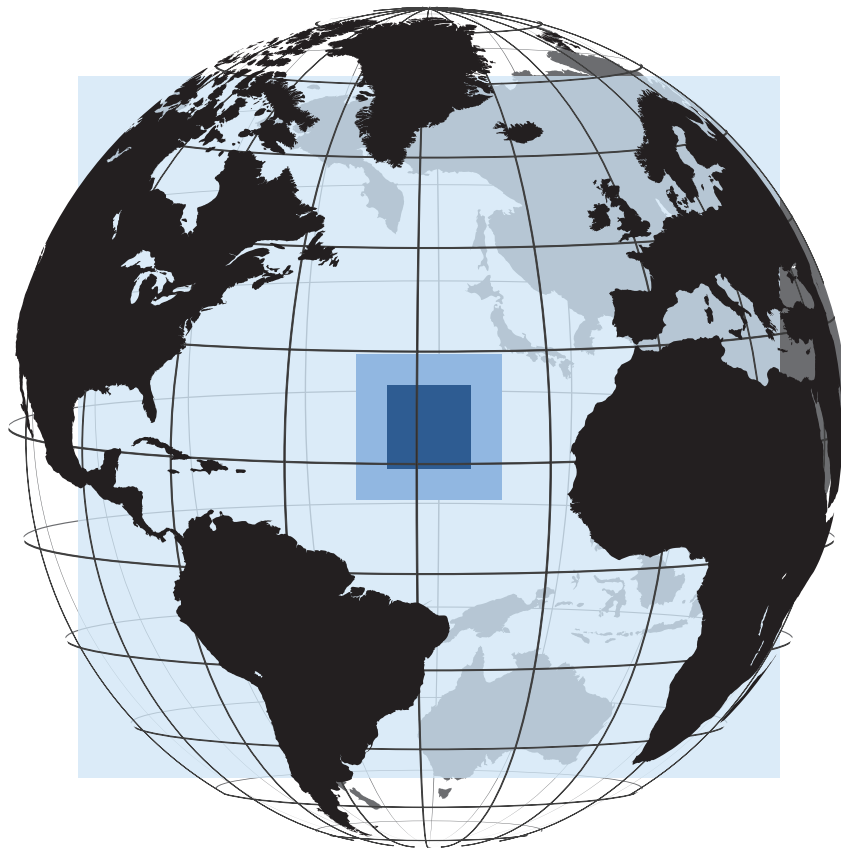
# **PART I: INTRODUCTION**

## **The Context & The Crisis**

# PROBLEM STATEMENT

## Resource Water

To understand what it means to live under water stress, it is necessary to reflect on our current relationship with water. Although approximately 70% of the Earth's surface is covered by water, only about 3% of this is freshwater. Of this fraction, nearly two-thirds are locked in ice caps or deep underground, leaving only around 1% accessible for human use (UN Water, 2023) (Platform, 2024). What appears to be an abundant resource is therefore extremely limited and increasingly under pressure.



70% of the planet's surface is water

3% of our water is freshwater

1% of it is accessible

Figure 1. Resource Water. By author.



# Water as Human Right

Access to water is a fundamental human right, yet today approximately 1.1 billion people lack access to water and 2.2 billion people lack access to safe drinking water (Human Rights to Water and Sanitation, n.d.; Nations, n.d.) (WHO & UNICEF, 2023).

Currently, 25 countries are exposed to extremely high water stress, meaning they use 80% or more of their available freshwater resources annually. Globally, around 2 billion people are already affected by water stress, a number projected to rise by an additional billion by 2050.

Importantly, water stress does not necessarily lead to a crisis. Cities and regions such as Venice, Singapore and Israel demonstrate that societies can function, and even thrive, under water scarce conditions through innovation, adaptation and systemic change (Kuzma et al., 2023).

**2,2 billion people**  
lack access to safe drinking water

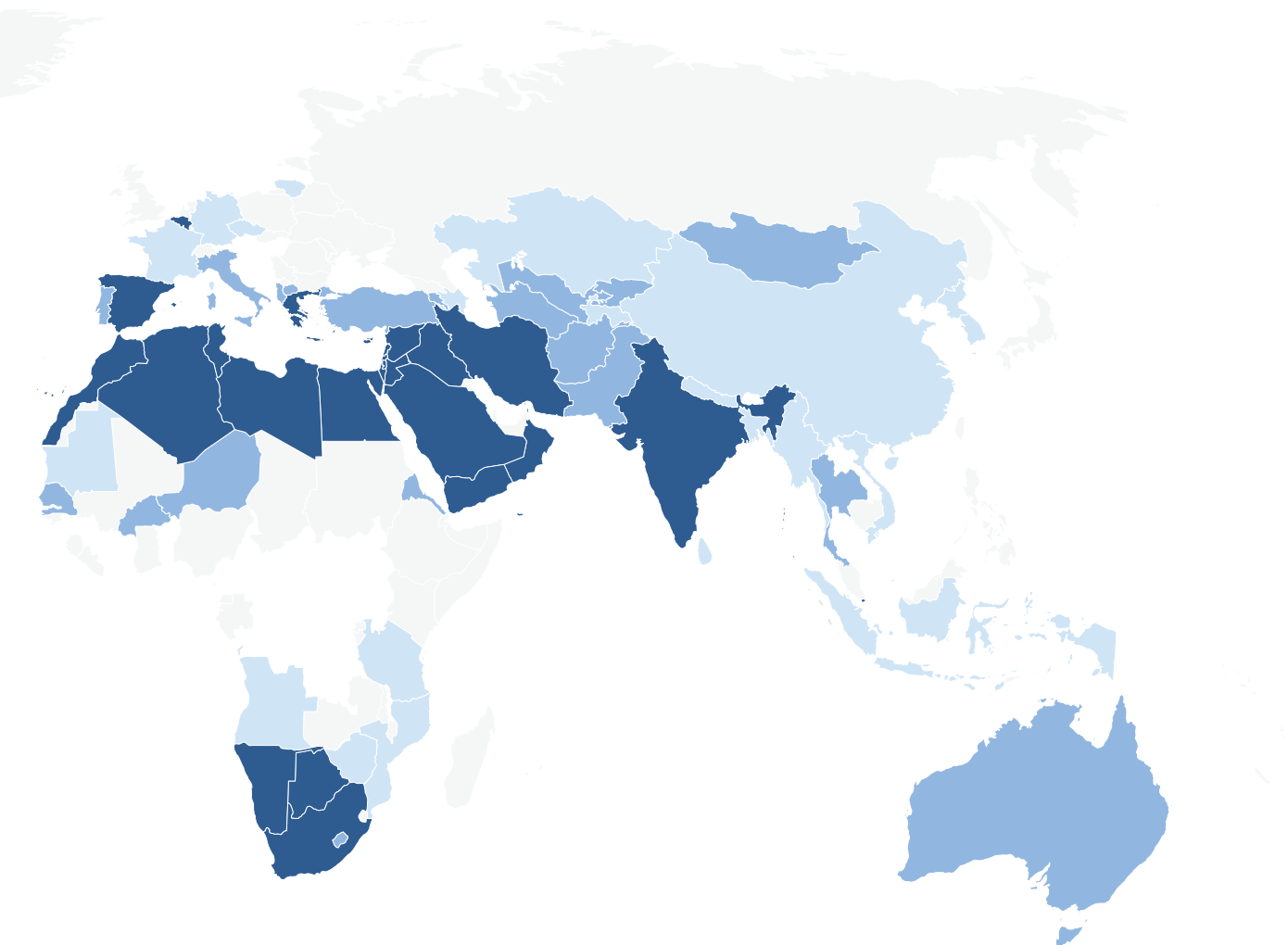
**25 countries**  
are exposed to extremely high water stress

**3 billion people**  
will live under extremely high water stress by 2050

## Water Stress

Currently, over two billion people live in water-stressed regions, a crisis acutely felt in Mediterranean cities like Barcelona where reservoirs frequently drop to critical levels. Driven by climate change and rapid urbanization, an additional one billion people are projected to live under conditions of extremely high water stress by 2050.





■ 3% of our water is freshwater      ■ 1% of it is accessible

Figure 2. Projected global water stress by 2050. Redrawn by author based on World Resources Institute (WRI), 2023.

# Heat Stress

Simultaneously, extreme urban heat relentlessly bakes the city's impermeable hardscapes, actively intensifying the Urban Heat Island (UHI) effect. Because conventional building materials like concrete and asphalt act as massive thermal batteries, they absorb vast amounts of daytime solar radiation and continue to radiate that trapped heat long into the night. This artificially elevated baseline temperature eliminates the city's natural

nocturnal cooling cycle, placing severe physiological strain on the human body. Ultimately, this constant thermal load compromises basic human comfort, exacerbates heat-related health risks, and drastically degrades the overall liveability of the urban environment.

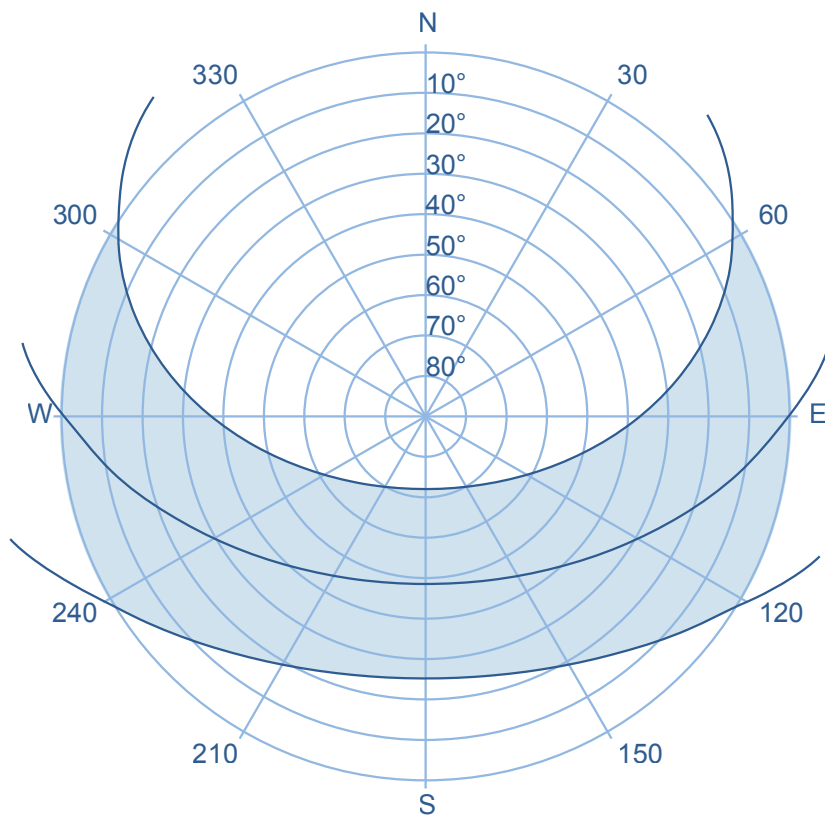
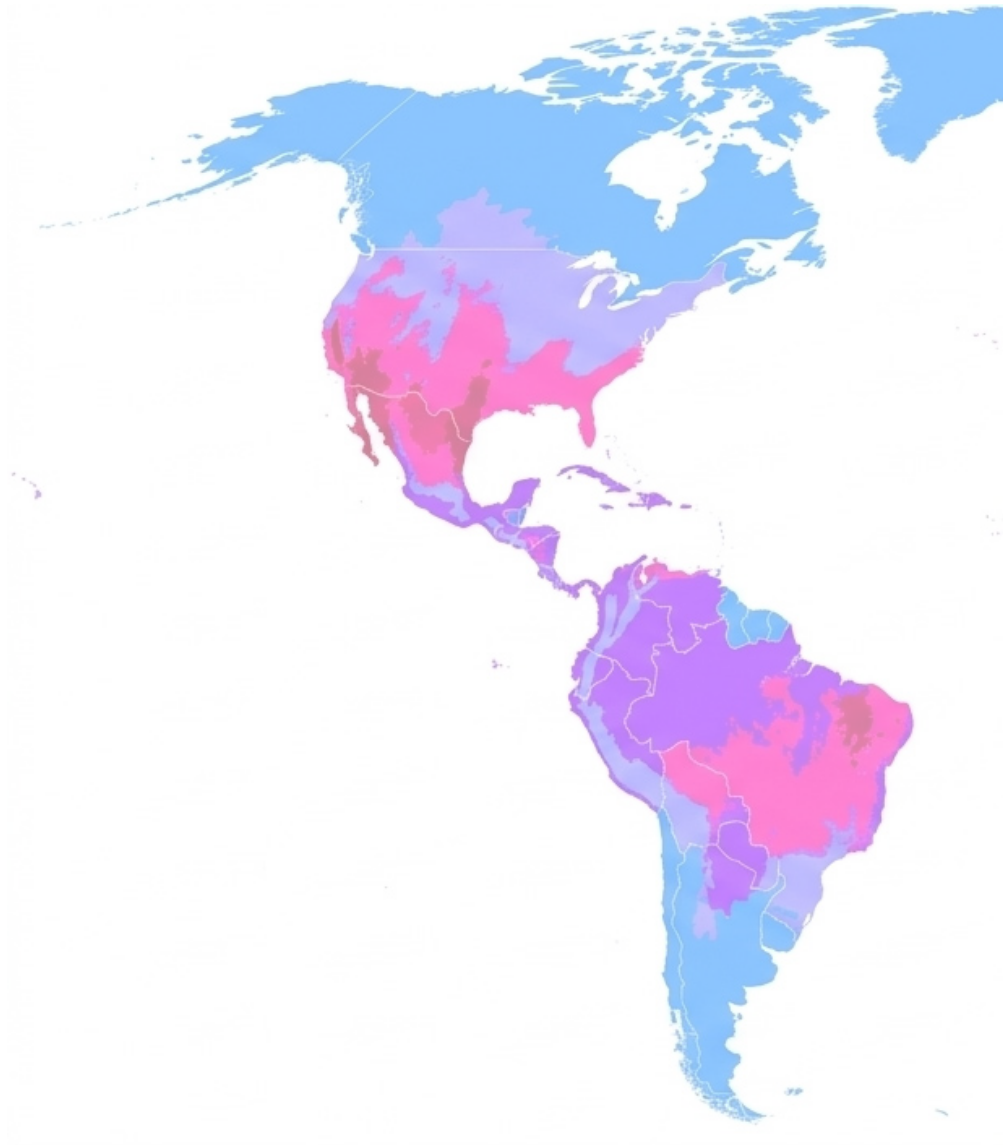


Figure 3. Sun path

**Heat Stress**



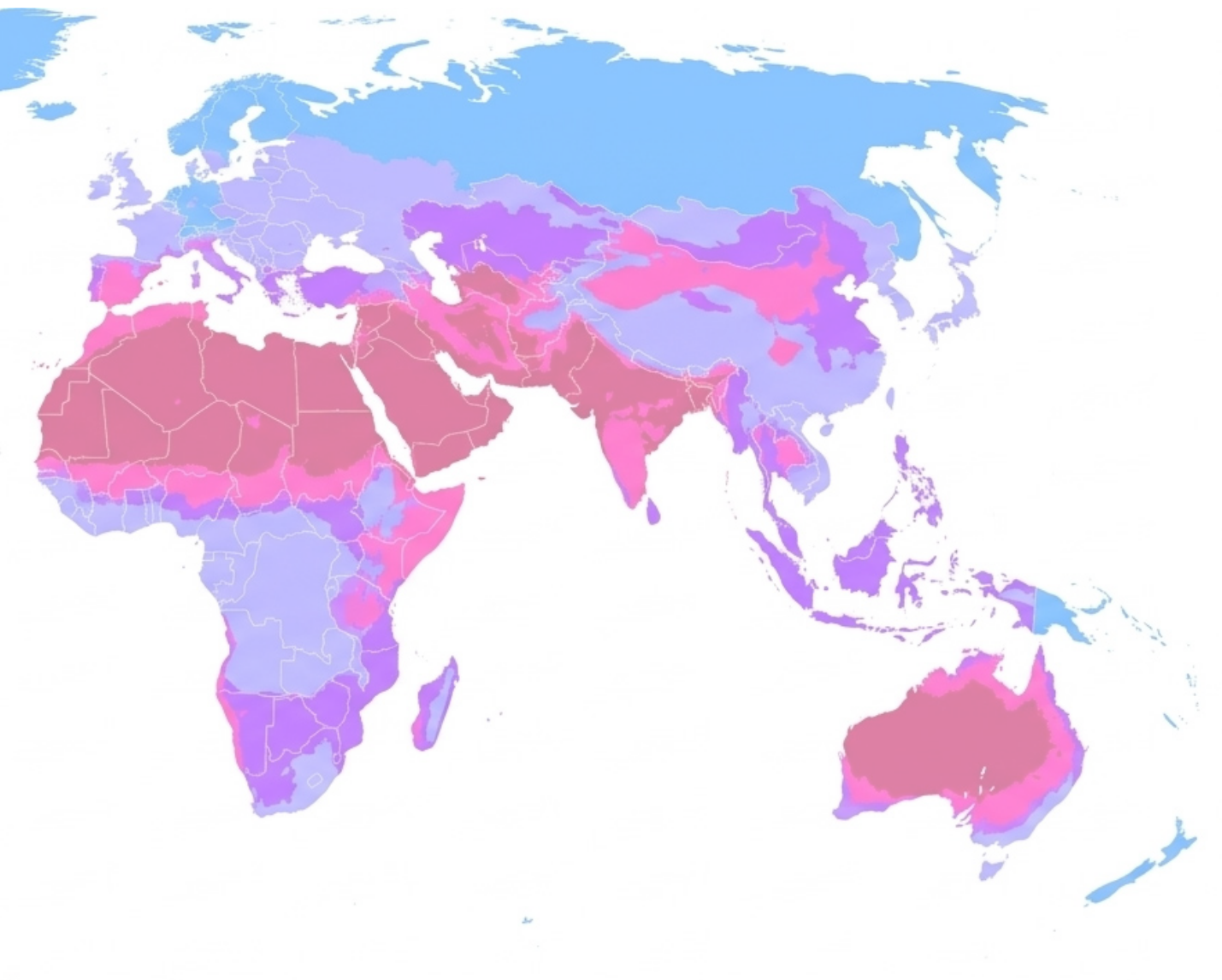


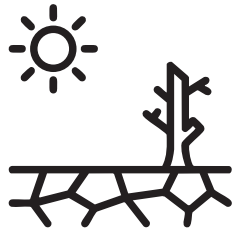
Figure 4. Heat Stress<sub>19</sub>





### **Pluvial Flooding**

Extreme rainfall resulting in  
too much water



### **Droughts**

Dry periods resulting in  
too less water



### **Heat Stress**

Extream Heat Events  
too less evaporation

## Compound risks

In dense urban environments, these threats do not occur in isolation. Extended droughts intensify heat stress, and when precipitation finally occurs, the baked, impermeable urban fabric cannot absorb it, triggering severe pluvial flash flooding—creating a compound crisis that demands a systemic architectural response (IPCC, 2022).

# The Urban reality

**68 % of the world population**

is projected to live in cities by 2050  
(Un,2018)

## Cities Vulnerability

The urban scale is where water stress becomes particularly critical. More than half of the global population now lives in cities, a share that continues to grow. Climate change amplifies urban vulnerability by increasing heat stress, extending drought periods, and concentrating rainfall into short, extreme storm events. This results in cities simultaneously facing water scarcity and flooding—conditions that directly affect buildings, public space, and everyday urban life (IPCC, 2022). Recent events in Barcelona, where reservoir levels fell below 20% and emergency water restrictions were imposed, illustrate the fragility of contemporary urban water systems (Ajuntament de Barcelona, 2024).

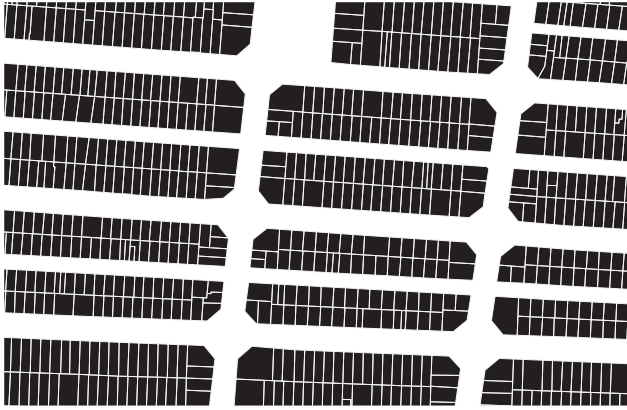


Figure 5. Maxico City



Figure 6. Cape Town

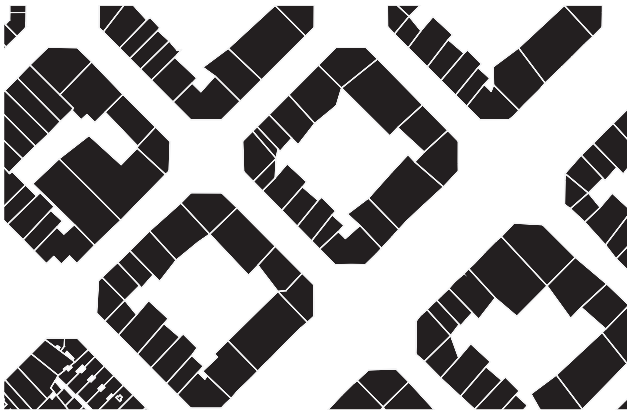


Figure 7. Barcelona



Figure 8. Chennai



Figure 10. Urban Scale

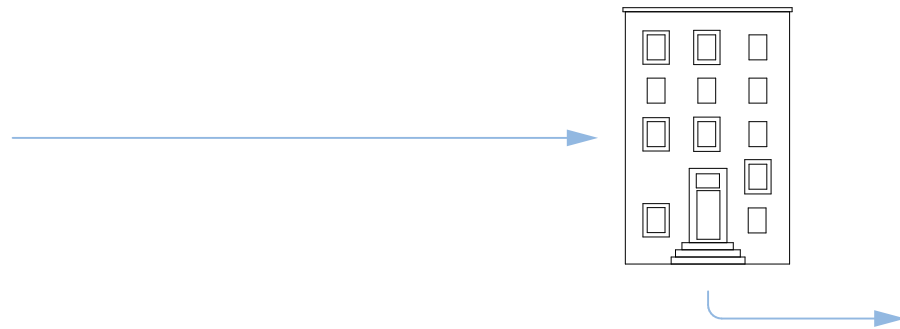


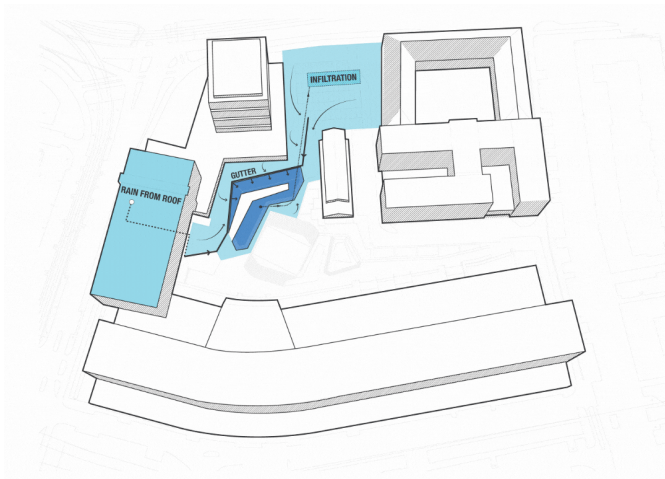
Figure 9. Building Scale

# The Linear Urban Metabolism

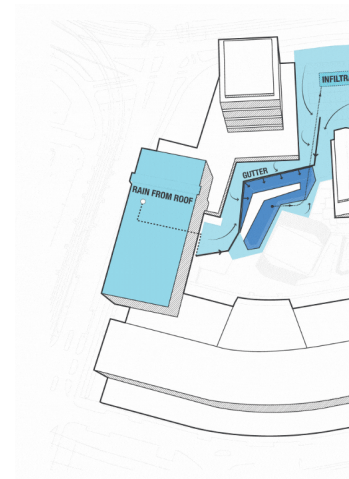
A core problem lies in the way architecture currently treats water. Urban infrastructure relies on a vulnerable, linear model that rapidly discharges water away from the city, while buildings act as passive endpoints that consume portable water and immediately discharge blackwater. To build true climate resilience, architecture must shift from exclusionary waterproofing to becoming active nodes for circular water buffering and reuse.

# RELEVANCE

## Existing Solutions



Too big, slow and expensive



Too ind

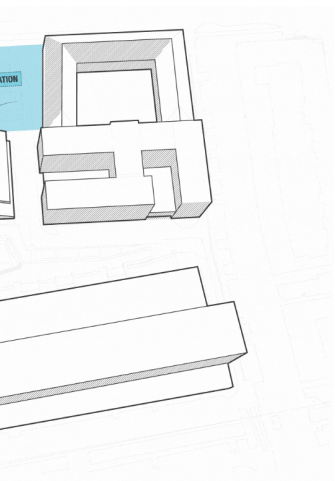


Figure 12.Neighbourhood

Individual

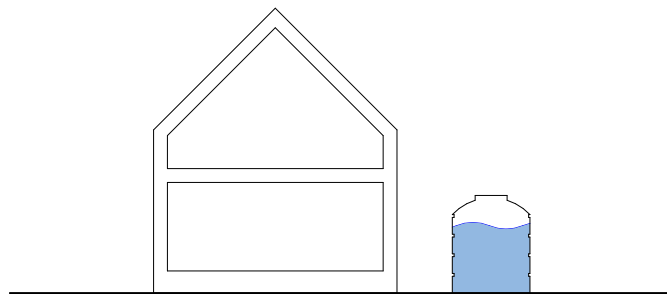


Figure 11.Single Family Houses

Too small



## The missing scale – Knowledge Gap

Current responses to climate stress are heavily polarized by scale. On one extreme, cities rely on massive, slow, and inflexible infrastructure (reservoirs, desalination plants). On the other, decentralized solutions are frequently developed for low-density single-family homes. The critical intermediate scale—existing, high-density urban housing blocks—remains severely underexplored (Sapkota et al., 2015). Because the vast majority of urban residents live in collective housing, and most of the buildings that will exist in 2050 have already been built, retrofitting this intermediate block scale is arguably the most urgent architectural challenge of the century.

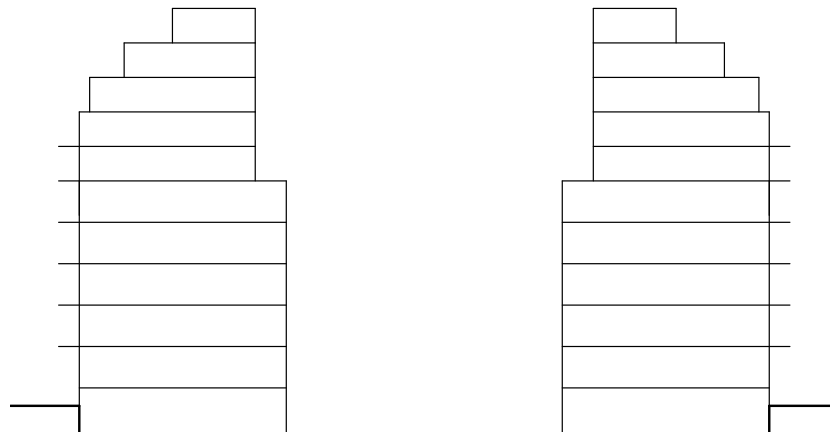


Figure 13.01.8 Urban Housing Block

## Urban Housing Block

# OBJECTIVE AND MOTIVATION

## Objective

The primary objective of this thesis is to redefine the architectural relationship with water in dense, climate-vulnerable environments. Rather than treating water as a hidden technical constraint, this research aims to spatialize water infrastructure, transforming domestic buildings from passive endpoints into active, decentralized climate engines. By integrating circular water metabolism—harvesting, buffering, and reusing rainwater and greywater on-site—this project seeks to prove that domestic water circularity is the essential prerequisite for passive evaporative cooling and long-term urban liveability.



Figure 15. Urban Scale First Solution Idea  
Redrawn by author based on Aquatecture – Studio Sway, n.d.

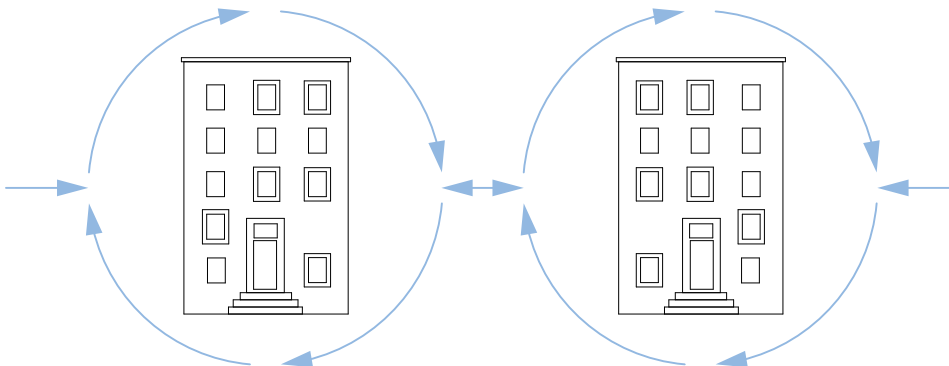


Figure 14. Building Scale First Solution Idea. Redrawn by author based on Aquatecture – Studio Sway, n.d.

# Motivation

Water is one of the most essential resources for human life, yet in contemporary cities it is largely hidden, controlled, and removed as quickly as possible. This project is motivated by the ambition to reclaim water as a primary spatial and atmospheric design driver, rather than a mere technical constraint. By transforming buildings into active nodes that harvest, store, and reuse water locally, this captured resource becomes the vital fuel needed to mitigate severe urban heat stress. Embracing the architect as a “system designer,” this thesis demonstrates how making hydrology visible and spatial can simultaneously build climate resilience and radically improve everyday urban liveability.



# RESEARCH AND DESIGN QUESTION

How can rainwater use combined with building-integrated, circular water system in urban housing blocks contribute to resilience against water stress while enhancing thermal comfort?

# Sub-questions

## **The System (Hydrology & Circularity):**

How can a cascading water system—integrating extreme rainfall buffering, strict greywater separation, and controlled aquifer recharge—minimize potable water demand and mitigate peak flood loads at the block scale?

## **Architectural Integration (The Interfaces):**

How can complex hydrological flows be spatialized across the Eixample block through a dual architectural intervention: retrofitting the existing courtyard and inserting a new Open Building to act as a “Lighthouse” prototype?

## **Climatic & Spatial Performance (The Outcome):**

To what extent do these integrated infrastructures, specifically dynamic courtyard retention and bio-based climatic façades, reduce urban heat stress and improve the socio-spatial experience of the block?



## SCOPE

This project operates in Barcelona, within the historic Cerdà grid—widely considered one of the most successful urban typologies globally, yet now facing unprecedented climatic volatility. The spatial boundaries of the design intervention are strictly limited to the scale of a single Eixample housing block (Carrer de Balma).

The architectural output consists of two interconnected moves: the strategic retrofitting of the collective courtyard to manage block-scale climate buffering, and the design of a single new “Lighthouse” building. This new building serves as the active metabolic engine for the block, housing residential units, public ground-floor amenities, and visible water/energy infrastructure.

The project does not attempt to redesign regional water networks. Instead, it deliberately pushes this iconic block to its absolute metabolic limits. By designing a radical, highly integrated prototype, the thesis aims to establish a high-water mark for urban resilience. The ultimate goal is to extract from this extreme intervention a scalable, slightly moderated blueprint that can be multiplied across the broader Eixample grid and adapted for other climate-vulnerable European cities.



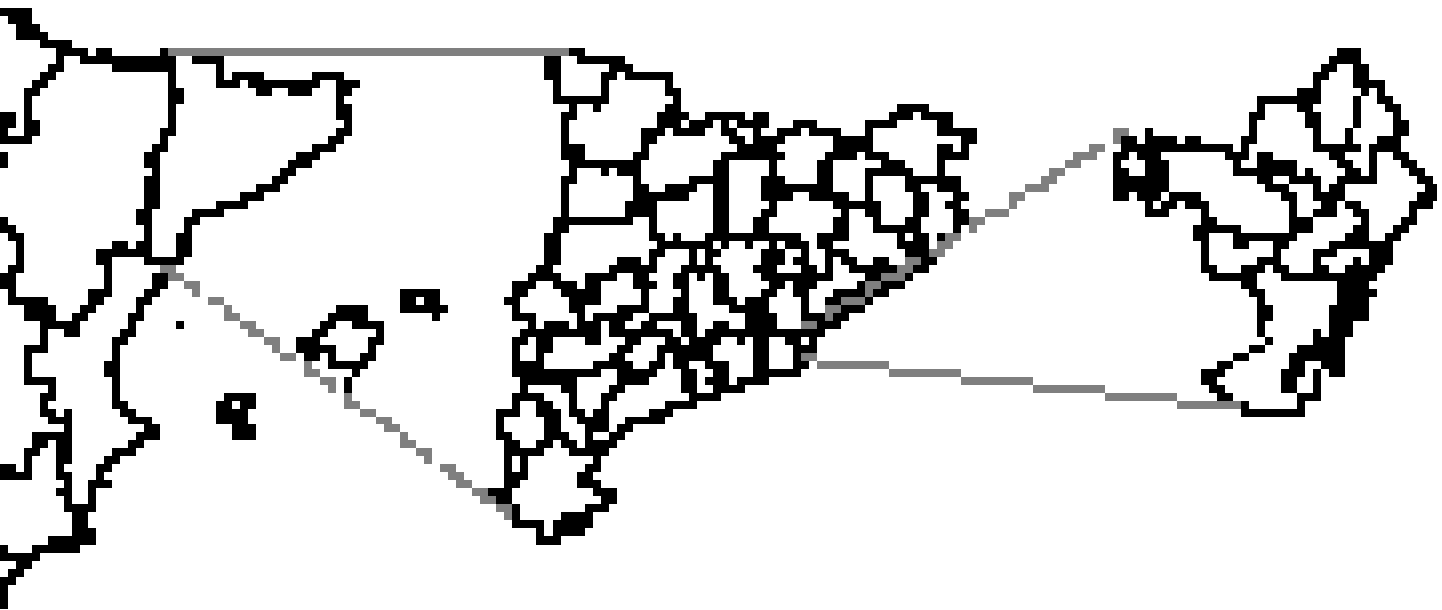


Figure 17. Scope: Spain, Catalonia, Metropolitan Area of Barcelona, Barcelona



## **PART II: APPROACH**

### **Methods and Theoretical Framework**

This chapter maps the current climatic and hydrological crisis in Barcelona. It proves that while the city has macro-level strategies for green development and water circularity, these top down plans fail to activate the micro scale of the Eixample block and the domestic sphere.

# METHODS

## Research by Design

This graduation project follows a research-by-design approach, in which architectural design is used as a tool to test hypotheses rather than as a final outcome. Design is employed to explore spatial and systemic possibilities, compare alternative scenarios, and evaluate the interaction between water systems and architectural space. Diagrams, plans, sections, and models function not only as representational tools, but as analytical instruments that generate knowledge through design.

The project starts with research to establish a solid conceptual and contextual foundation. From this point onward, the process develops through an iterative workflow in which phases of design development, testing and reflection, and further research are repeatedly looped. Insights gained in each cycle inform subsequent design decisions, allowing the project to progressively refine both system logic and architectural integration.

# Methods per Domain

The project addresses four interconnected domains, each requiring a specific methodological approach to translate systemic research into spatial design.

## **Water Infrastructure:**

This domain investigates rainwater harvesting, buffering, and storage at the block scale. Using system diagrams and extreme weather scenarios (floods versus prolonged droughts), the research evaluates how water can be temporarily retained and redistributed without relying on rigid engineering calculations, focusing instead on spatial logic and integration.

## **Circular Water Use:**

Focusing on the differentiation of domestic water streams, this domain explores treatment strategies and reuse loops to drastically reduce potable water demand. Diagrammatic flow cycles and digital simulations are used to organize multiple water qualities

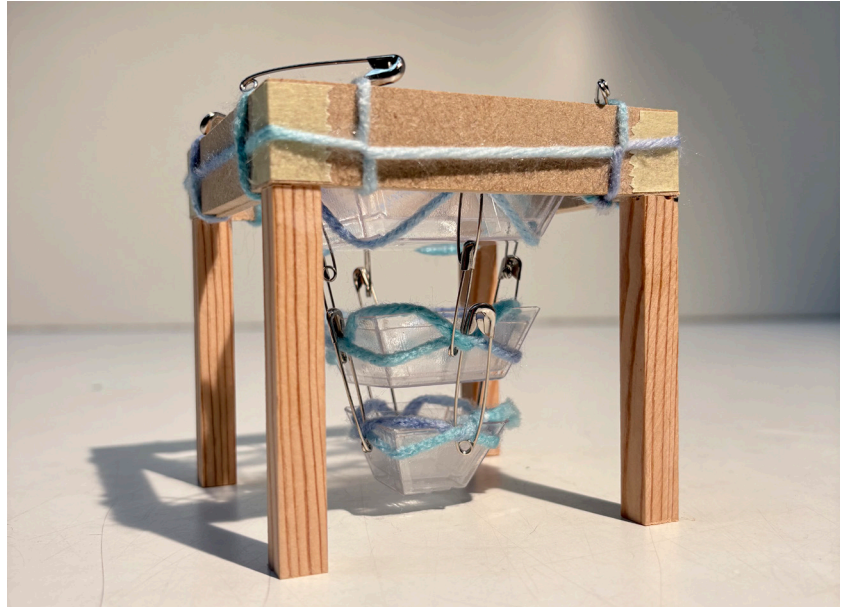
into coherent, safe, and legible residential systems.

## **Heat Stress Mitigation:**

Acting as the crucial output of the water domains, this methodology evaluates the building's thermodynamic performance. It analyzes how the harvested and circular water can be deployed to fuel evaporative cooling, sustain bio-shading, and integrate with ATES systems, ultimately neutralizing the Urban Heat Island effect and ensuring long-term thermal comfort.

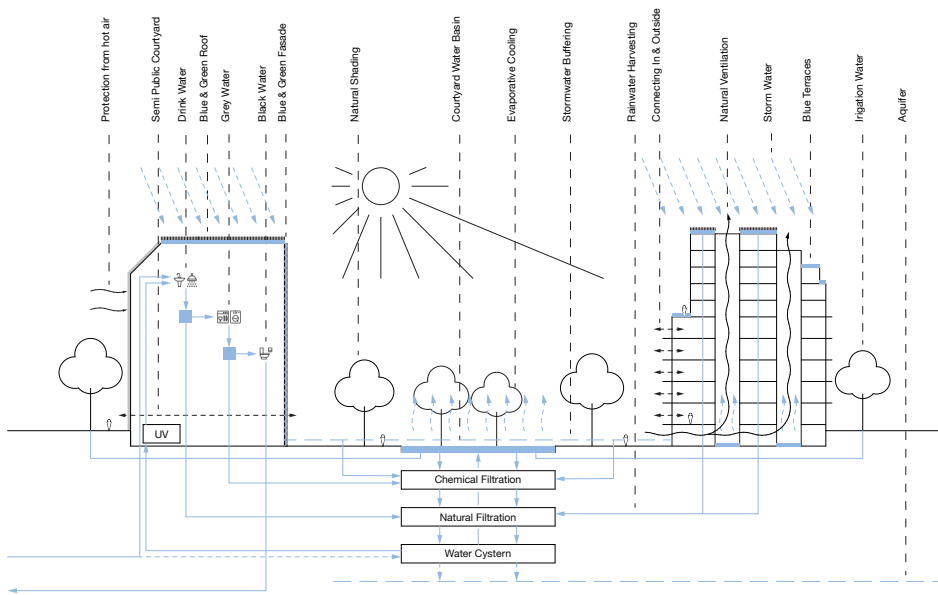
## **Architectural and Spatial Qualities:**

This domain examines how these climate systems impact user interaction within dense housing. Through plans, sections, and physical sectional models, water is elevated from a technical resource to an architectural driver that actively shapes the atmosphere, scale, and everyday experience of the courtyard.



## Prototyping Strategy

Prototyping serves as the primary tool to test the intersection of system logic and architectural space. The methodology relies on two distinct approaches: architectural prototypes (physical sectional models evaluating spatial quality, microclimate, and experiential presence) and system prototypes (diagrammatic models exploring water flows, separations, and circular loops). Investigations are primarily conducted at a 1:200 scale to analyze building-court-yard relationships, shifting to a 1:50 scale to resolve critical systemic intersections. Engineering-level detailing is deliberately excluded to maintain focus on spatial integration.



## Iterative Workflow

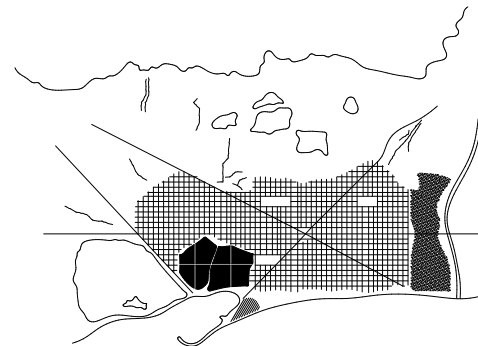
The project's domains are designed to be developed in parallel through a continuous feedback loop. Decisions made within one domain—such as the placement of water storage or bio-filtration elements—directly dictate the spatial organization and user interaction in the others. This iterative testing of configurations allows for the rapid identification of conflicts between technical systems and spatial quality, gradually aligning water infrastructure and architectural design into a single coherent proposal.



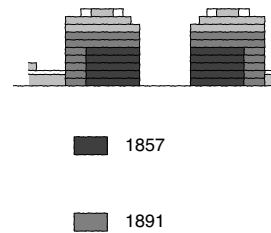
# THE URBAN CONDITION



The Confined City



Cerdà's Scientific Urbanism



The Perversion of

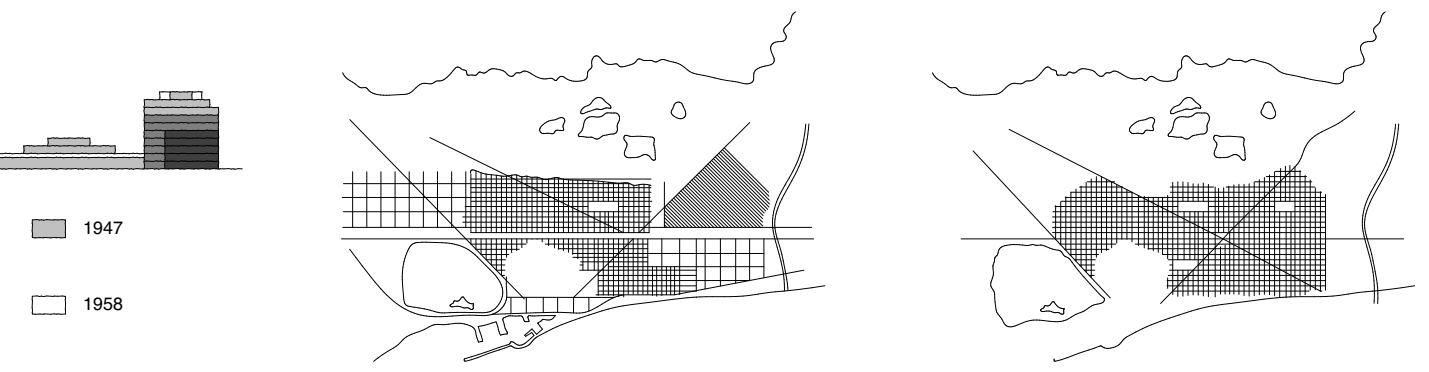


Figure 18. The Evolution of the Eixample. Redrawn by author based on El globus vermell, 2018.

of the Plan

**Early Demands for Greenery**

**Revisiting the Spirit of Cerdà**

# From Barcino to the Confined City



Barcelona's urban form was shaped by centuries of physical confinement and military control. Founded as the Roman settlement of Barcino, the city's dense core was repeatedly compressed by reinforced walls, particularly following the War of the Spanish Succession when the Bourbon regime constructed a massive citadel to control the population. For nearly two

centuries, construction outside these walls was strictly prohibited, leading to extreme overcrowding, a lack of sanitation, and severe public health crises by the mid-19th century.

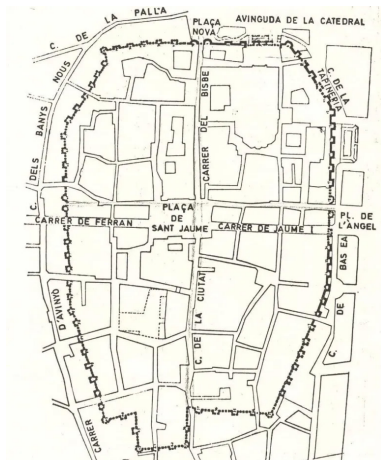
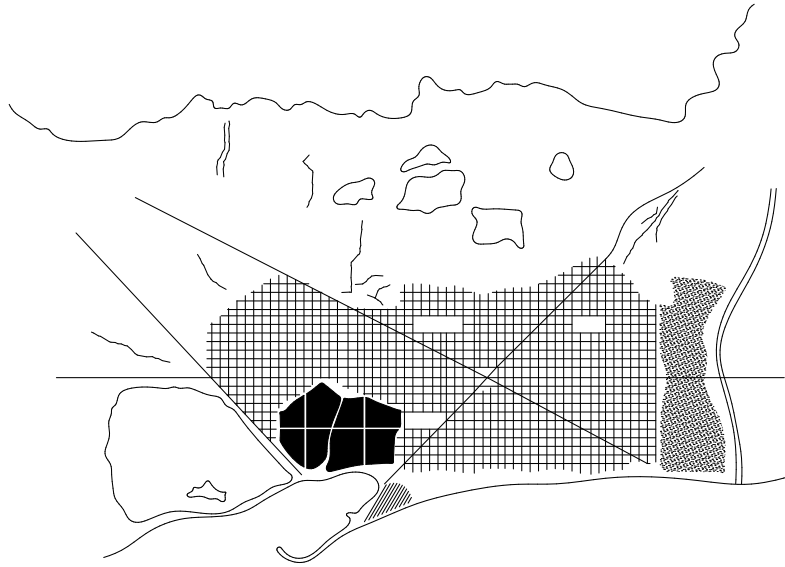


Figure 19. La Porta Ferriça. The Historical Marker Database, 2023.



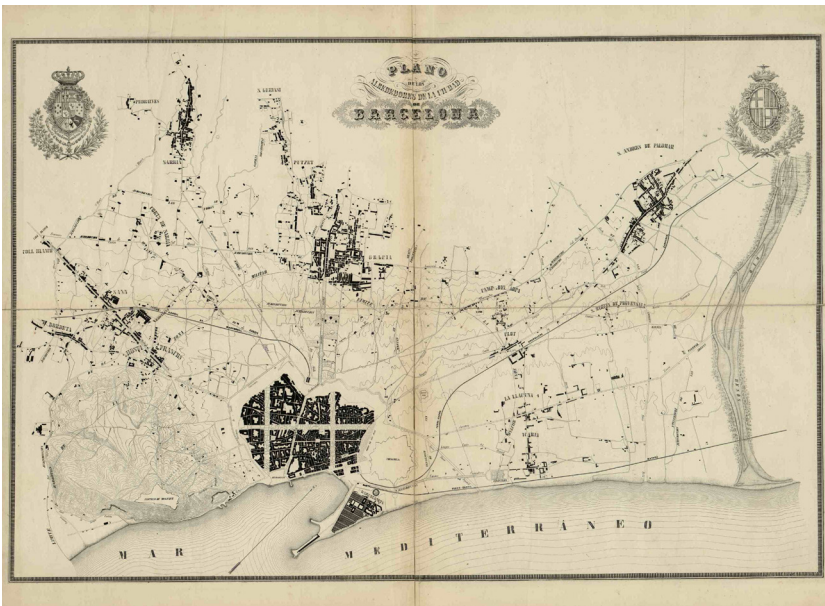
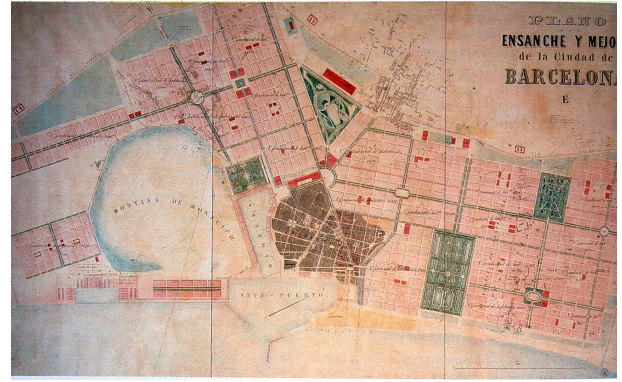
# Cerdà's Scientific Urbanism



In 1859, the Spanish government approved an urban expansion plan by engineer Ildefons Cerdà to address the walled city's critical density. Approaching urbanism as a scientific and egalitarian discipline, Cerdà conducted detailed surveys revealing severe disparities in living conditions between the bourgeoisie and the working class. His revolutionary design

aimed to correct these imbalances by prioritizing public health, ensuring that all residents had equal access to sunlight, ventilation, and open space regardless of social class

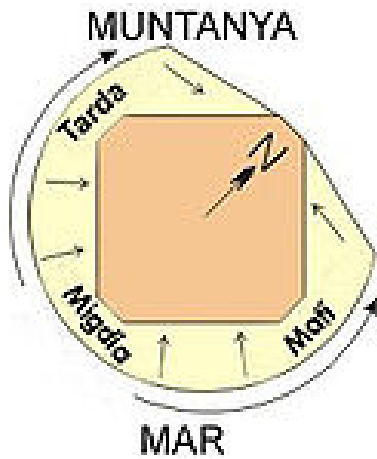




# The Egalitarian Block

The Eixample introduced a uniform 113 × 113-meter grid characterized by 20-meter-wide streets and distinct chamfered corners to improve visibility, circulation, and airflow. Cerdà originally designed these manzanas (blocks) to be built on only two or three sides, limiting building heights to 16 meters and capping land occupation at less than 50 percent. The

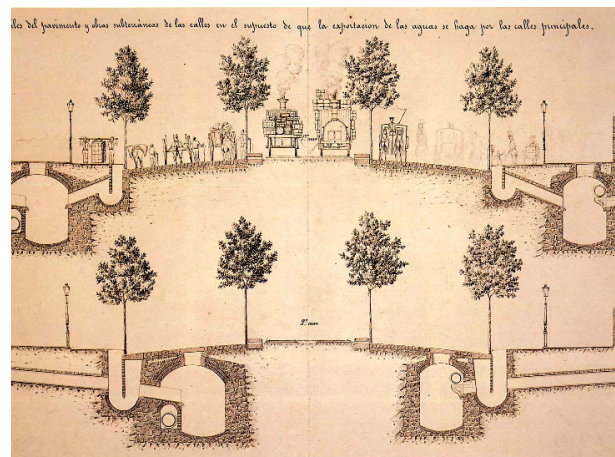
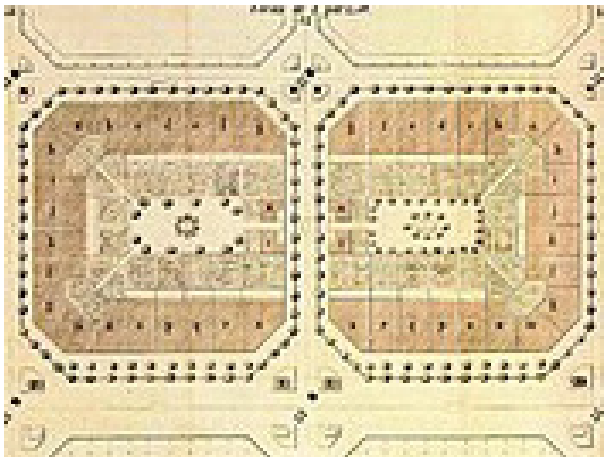
spacious interior courtyards were intended to serve as green communal spaces, transforming the urban block from a mere building unit into an infrastructural module for equitable living.



**equal distribution**

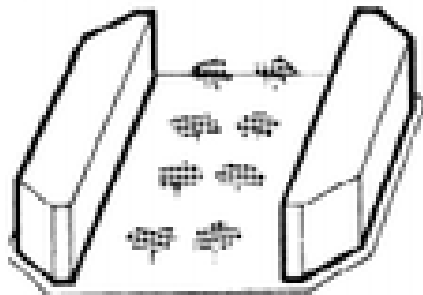
**natural ventilation**

**enough sunlight**





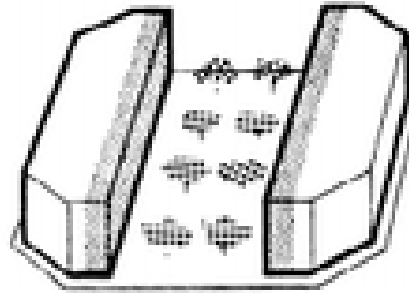
# The Perversion of the Plan



67,200 m<sup>2</sup>

1859

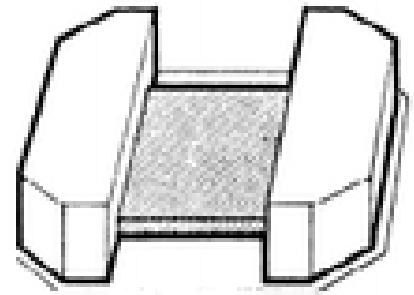
Ideal



+ 29,440 m<sup>2</sup>

1860

Emergence



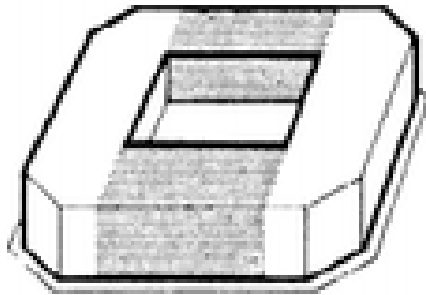
+ 18,944-41 m<sup>2</sup>

1891

Expansion

The Eixample introduced a uniform 113 × 113-meter grid characterized by 20-meter-wide streets and distinct chamfered corners to improve visibility, circulation, and airflow. Cerdà originally designed these manzanas (blocks) to be built on only two or three sides, limiting building heights to 16 meters and capping land occupation at less than 50 percent. The

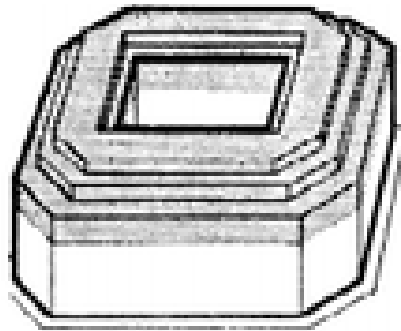
spacious interior courtyards were intended to serve as green communal spaces, transforming the urban block from a mere building unit into an infrastructural module for equitable living.



+ 52,864 m<sup>3</sup>

1924

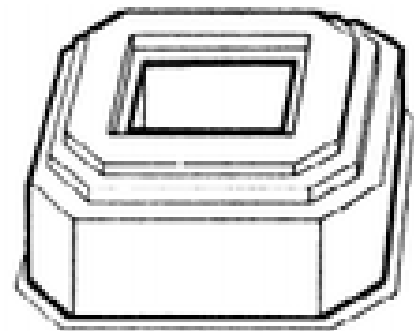
Consolidation



+ 126,323.20 m<sup>3</sup>

1976

Saturation

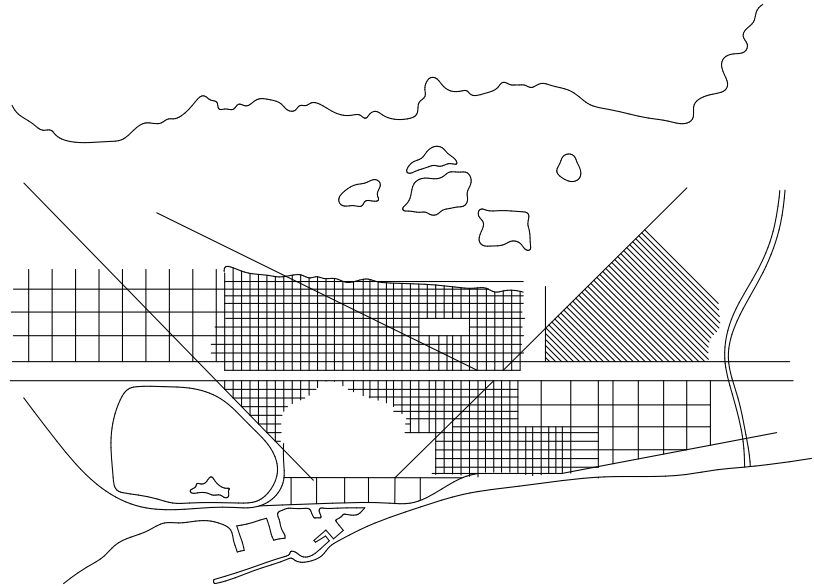


= 294,771.61 m<sup>3</sup>

1988

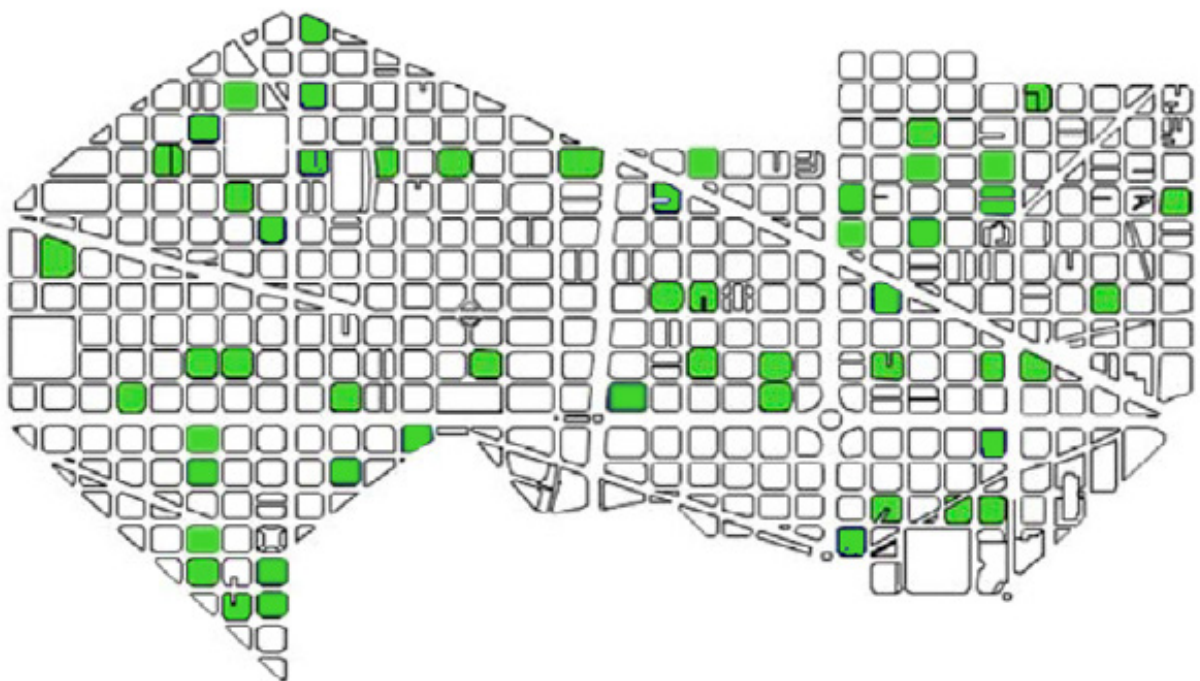
Privatization

## Early Demands for Greenery



Even as the blocks were being aggressively filled, resistance emerged against the loss of Cerdà's intended open spaces. By the late nineteenth and early twentieth centuries, civic groups, health advocates, and avant-garde architectural collectives like GATCPAC began actively campaigning against the hyper-densification. They argued that the city had

been stripped of its essential "lungs" and demanded the restoration of the interior courtyards to provide recreation, improve air quality, and secure vital outdoor space for children.



# Connecting the Urban Landscape

The Barcelona Green Infrastructure and Biodiversity Plan 2020 seeks to address the city's profound environmental deficit by establishing a continuous network of ecological corridors. Shifting focus toward macro-scale connectivity, the strategy aims to link major natural assets by drawing green axes from the Collserola mountain range down to Montjuïc, the Ciutadella, and the Mediter-

anean seafront. However, a critical blind spot remains within this sweeping vision: the Eixample blocks are completely unrecognized as potential ecological nodes. By overlooking the latent capacity of these interior courtyards, the municipal framework misses a vital opportunity to weave biodiversity and thermal relief directly into the dense, historical urban fabric.

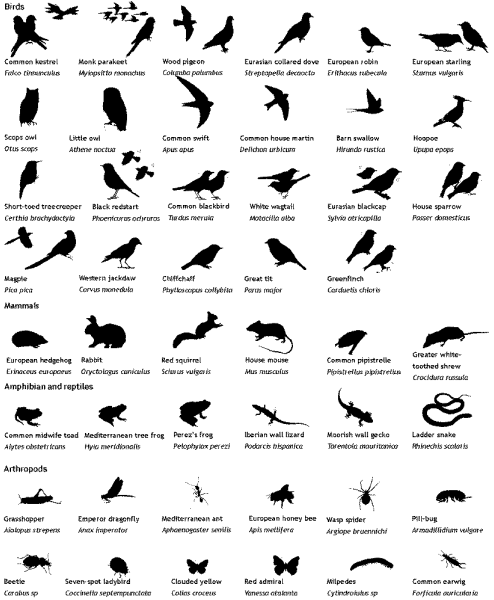
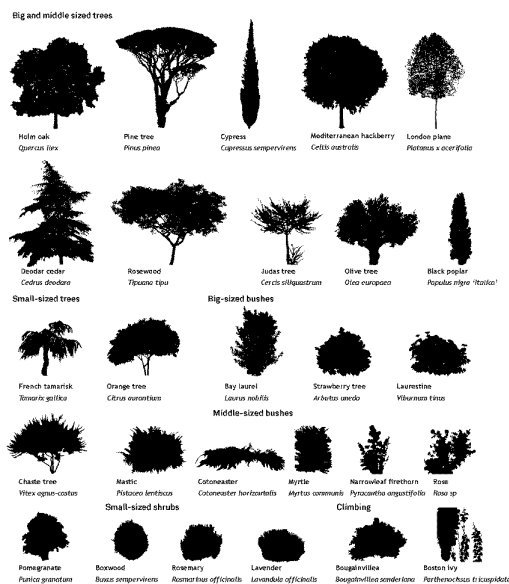




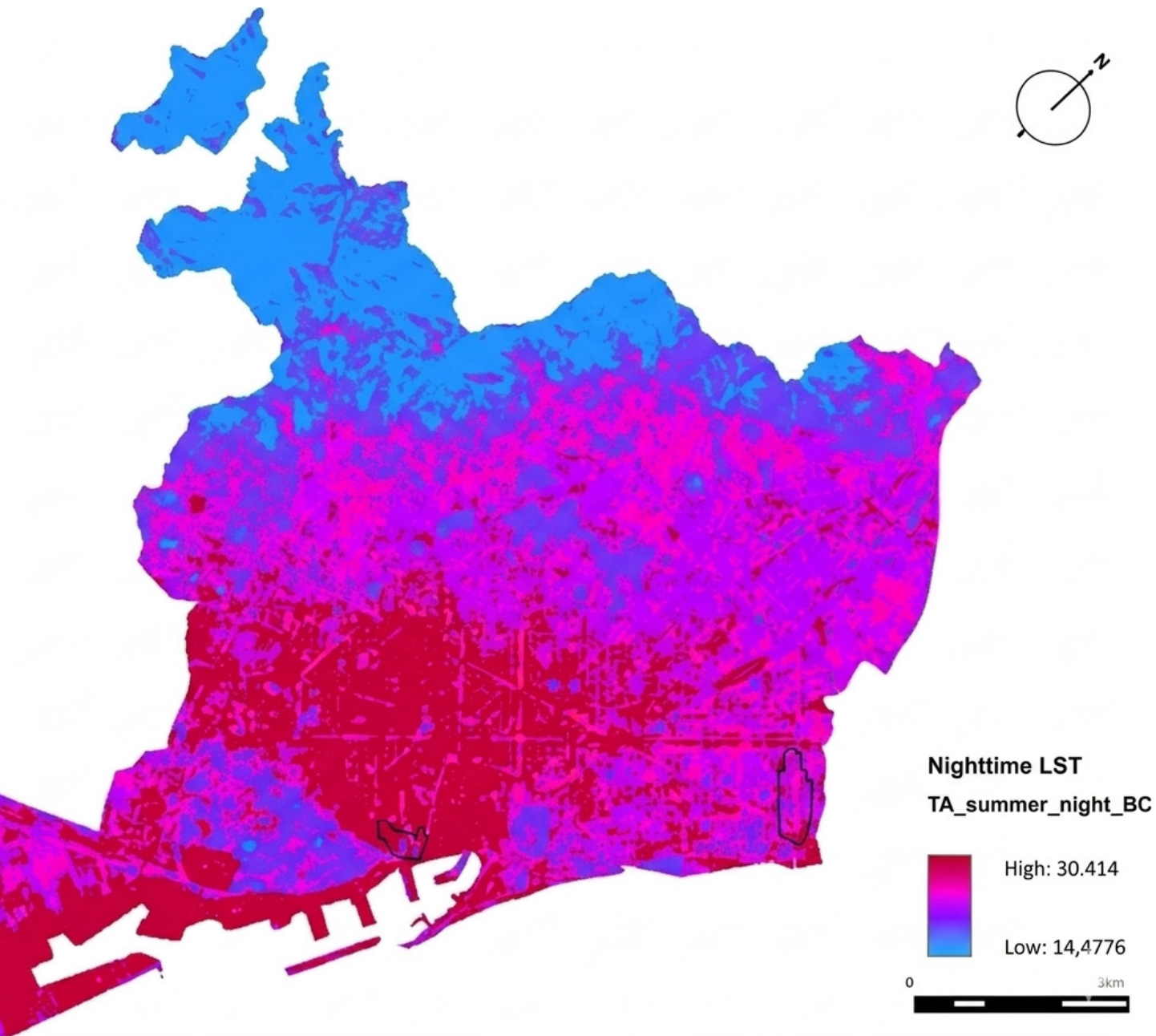
Figure 21. Green corridors (Barcelona City Council, 2013)

# The Urban Heat Island in Barcelona

Barcelona's dense, concrete-heavy grid creates a severe Urban Heat Island (UHI) effect, actively trapping daytime solar radiation and artificially holding the heat long into the night. Because the city's conventional hardscapes prioritize rapid water drainage over structural retention, the urban microclimate lacks the natural evaporative cooling required to break this relentless thermal cycle. This excessive heat accumulation places massive strain on both the human population and the energy grid, demanding immediate architectural interventions to dismantle the city's heat-trapping infrastructure.

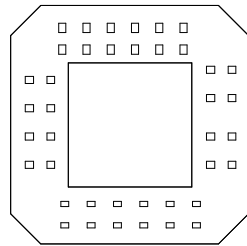
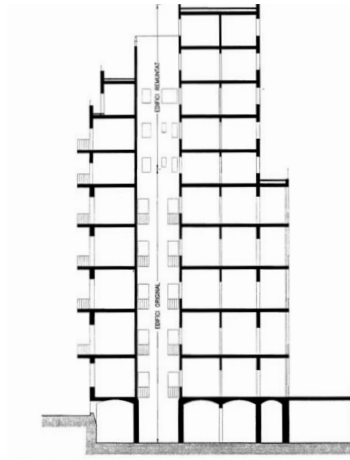








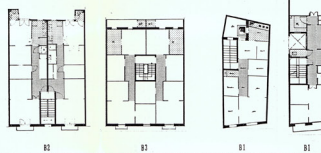
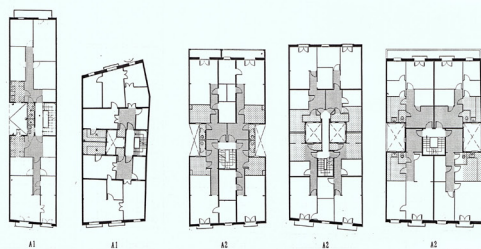
# The Eixample Typology



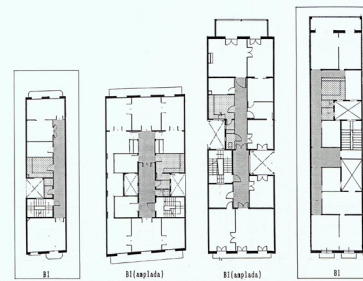
The structural and spatial evolution of the typical Eixample building reveals a highly standardized approach to distributing light and air within deep, narrow mid-block plots. Virtually all of these basic 19th-century residential models rely on a central core consisting of a communal stairwell and one or two internal lightwells (celoberts). These central vertical shafts effectively act as the functional engine of the building, dictating the internal layout; they are systematically surrounded by the “wet cells” — such as kitchens, bathrooms, and utility spaces. By clustering these service zones around the central voids, architects were able to free up the prime, well-lit spaces along the street and inner courtyard facades for the primary living and sleeping areas.

## II.15. MODEL DISTRIBUTIU-ORGANITZACIO ESPALAL, CONDICIONS HIGIENIQUES, EVOLUCIO.

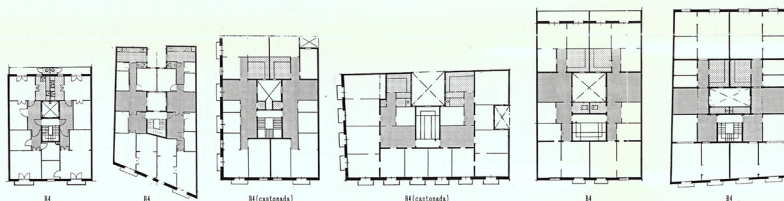
15.1. EL L'INTER CONTRAT, REPALS DE SERVEI A CLOUERTS O PAGANA INTERIORE FINS 1870-1880.  
Model d'habitatges d'època.



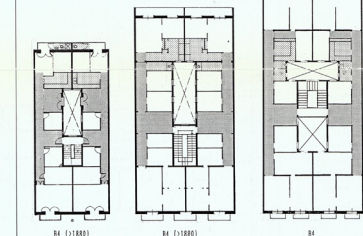
15.2. DESPLAÇAMENT A MITJERA DE L'EL L'INTER A PARTIR DE 1880.  
Model universal B1.



15.3. EL L'INTER CONTRAT, TENDÈNCIA A L'ESPECIALITZACIO DELS CLOUERTS.  
Model universal B4.



15.4. DESPLAÇAMENT A MITJERA DE L'EL L'INTER A PARTIR DE 1880.  
Model universal B4.



15.5. EL L'INTER CONTRAT, TENDÈNCIA A L'ESPECIALITZACIO DELS CLOUERTS.  
Model B5 i model de residència burgesa.

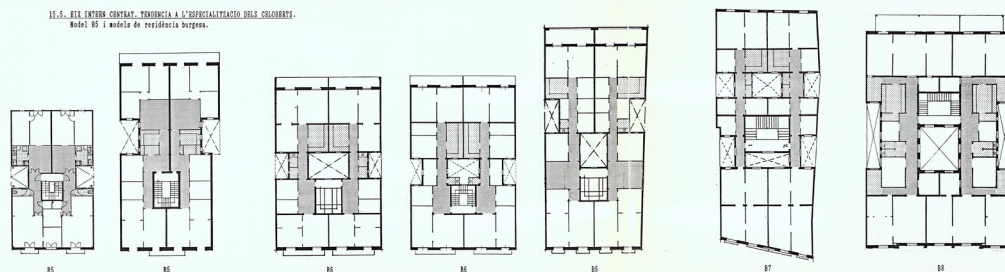
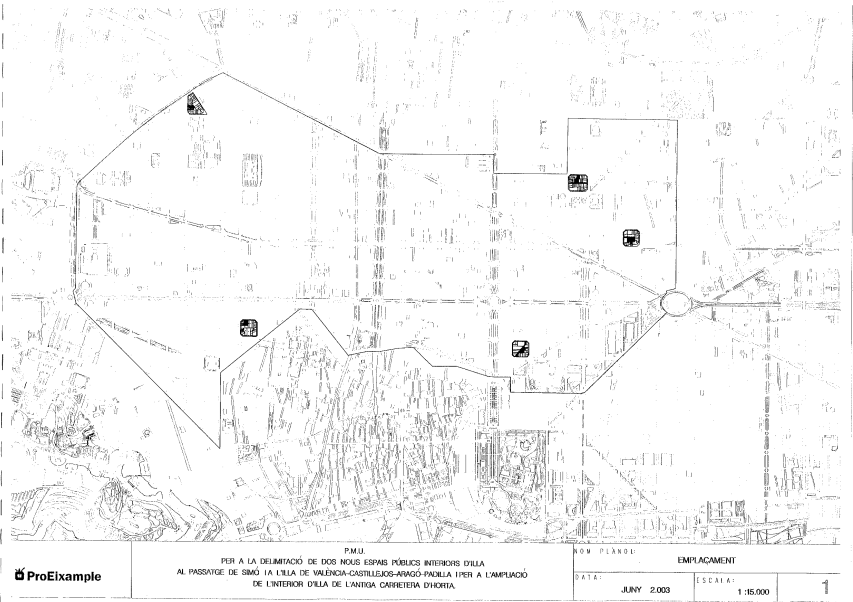


Figure 22. Typological Evolution of the Eixample Block: Spatial Organization and Hygienic Conditions. Giol i Draper, 1995.

# The Lighthouse Block

The Barcelona Green Infrastructure and Biodiversity Plan 2020 seeks to address the city’s profound environmental deficit by establishing a continuous network of ecological corridors. Shifting focus toward macro-scale connectivity, the strategy aims to link major natural assets by drawing green axes from the Collserola mountain range down to Montjuïc, the Ciutadella, and the Mediter-

anean seafront. However, a critical blind spot remains within this sweeping vision: the Eixample blocks are completely unrecognized as potential ecological nodes. By overlooking the latent capacity of these interior courtyards, the municipal framework misses a vital opportunity to weave biodiversity and thermal relief directly into the dense, historical urban fabric.



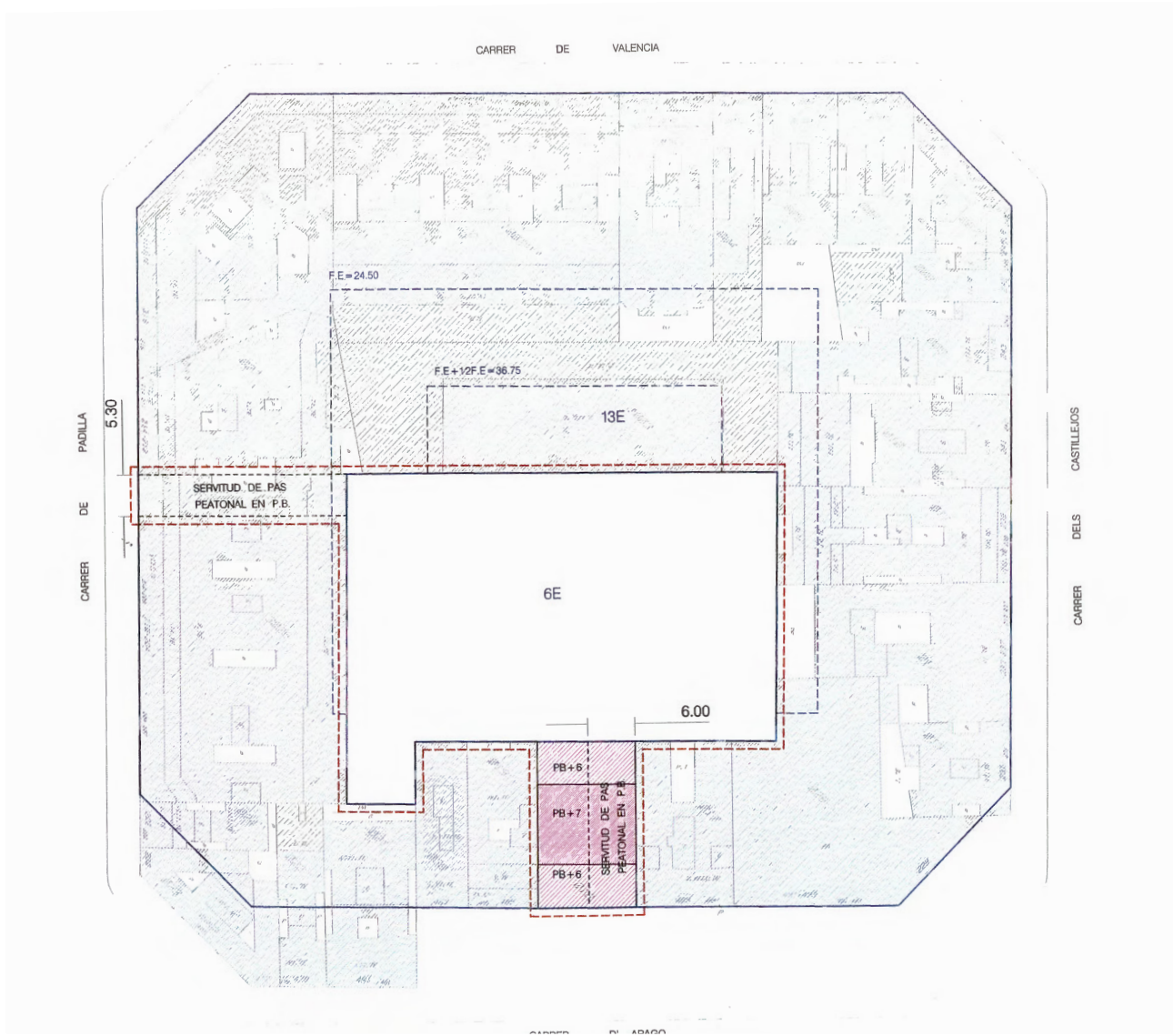
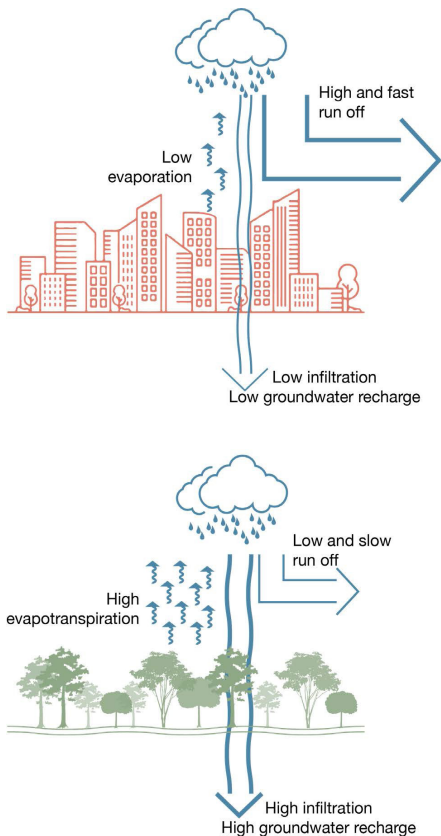


Figure 23. Plan of the Lighthouse Block. ProEixample, 2003

# WATER METABOLISM

## Conventional Stormwater Management and WSUD



The process of urbanization fundamentally breaks the natural water cycle. In traditional urban planning, previously pervious surfaces are transformed into impervious landscapes. Consequently, rainwater runoff increases dramatically compared to pre-urbanization levels, preventing the natural recharge of underground aquifers. Furthermore, without sustainable interventions, this conventional runoff reaches depuration stations significantly more polluted.

Figure 24. Conventional Stormwater Management. Fumero, 2020

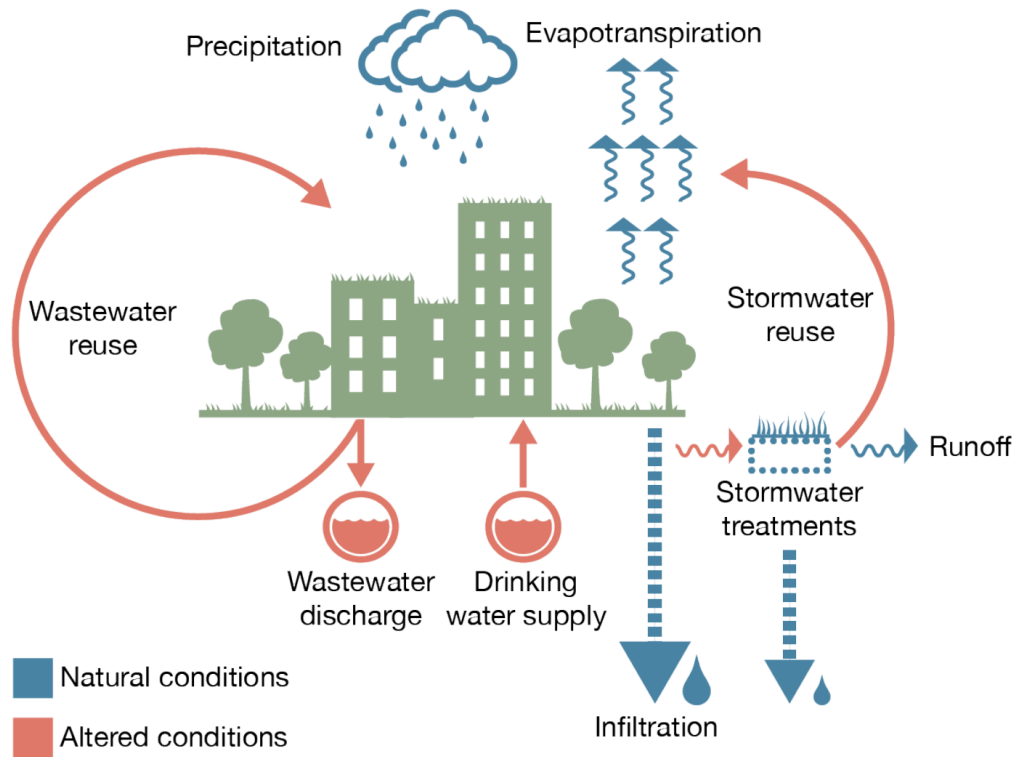


Figure 25. WSUD Strategies. Fumero, 2020

**Water Sensitive Urban Design (WSUD)** is an essential strategy that integrates complete water cycle management directly into urban planning and architectural design. The primary objective of WSUD is to create urban environments that allow the water cycle to function as it would naturally, thereby reducing the adverse impacts of development. By implementing

**WSUD**, cities actively attempt to recuperate a circular water cycle life during the planning, urbanizing, and construction phases.



# Scaling Up: The City of 1,000 Tanks

To illustrate the maximum potential of scaling these metabolic strategies, the City of 1,000 Tanks project in Chennai, India, serves as a radical urban precedent. Moving beyond the scale of a single block, this initiative deploys a massive, city-wide network of Nature-Based Solutions (NBS)—including constructed wetlands, bioswales, detention parks, and deep groundwater recharge wells. By abandoning conventional, heavy-en-

gineered concrete infrastructure in favor of highly adaptive ecological instruments, the project simultaneously mitigates severe pluvial flooding and extreme urban droughts. It proves that decentralized, circular water management is not just a localized architectural feature, but a highly cost-effective, low-carbon blueprint capable of regenerating an entire metropolitan landscape.

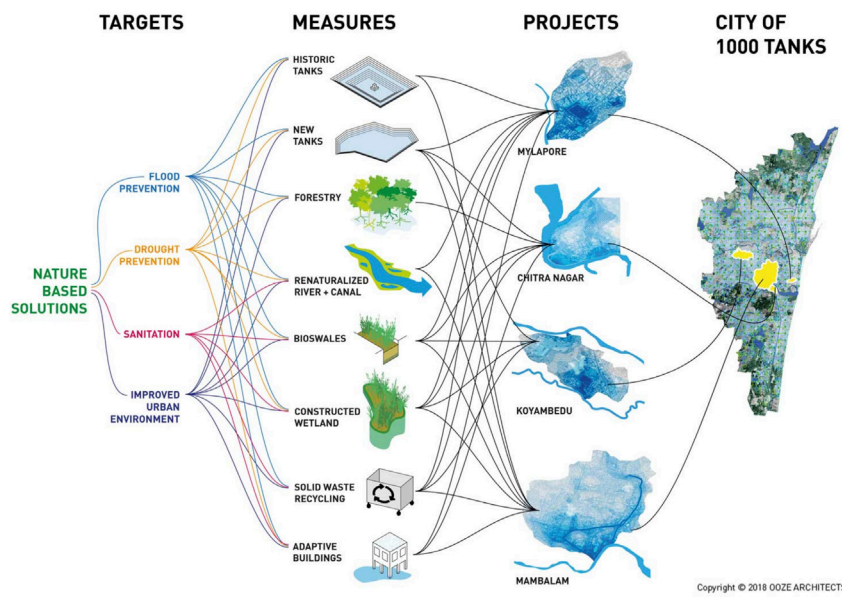
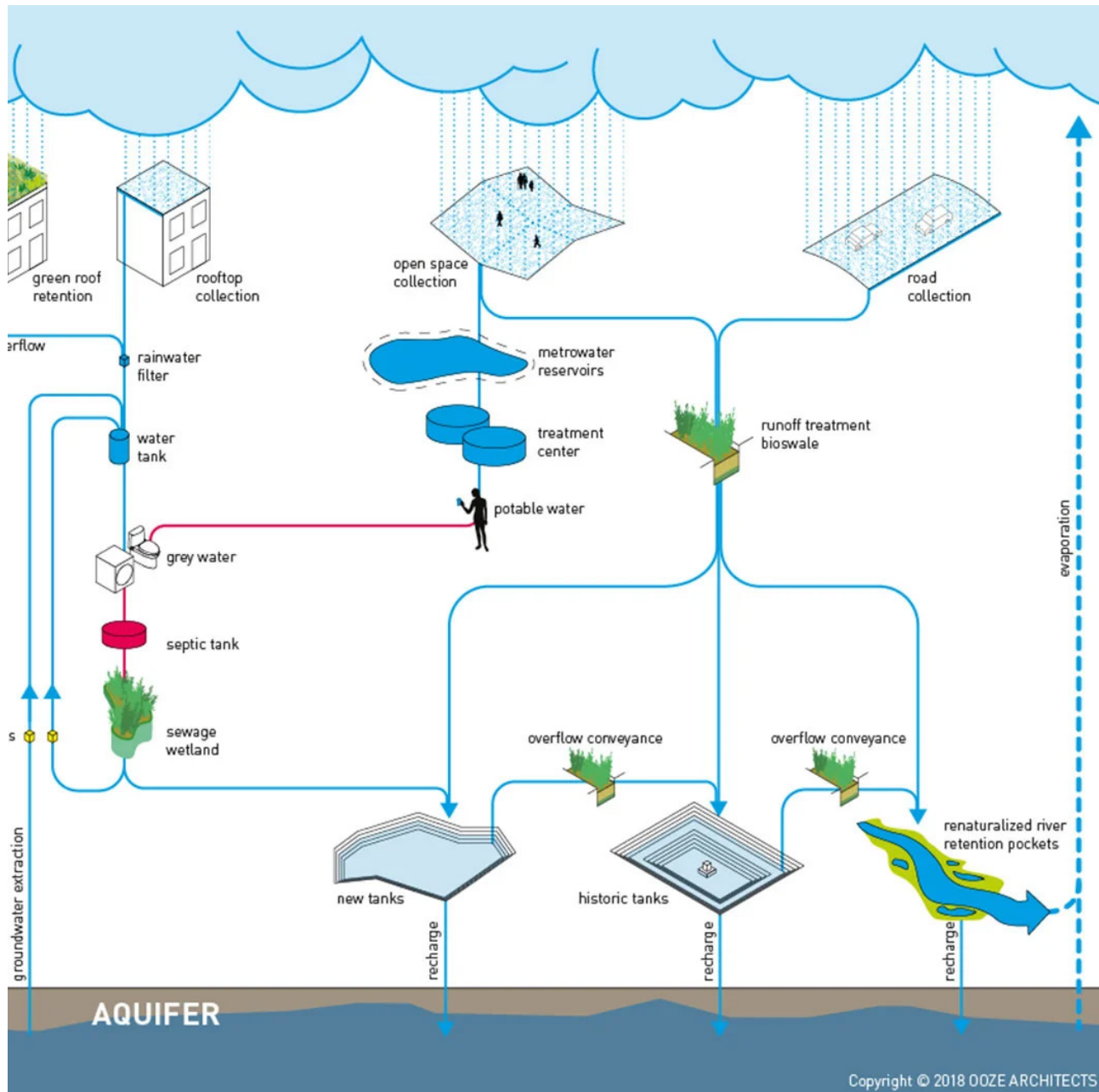


Figure 26. (left) Copyright OOZE Architects, City of 1,000 Tanks

Figure 27. (right) Copyright OOZE Architects, City of 1,000 Tanks

Copyright © 2018 OOZE ARCHITECT.





# Water use in Barcelona

To determine the metabolic load of the Lighthouse Block, a precise population baseline must first be established. Because block-by-block census data is not publicly available, a proportional projection was calculated by analyzing the demographic shift within the Sagrada Família neighborhood. Between 2009 and 2024, the neighborhood experienced a 5.6% population contraction, dropping the average inhabitants per

block from 1,036 to 978. Applying this real-world demographic trend to the block's historical baseline yields an estimated population of 1,175 residents. When paired with the Eixample's high per capita water use, this population calculation reveals the true scale of the block's daily linear water dependency.

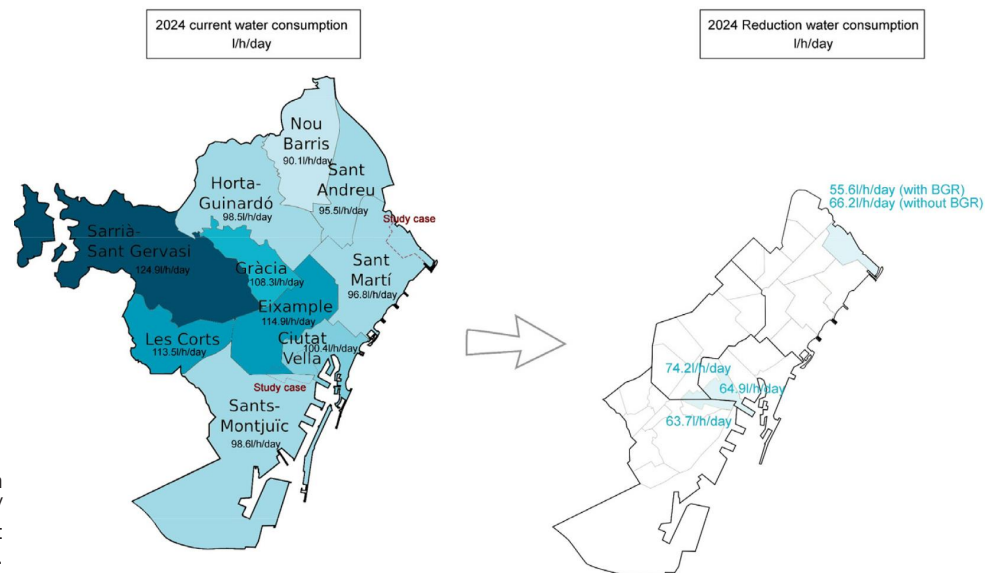


Figure 28. Water use in Barcelona per district (liters / inhabitant / day). Ajuntament de Barcelona, 2025.

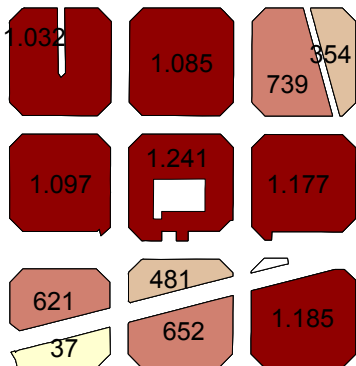


Figure 29. Inhabitants per block. Ajuntament de Barcelona, 2025.

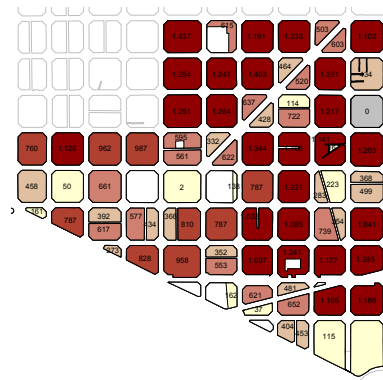


Figure 30. Sagrada Família Neighborhood. Ajuntament de Barcelona, 2025.

### Neighborhood Demographic Shift (Sagrada Família)

2009 Baseline: 51,820 people across 50 housing blocks = 1,036 inhabitants / block average

2024 Census (Padró Municipal): 48,914 people across 50 housing blocks = 978 inhabitants / block average

Demographic Trend:

$$978 - 1036 / 1036 = -5.6\% \text{ population decrease}$$

### The Lighthouse Block Population Projection

Historical Block Base: 1,241 inhabitants

Adjusted Calculation:

$$1,241 \times (1 - 0.056) = 1,175 \text{ inhabitants}$$

### Resulting Daily Water Volume Load

District Per Capita Consumption: 114.9 liters / inhabitant / day

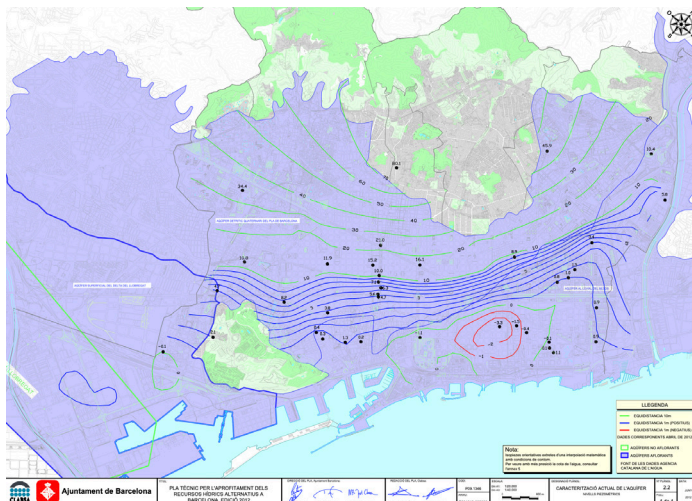
Total Block Metabolic Demand:

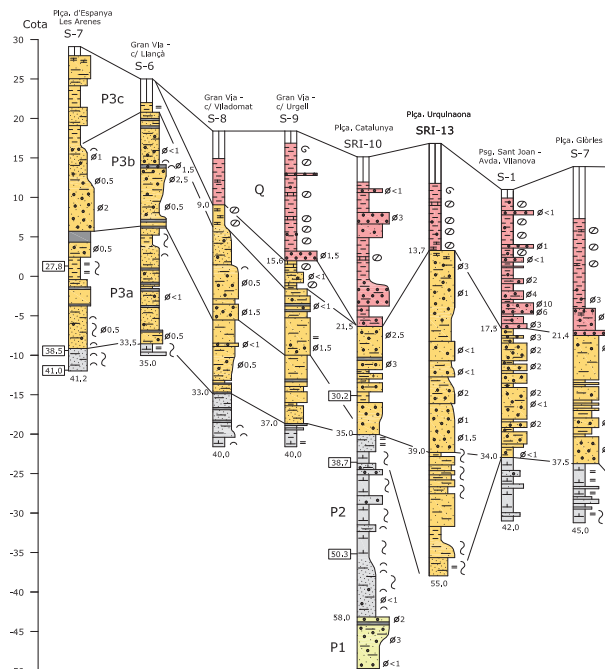
$$1,175 \text{ inhabitants} \times 114.9 \text{ liters} = 135,008 \text{ liters / day}$$

# Managed Aquifer Recharge (MAR)

Geological analysis of the intervention site reveals a highly stratified subterranean profile characterized by two distinct aquifer layers. Beneath the initial urban fill and a 12-meter-deep aquitard of silty clay, the first permeable layer consists of a mixed sand and gravel deposit. This upper aquifer is separated from a massive, 26.5-meter-thick deep sand aquifer by a strict 2-meter impermeable barrier of clay and silt. The entire dual-layered hydrological system ultimately rests upon a solid marl base.

This geological framework is essential for the implementation of Managed Aquifer Recharge (MAR). By capturing site-specific stormwater and high-quality runoff within the “Lighthouse Block,” the system actively replenishes the urban aquifer. This process mitigates local flood risks by diverting water from the municipal sewer and ensures the long-term volumetric viability of the groundwater reservoir, transforming the block from a passive consumer into an active participant in the city’s hydrological cycle.





The map shows the geological structure of the Montjuïc area. Key features include:
 

- Geological Units:** Labeled as 'C', 'D', 'A', 'B', and 'E'.
- Topography:** Indicated by brown contour lines.
- Urban Layout:** Shown with grey lines representing streets and building footprints.
- Geological Periods:**
  - Holocè:** Light yellow background.
  - Plistocè:** Yellow background.
  - Pliocè:** Orange background.
  - Miocè:** Dark orange background.
  - Paleozoic:** Purple background, located in the northern part of the map.
- Labels:** 'COLLSEROLA', 'TURONS', 'MONTJUÏC', 'TÀBER', 'DELTA DEL BESÒS', and 'MAR MEDITERRANEE'.
- Legend:** Located at the bottom, showing color-coded boxes for each geological period.
- Scale:** A scale bar at the bottom right indicates distances from 0 to 3 km.
- North Arrow:** A circular arrow indicating North is located at the bottom right.



71

# Aquifer Thermal Energy Storage (ATES)

Building upon the hydrological foundation of the site, the Lighthouse Block integrates Aquifer Thermal Energy Storage (ATES) to function as a seasonal thermal battery. Utilizing the groundwater stored within the deep aquifer, the system provides a low-carbon solution for the block's heating and cooling demands. Because geological soil material acts as a thermal insulator, the subterranean environment functions much like a thermos flask, effectively isolating and preserving energy with minimal loss.

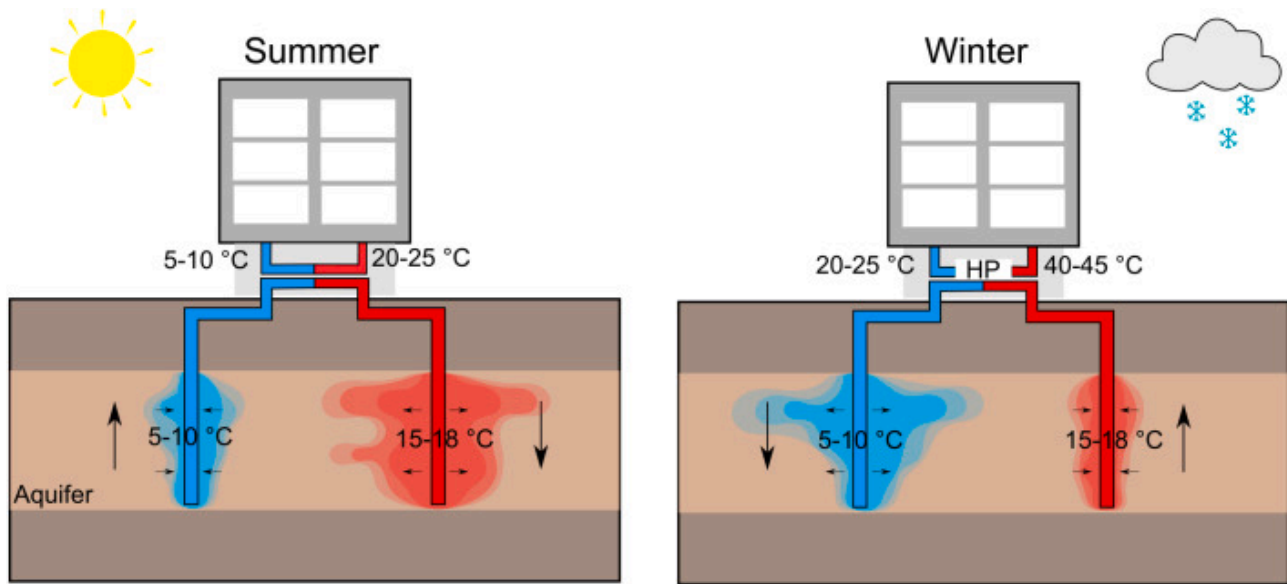


Figure 33. Operational principle of low-temperature Ates in summer (left) and winter (right). HP = heat pump. Jackson et al. (2024)

### Summer Cooling

Naturally cold groundwater is extracted to cool the buildings, absorbing heat from the interior and re-injecting warmed water into the aquifer.

### Winter Heating

The process reverses, with the stored warmth extracted from the aquifer to heat the building, returning cooled water to the subterranean reservoir.

# Circularity

The AMB Strategic Master Plan for the Integral Water Cycle outlines a critical climate trajectory for the Barcelona metropolitan area by 2050. As surface and underground water reserves face severe depletion, the city will simultaneously endure a sharp rise in average temperatures, drastically compounding the urban heat island effect. This dual threat of water scarcity and intensifying heat demands an immediate architectural response to secure the city's future habitability.

## 12% reduction

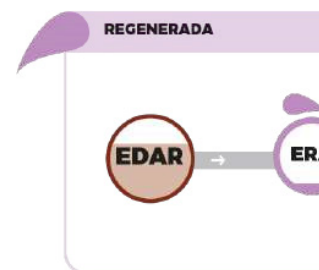
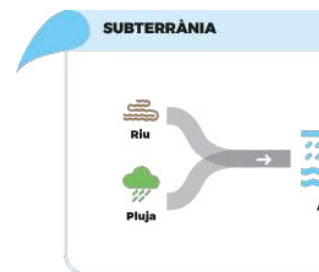
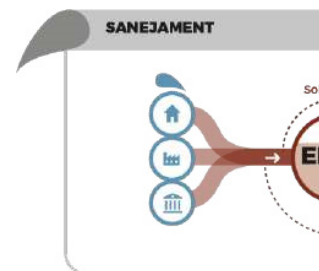
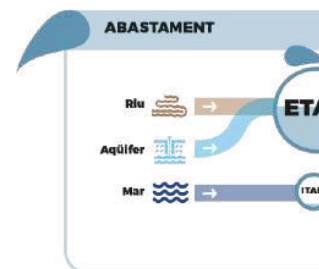
Expected decrease in surface water resources within the Ter and Llobregat basins by 2050

## 9% reduction

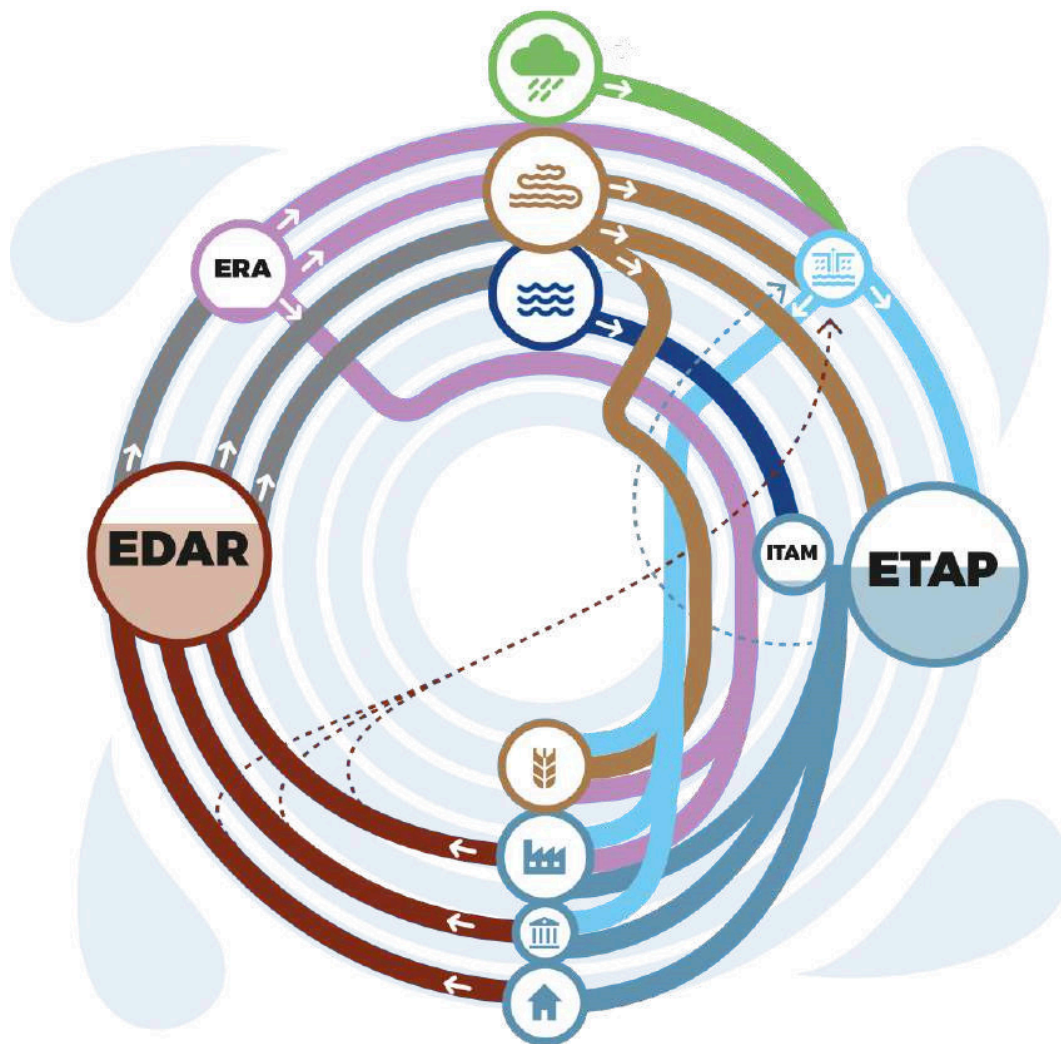
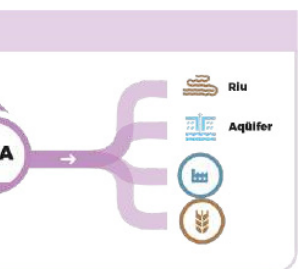
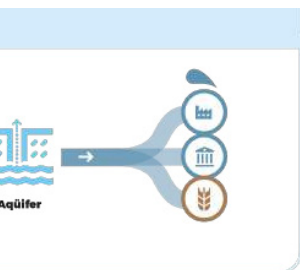
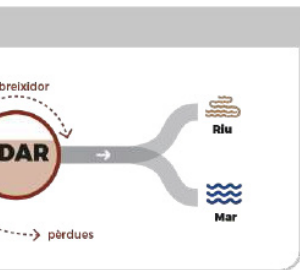
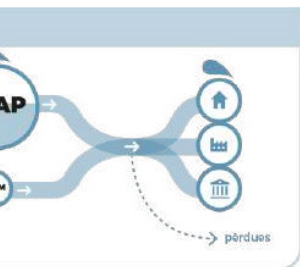
Anticipated depletion of critical underground water resources in the Llobregat, Besòs, and local aquifers.

## 1.5 to 4°C increase

Projected rise in average metropolitan temperatures, intensifying urban heat stress through significantly hotter days and nights.

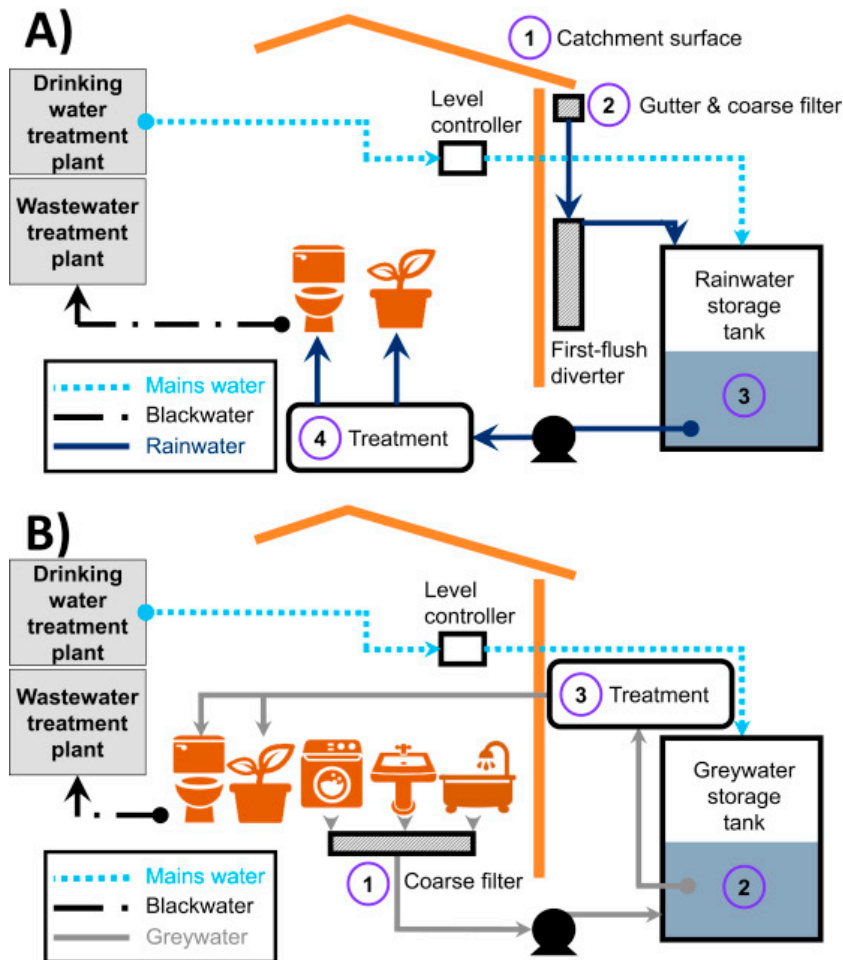








# Decentralized Treatment: Source Separation



To optimize the Lighthouse Block's circular water economy, treating all domestic effluent to a single, high standard is energy-intensive and inefficient. Instead, the architecture implements source separation. By dividing wastewater streams based on their biological and chemical qualities, the system ensures water is recycled with the lowest possible energy input and operational complexity.

Figure 34. (a) Rainwater harvesting system and (b) Greywater recycling system. Leong et al. (2016)

**Light Greywater (Low Load):**

Originating from showers, bathtubs, and bathroom washbasins, this fraction accounts for a high volume of water but contains minimal organic matter. Because it is only lightly contaminated, it is highly economically viable and easy to recycle with minimal intervention for immediate indoor reuse or irrigation (Leiva et al., 2021).

**Heavy Greywater (High Load):**

Also known as “dark” greywater, this stream comes from kitchen sinks, dishwashers, and laundry machines. It carries a heavy biological and chemical load, including food particles, fats, oils, and concentrated detergents. Due to this complexity, it cannot be reused immediately and demands a much more robust, multi-stage treatment process (Leiva et al., 2021).

**Blackwater (Extreme Load):**

Originating exclusively from toilets, this stream contains high levels of pathogens and must be strictly isolated. It requires dedicated septic routing or can be bypassed entirely through advanced composting toilet cycles, effectively removing this extreme biological load from the liquid stream altogether.

# Visible Metabolism: Architecture as Eco-Machine

Rather than burying technical infrastructure in the basement, the Lighthouse Block elevates water filtration into a visible, performative architectural element. This design strategy draws direct inspiration from projects like Diller Scofidio + Renfro's award-winning Canal Café at the Venice Architecture Biennale, which successfully transformed a hybrid natural-artificial purification system into a celebrated public centerpiece. By openly displaying the journey of its distinct water fractions, the build-

ing becomes a living, educational "eco-machine." As rainwater, light, and dark greywater are independently routed through a cascading series of visible screens, bio-filtration terraces, sand filters, and membrane bio-reactors, the architecture demystifies the urban water cycle. This approach successfully reclaims water for non-potable reuse while transforming essential ecological infrastructure into an aesthetic and social amenity for residents.



Figure 35. Canal Café in Venice.  
BauNetz Wissen, 2026

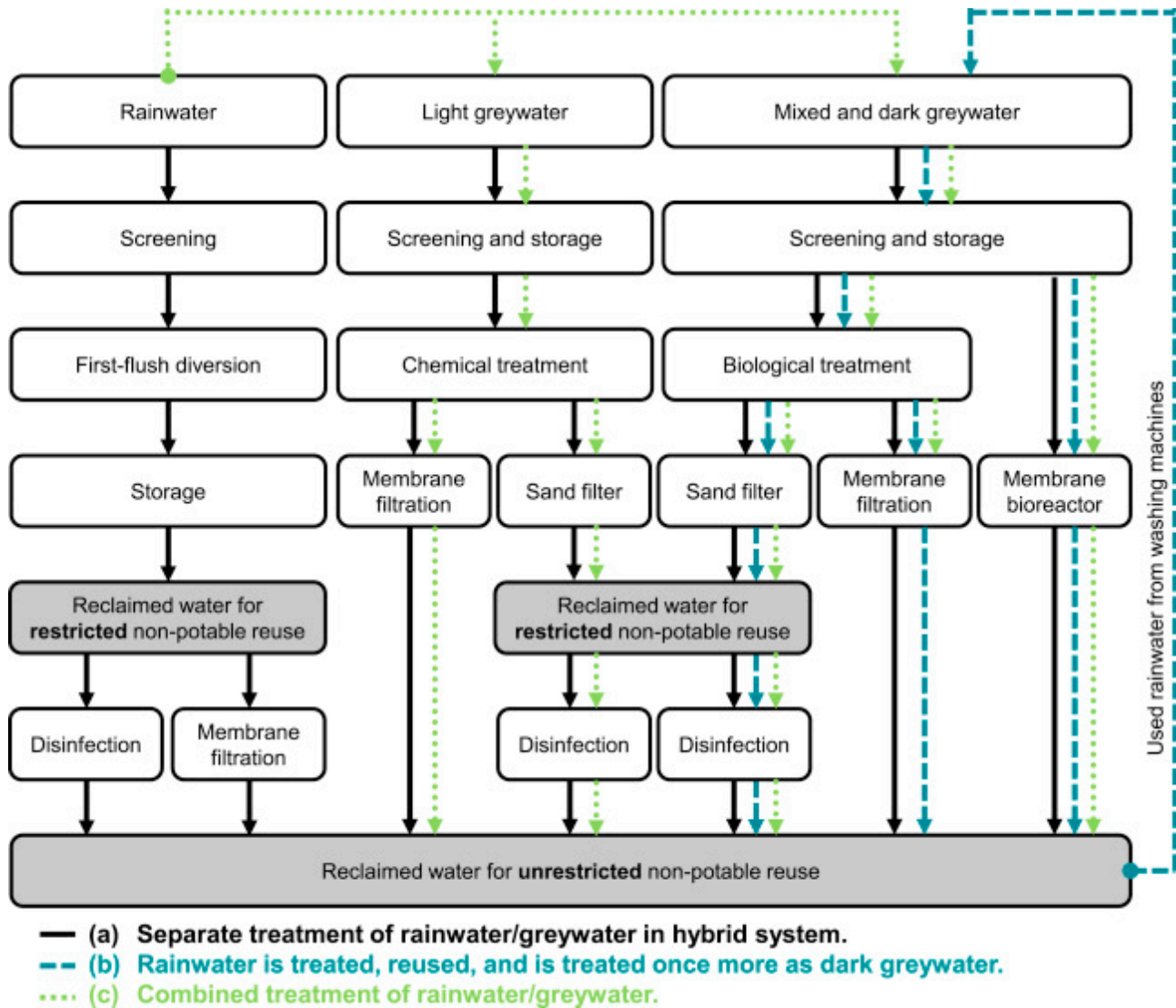


Figure 36. Filtration Methods for Rain and Greywater. Leong et al. (2016)

# THERMODYNAMICS & THERMAL COMFORT

## Architecture as Augmented Thermoregulation

To survive, human beings must maintain a constant core body temperature of  $37^{\circ}\text{C}$ . The ideal thermal comfort zone for external air temperature falls between  $21^{\circ}\text{C}$  and  $29.4^{\circ}\text{C}$ . When external temperatures drop below  $21^{\circ}\text{C}$ , the body initiates thermogenesis to create heat; when temperatures rise above  $29.4^{\circ}\text{C}$ , it triggers ther-

molysis to cool down. Because these physiological processes take energy and put significant strain on the human body, the fundamental role of architecture is to act as an augmented form of thermoregulation—shielding the body from climatic extremes to prevent the necessity of these internal biological processes.

**Radiation:** The transfer of heat via electromagnetic waves. In urban environments, unshaded hardscapes absorb solar energy and re-radiate it, drastically increasing the ambient heat load on pedestrians.

**Evaporation:** The cooling process of liquid turning to vapor, such as human perspiration. If urban air is excessively humid, this process stalls; sweat cannot evaporate, neutralizing the body's primary cooling engine.

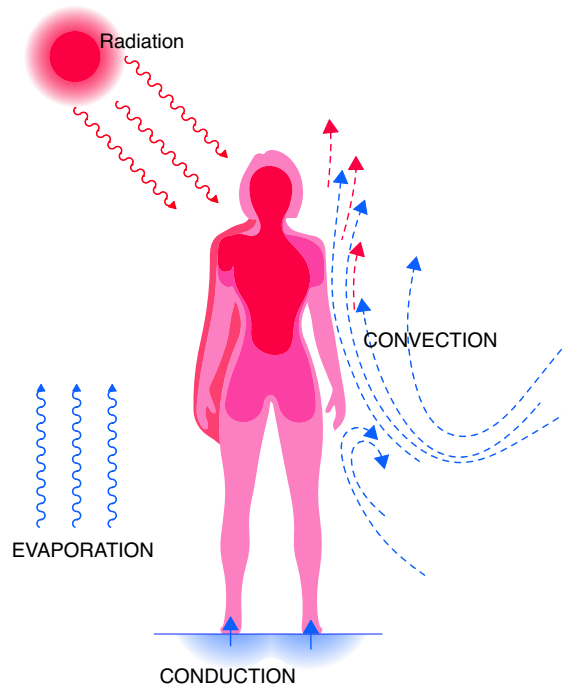


Figure 37. Thermoregulation. Redrawn by author based on (Rahm, 2023)

**Convection:** The exchange of heat through air movement. Strategic urban geometry can channel wind to enhance convective cooling, actively stripping away the boundary layer of hot air surrounding the body.

**Conduction:** The direct transfer of heat through physical contact. Heat-retentive urban materials, like dark asphalt, continually transfer their stored thermal energy directly to the air and to the pedestrians traversing them.

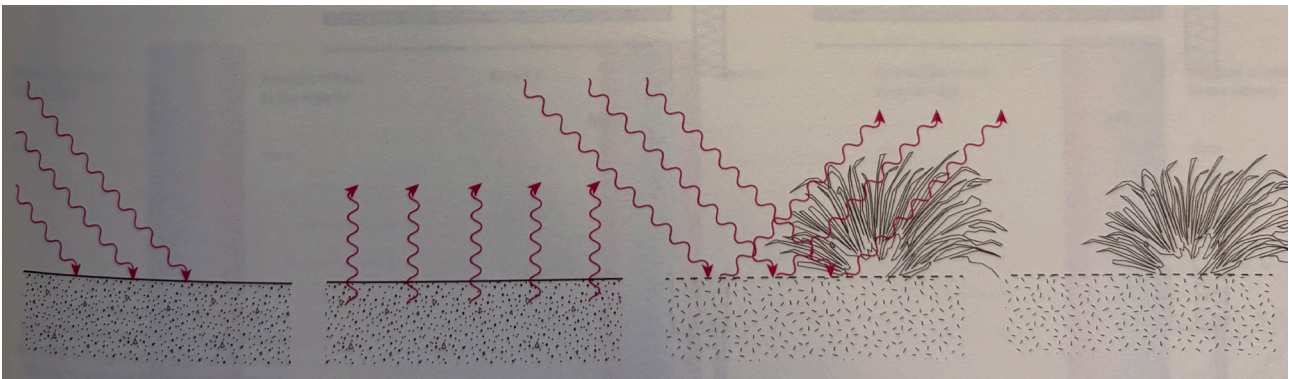
# Material Physics

The Urban Heat Island (UHI) effect is fundamentally a material problem. The microclimate of a city block is dictated by how its surfaces interact with solar radiation. To dismantle the UHI, we must move away from conventional, heat-trapping hardscapes and design with materials optimized for their specific thermodynamic properties:

**Albedo** (the ability to reflect solar energy): High is ideal. Highly reflective surfaces bounce solar radiation back into the atmosphere before it can be absorbed and converted into ambient heat.

**Thermal Effusivity** (the rate at which a material absorbs and releases heat): Low is optimal. Materials with low effusivity (like timber) act as natural insulators. They prevent surfaces from rapidly drawing in daytime heat and radiating it back into the surrounding air.

**Volumetric Heat Capacity** (the total amount of heat energy a material can store): Low is crucial for solid structures. It prevents hardscapes from acting as “thermal batteries” that hoard daytime heat only to slowly release it, which keeps the urban microclimate artificially hot throughout the night.





**Concrete**

- Albedo: 0.15 – 0.35
- TE: 1,500 – 2,000
- VHC: 2.0 – 2.2

Concrete is the primary engine of the Urban Heat Island. It rapidly absorbs solar radiation and stores massive amounts of thermal energy, slowly releasing it at night to keep the microclimate artificially hot.

**Rammed Earth**

- Albedo: 0.20 – 0.40
- TE: 1,000 – 1,500
- VHC: 1.5 – 1.8

While providing high thermal mass similar to concrete, rammed earth is highly porous and hygroscopic. It naturally buffers extreme temperature swings by absorbing daytime heat and passively cooling the surrounding air as its internal moisture evaporates.

**Timber**

- Albedo: 0.10 – 0.20
- TE: 300 – 500
- VHC: 0.5 – 0.9

Characterized by extremely low thermal effusivity and low heat capacity, timber acts as a natural insulator. It cannot absorb or transfer heat quickly, ensuring structural surfaces remain thermally neutral without radiating secondary heat into the environment.

**Greenery**

- Albedo: 0.15 – 0.25
- TE: Variable
- VHC: Dependent

Rather than storing thermal energy as a solid mass, vegetation utilizes solar radiation to fuel photosynthesis and evapotranspiration. Plants actively convert sensible heat (which warms the air) into latent heat (which vaporizes water), serving as biological air conditioners.

**Water**

- Albedo: 0.05 – 0.10
- TE: ~1,580
- VHC: 4.18

Possessing the absolute highest volumetric heat capacity of any common material, water absorbs enormous amounts of solar energy with minimal temperature fluctuation. Integrated into urban design, it acts as a powerful thermal buffer and the primary driver of evaporative cooling.



# The Thermodynamics of Water Retention

Rainwater is a vital thermodynamic agent for urban cooling. To harness it, surfaces must actively retain water rather than instantly draining it away. **The Cooling Engine:** Because water has an exceptionally high specific heat capacity, surfaces that retain it (like vegetated basins) strongly resist heating up.

**Proven Impact:** Field data from Barcelona proves that water-retaining surfaces stay consistently cooler than the ambient summer air, with infiltration basins measuring up to

5.3°C cooler.

**UHI Reduction:** By absorbing less daytime heat, these damp surfaces release less thermal energy at night, directly mitigating the Urban Heat Island effect.

**The Drainage Flaw:** Systems that rapidly drain water into the subsoil, such as gravel or porous concrete, completely lose this thermal benefit and reach significantly higher surface temperatures.

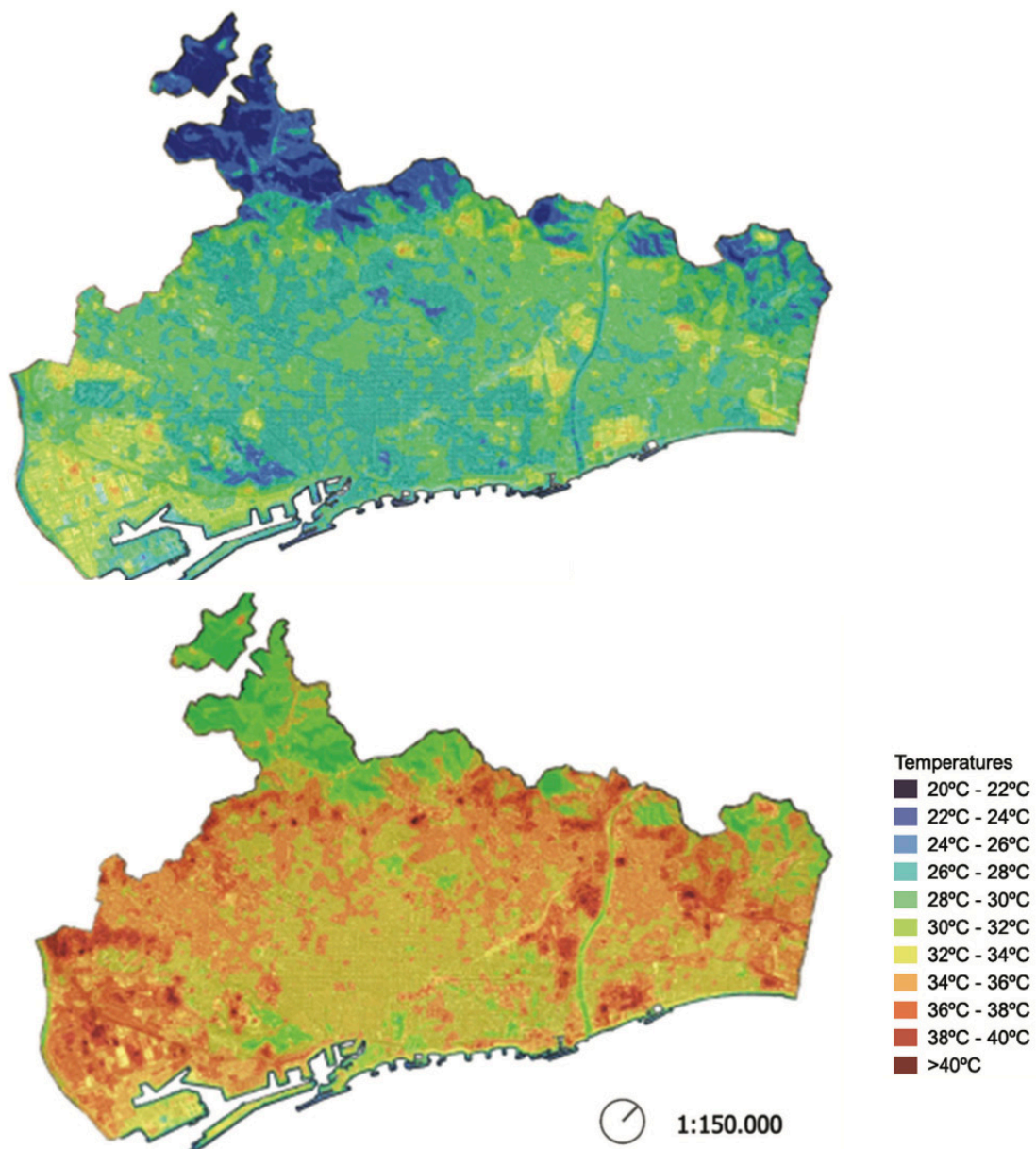
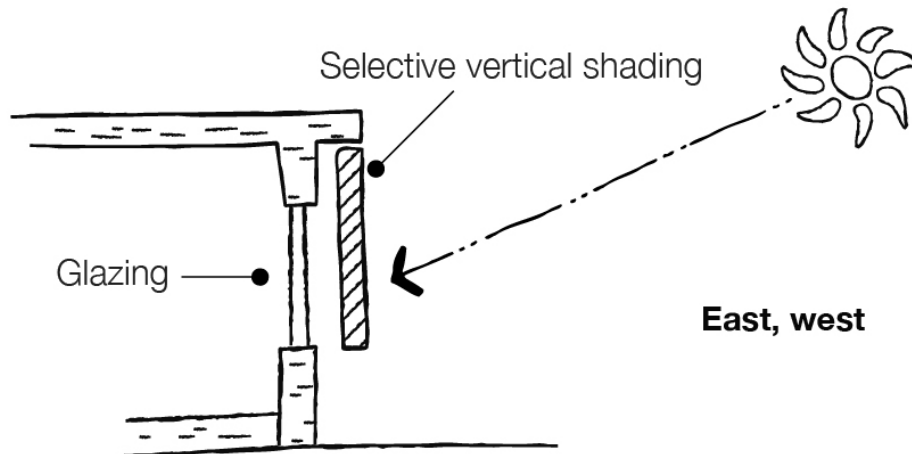
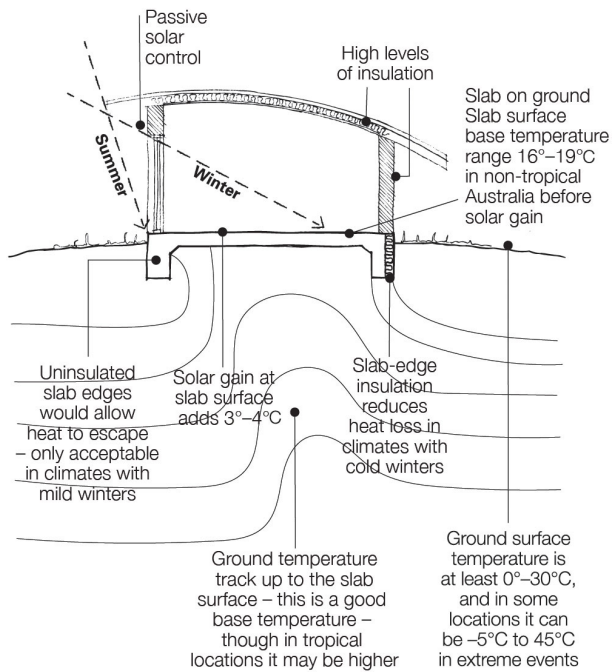


Figure 38.(Pérez Cambra et al., 2024)

# ARCHITECTURAL TYPOLOGY & TECTONICS

## Passive Design Strategies

Before mechanical HVAC, architecture relied on its physical form for thermal regulation—a principle essential for cooling Barcelona's dense urban blocks. By adapting historical typologies like the ancient Roman atrium or Arabic sahn, the design centers around a thermodynamic courtyard where integrated water sources act as micro-climatic engines. These spaces drive evaporative cooling to create a reservoir of dense, cool air, which is then pulled through the building via strategically aligned openings to maximize natural cross-ventilation and passively strip away trapped interior heat. Simultaneously, the building's skin utilizes deep tectonic overhangs to block intense, high-angle summer solar radiation, while allowing low-angle winter sunlight to penetrate and naturally warm the interior thermal mass.



# Open Building Principles

## Design for Adaptability

A climate-resilient building must also survive programmatic and technological changes. The Lighthouse Block achieves long-term survival through the principles of Open Building (OB). Decoupled Architecture: Open Building separates the permanent “Support” (core structure) from the transient “Infill” (interior layouts and technical services).

**Shearing Layers:** Following Stewart Brand’s concept, separating fast-moving layers (like water filtration systems

or space plans) from slow-moving layers (the concrete structure) ensures the building can be upgraded over time without destructive demolition.

**Tectonic Precedent (Patch22):** The project in Amsterdam exemplifies this. Its structure allows all technical services to be routed independently of the load-bearing frame. Applying this logic to the Lighthouse Block ensures its complex, circular water-metabolism systems can be easily accessed, maintained, and upgraded as technology evolves.

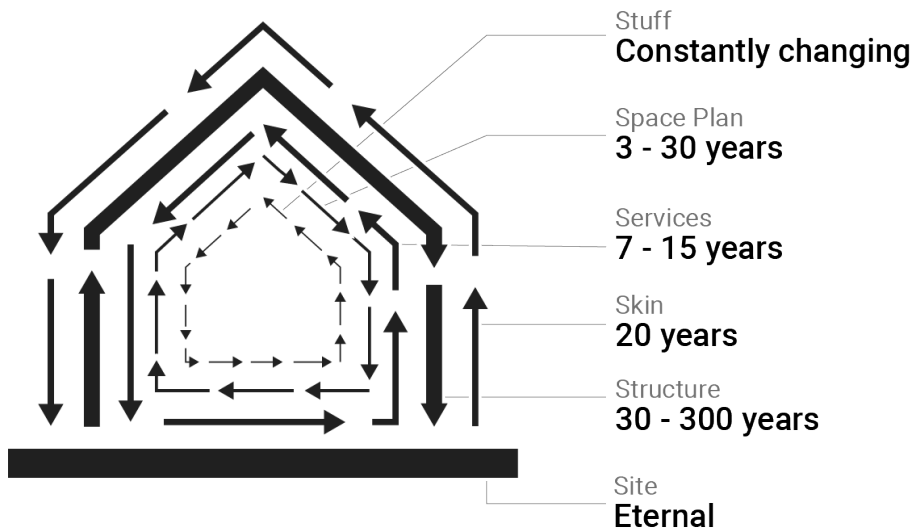
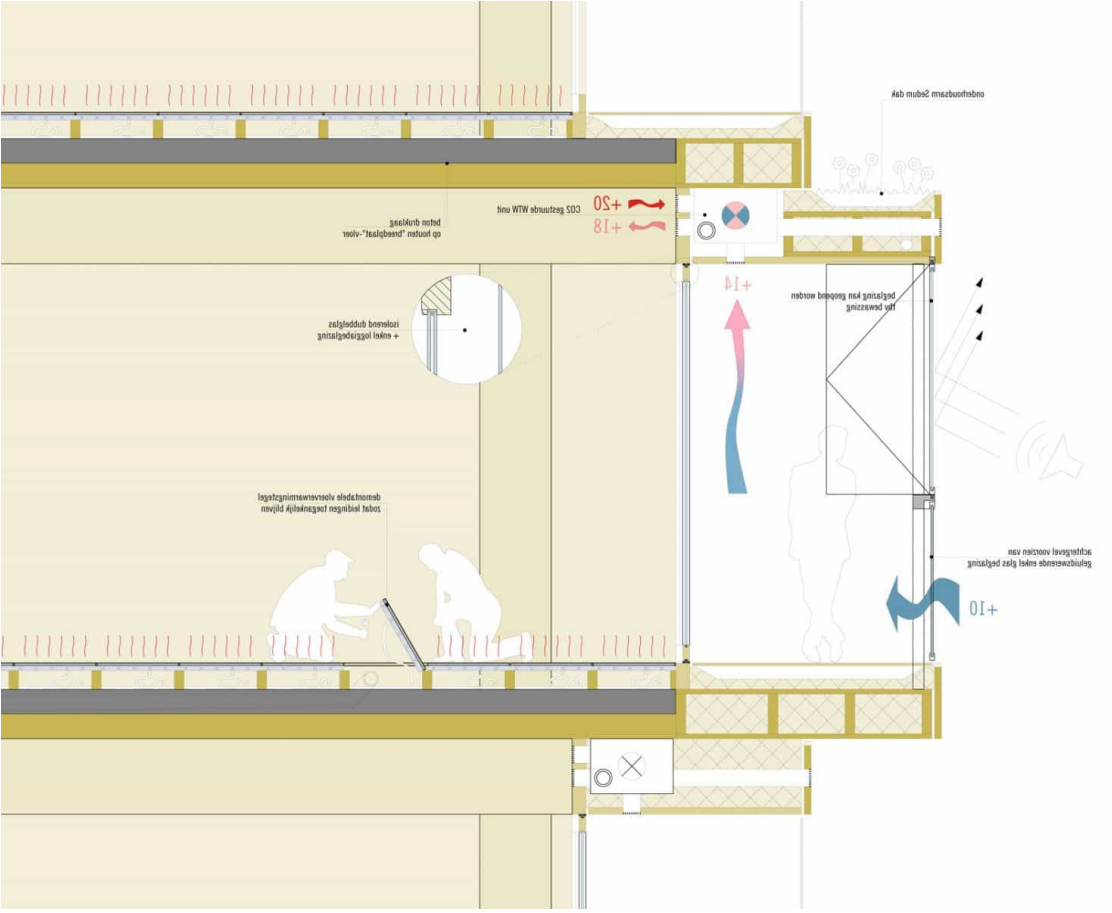
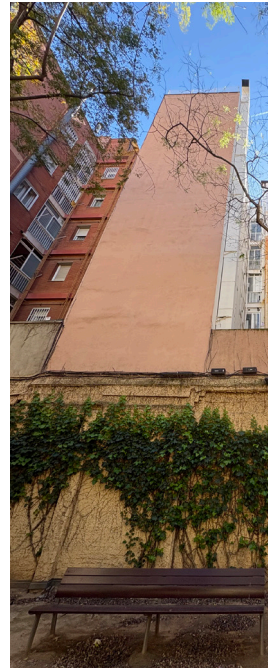


Figure 39. Shearing Layers of Change, Stewart Brand (1





# EXCURSION TO BARCELONA



# Courtyard





### 3 Types of Block Facade









Underused space infront of the Block





Two Blocks West

# Water Sensitive Pavement Design

Parcs i Jardins

## JARDÍ DE PLUJA NATURALITZAT

### APROFITAMENT DEL CICLE NATURAL DE L'AIGUA

El disseny dels elements inclosos en aquest espai està pensat per augmentar la permeabilitat del sòl i recollir les aigües pluvials temporalment, per atenuar-ne el cabal i facilitar l'absorció d'aigües d'escurriments.

En aquest sentit, la combinació de diferents solucions de sistemes urbans de drenatge sostenible (SUDS) d'aquest jardí, que inclou franges de bioretenció, parterres inundables i dipòsits d'infiltració, aprofita millor l'aigua de la pluja i en disminueix el volum que es perd per la xarxa de sanejament convencional o de tractament d'aigües residuals.

### LA VEGETACIÓ I LA BIODIVERSITAT

Hi trobem espècies arbustives, herbàcies i vivaces amb fulles complexes, rugoses, peludes, enganxoses i petites que ofereixen la possibilitat de refugi, alimentació i nidificació a la fauna de la ciutat.

Principalment són:

- Plantes pròpies del sotabosc mediterrani, amb floracions d'interès pel seu contingut nectarífer elevat que afavoreixen la presència d'insectes pol·linitzadors.
- Plantes de fructificació tardana, que afavoreixen la disponibilitat d'aliment per als ocells durant la tardor i l'hivern.
- Plantes que proporcionen aliment a les erugues de les papallones.

Millora de la biodiversitat proporcionant un hàbitat per a petits invertebrats.



En aquest jardí s'aposta per la naturalització, amb unes plantes que esdevenen un hàbitat acollidor per a la flora i la fauna, amb l'objectiu d'augmentar la vegetació a la ciutat i millorar la qualitat





Parcs i Jardins

Jordi Pujol i  
FAMÍLIA COLLA  
Nodes de biodiversitat

Els nodes de biodiversitat són petits refugis de natura que augmenten la riquesa d'espècies del parc i afavoreixen la connectivitat ecològica.

QUINES ESPÈCIES HI PODEM TROBAR?

| arbres                                                                                                                      | ocells                                                                                                                                   | arbustos                                                                                                                           | insectes                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| <br>Alzina<br>( <i>Quercus ilex</i> )      | <br>Pit-roig<br>( <i>Erithacus rubecula</i> )           | <br>Arbust de la mel<br>( <i>Apis mellifera</i> ) | <br>Abella de la mel<br>( <i>Apis mellifera</i> )     |
| <br>Roure<br>( <i>Quercus cerrioides</i> ) | <br>Tallard capnegre<br>( <i>Sylvia melanocephala</i> ) | <br>Verdum<br>( <i>Chloris chloris</i> )          | <br>Papallona atalanta<br>( <i>Vanessa atalanta</i> ) |

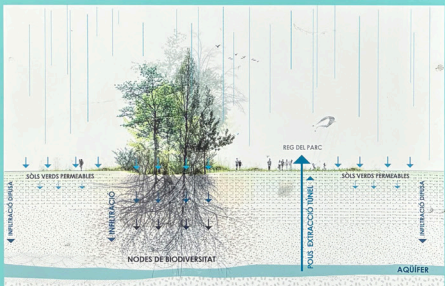
Els nodes reproduïxen els hàbitats d'un bosc mediterrani a petita escala. Són espais especialment pensats per dotar d'una gran biodiversitat el parc de les Glòries.

Hi trobem arbres com l'alzina (*Quercus ilex*), el roure (*Quercus cerrioides*) i l'auró negre (*Acer monspessulanum*); i arbustos com l'arboç (*Arbutus unedo*), el llentiscle (*Pistacea lentiscus*), el marfull (*Viburnum tinus*) o els rosers silvestres (*Rosa canina* i *Rosa moschata*).

Aquests ambients poden atreure ocells com el tallard capnegre (*Sylvia melanocephala*), el verdum (*Chloris chloris*) o el pit-roig (*Erithacus rubecula*), i insectes com la papallona atalanta (*Vanessa atalanta*), la safranera de l'alfals (*Colias crocea*) i l'abella de la mel (*Apis mellifera*).

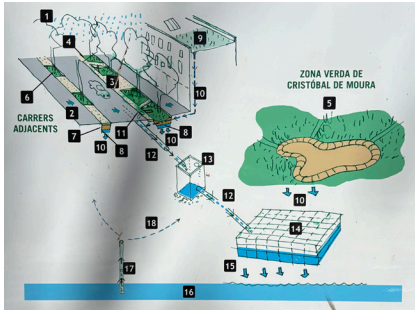
COM FUNCIONA EL CICLE DE L'AIGUA?

Els nodes de biodiversitat són fonamentals en l'estratègia de la gestió de l'aigua al parc. D'una banda, s'ha dut a terme una selecció d'espècies d'arbres i arbustos adaptades a les condicions climàtiques de Barcelona. De l'altra, aquests indrets del parc, amb un terreny lleugerament enfonsat i amb un substrat específic, actuen com a grans embornals que capturen l'aigua de pluja i la reinfiltren lentament al subsol.

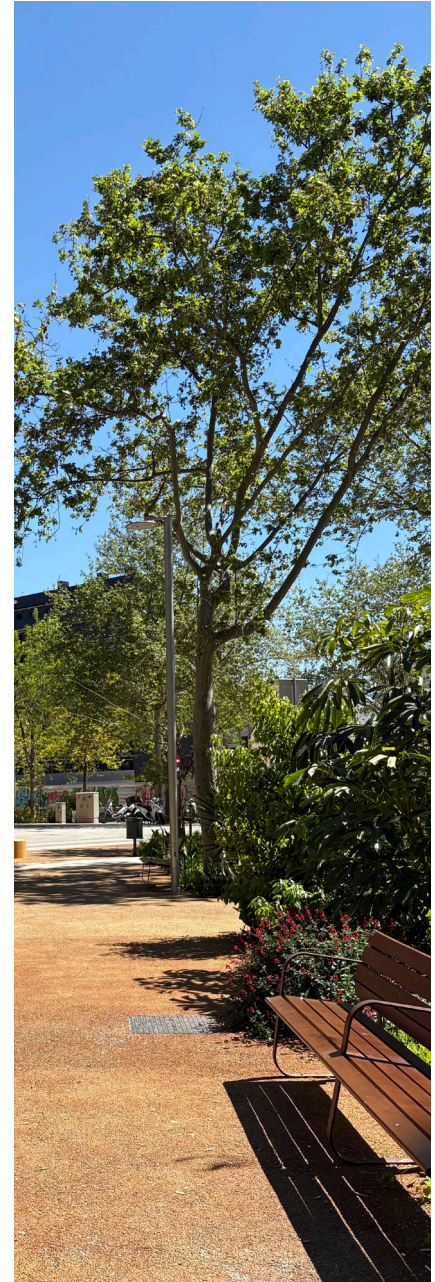





# Carrer de Cristóbal de Moura



01. Lluvia
02. Agua de escorrentia
03. Pavimento permeable
04. Franja de biorretención inundable
05. Zona verde inundable
06. alcorque con vegetación
07. Suelo vegetal estructural
08. Sustrato permeable
09. Cubierta vegetal
10. Bajante de pluviales
11. Aliviadero
12. Colector separativo pluviales
13. Pozo arenoso registrable
14. Depósito de retención subterráneo
15. Infiltración, recarga del acuífero
16. Acuífero, nivel freático
17. Extracción de agua freática
18. Red de riego con agua freática









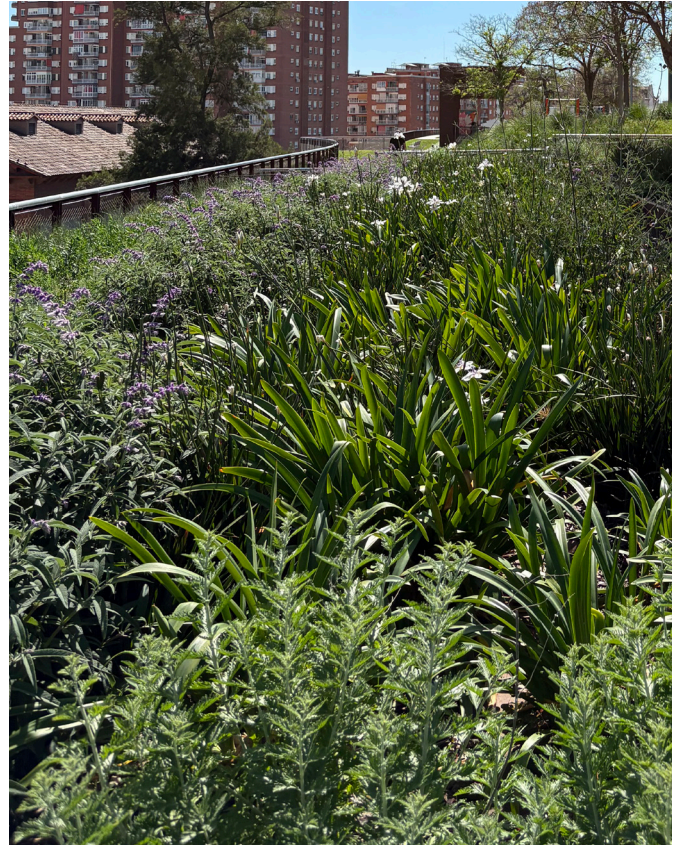
# The Plants







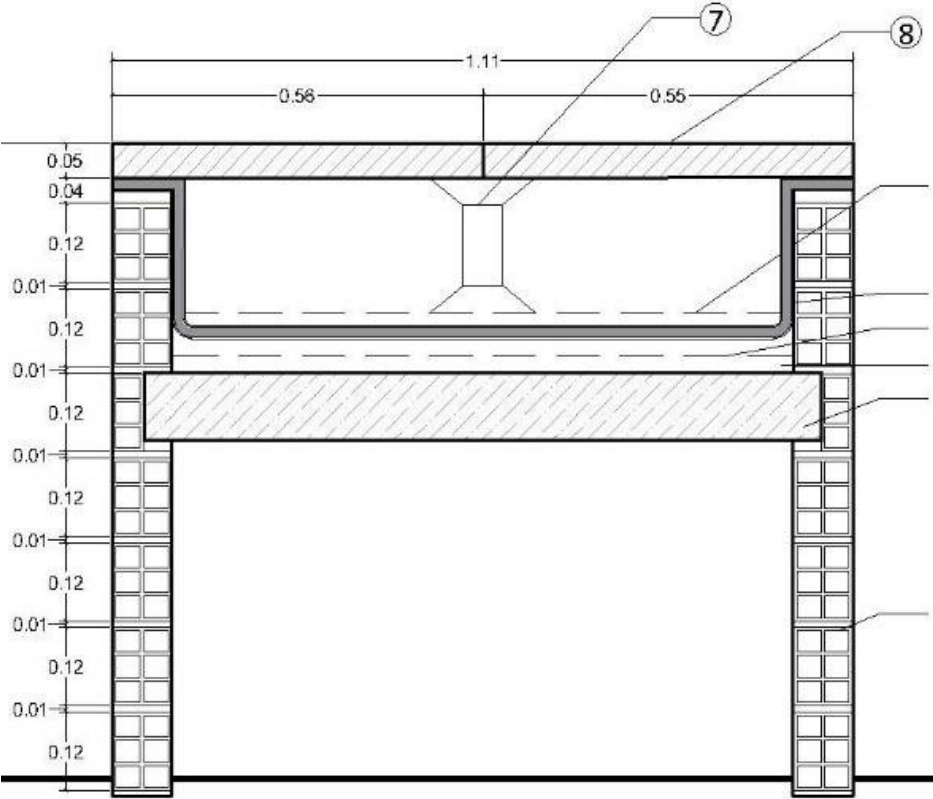
# Hihgline Park Barcelona







# Blue Roof at Fàbrica del sol



**Detail of the blue roof**

(Figure 9. Blue Roof Prototype Figure10. La Fábrica Del Sol Blue Roof, n.d.)



**Water underneath the e**





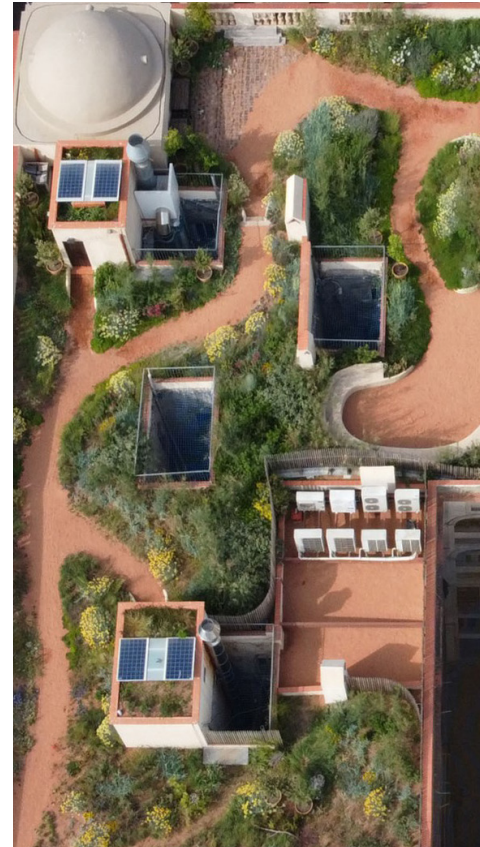
exposed aggregate slab



Blue & Green Roof



# Xifré's Rooftop: Floating Wild Garden



(Xifré's Rooftop: Floating Wild Garden)





ing Wild Garden, n.d.)



## Green wall at Fàbrica del sol



Detail of the blue roof



Water underneath the e



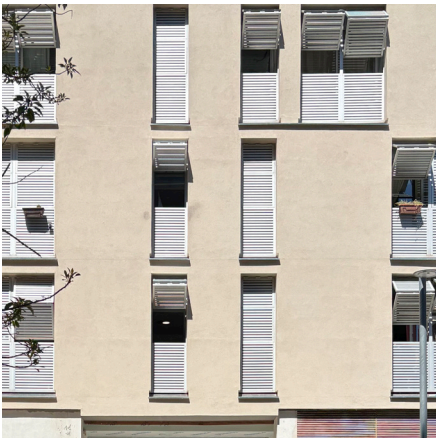
exposed aggregate slab



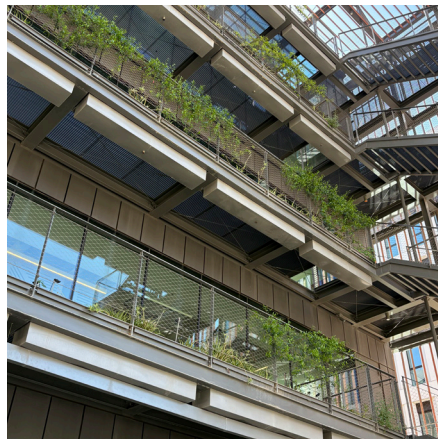
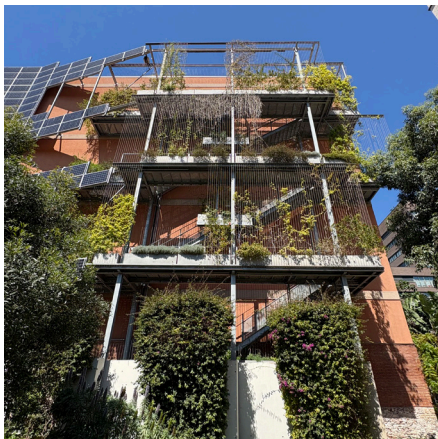
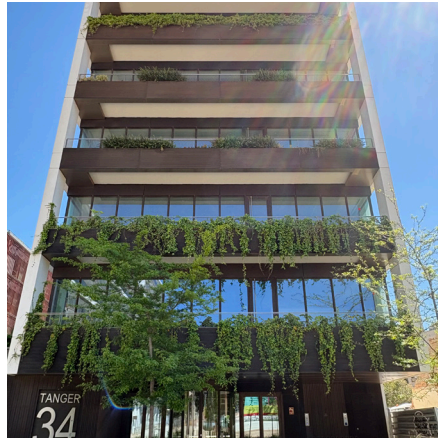
Blue & Green Roof



# Catalog of Barcelona's shading elements

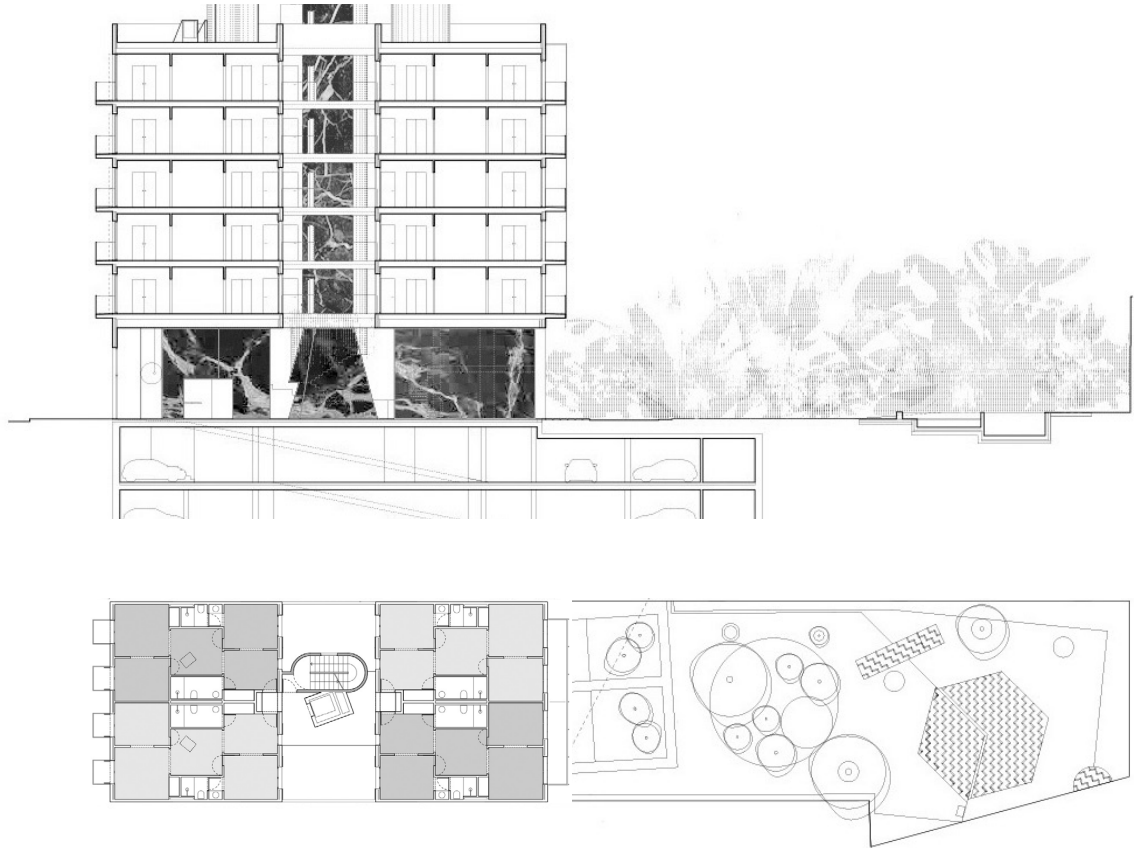








# Collective Housing 110 Rooms, MAIO

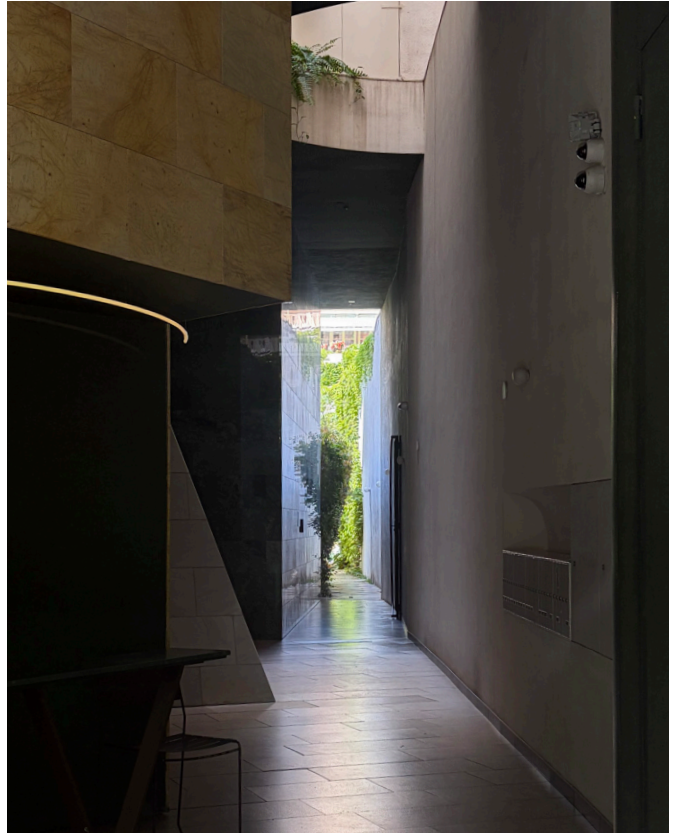


(Gallery of Collective Housing 110 Rooms / MAIO - 12, n.d.)

Caballero, P. (2024, July 1). Collective Housing 110 rooms / MAIO. ArchDaily. <https://www.archdaily.com/968030/collective-housing-110-rooms-maio?auth=hadid>



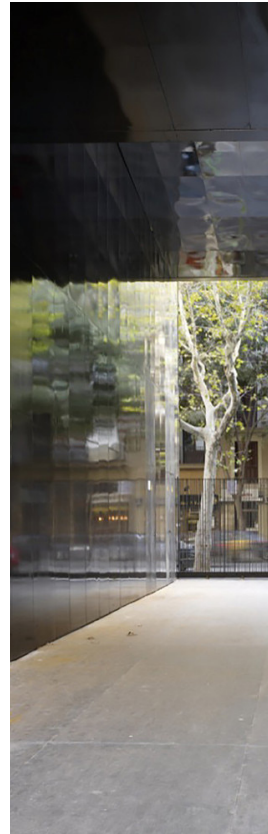
entrence



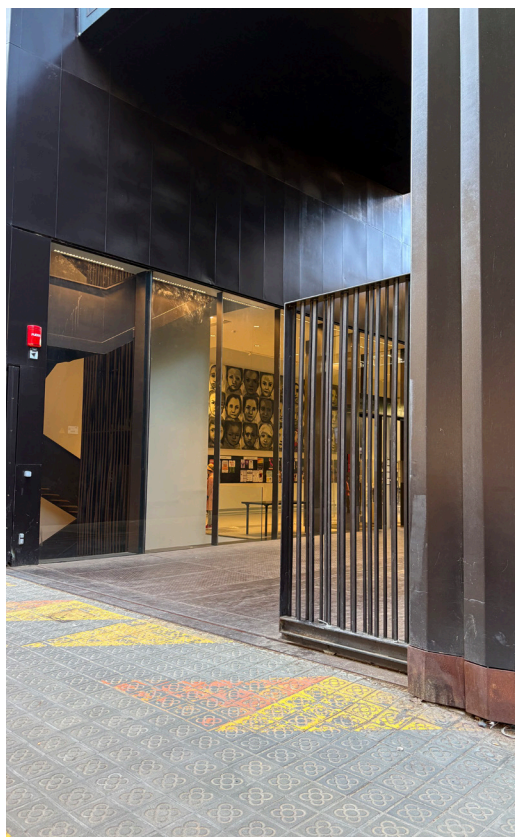
behind the glass

# Sant Antoni - Joan Oliver Library, RCR Arquitectes

The Sant Antoni - Joan Oliver Library exemplifies how conscious material choices and strategic massing can create a highly porous ground floor, drawing natural awareness to the inner courtyard entrance. This open configuration thrives today because the adjacent street was recently transformed into a pedestrian superilla. With traffic eliminated, the generous entryway welcomes people, rather than car noise pollution, directly into the tranquil park.

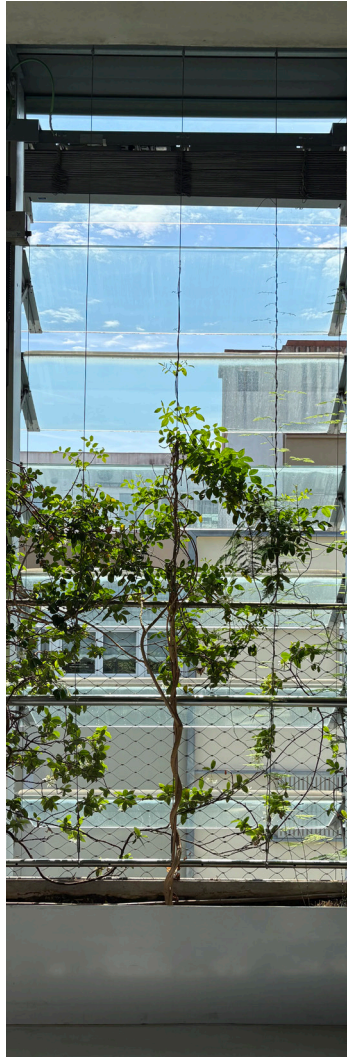




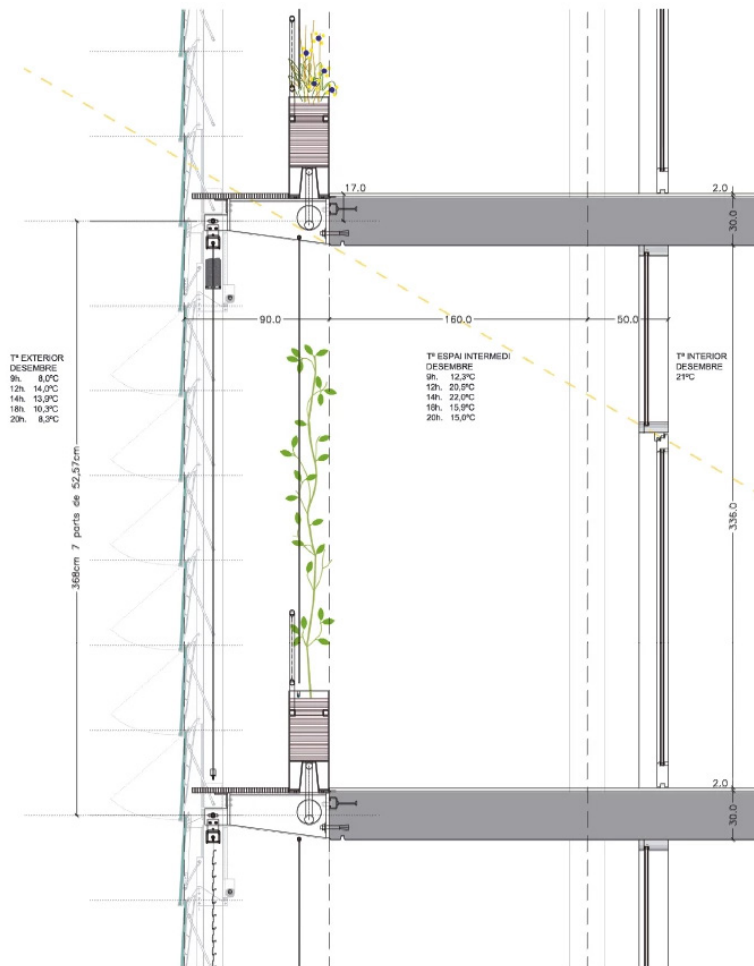
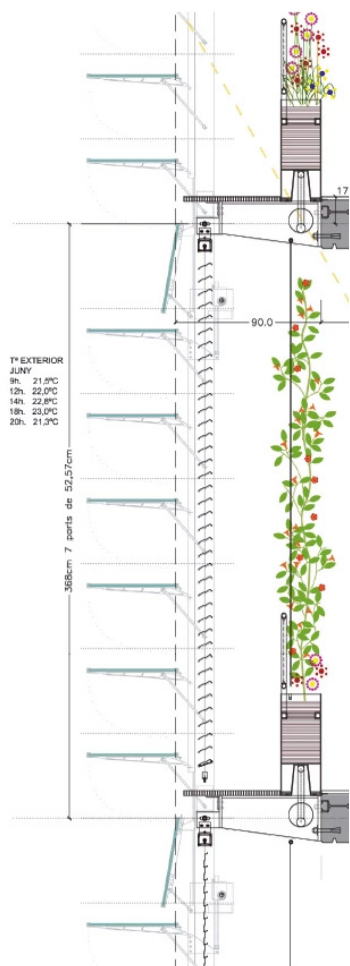


picture of the reality

# Villa Urània, SUMO Arquitectes SLP + Y.Olmo







(Galería De Vil-La Urània, Complejo De Equipamientos nZEB / SUMO Arquitectes SLP + Y.Olmo - 35, n.d.)



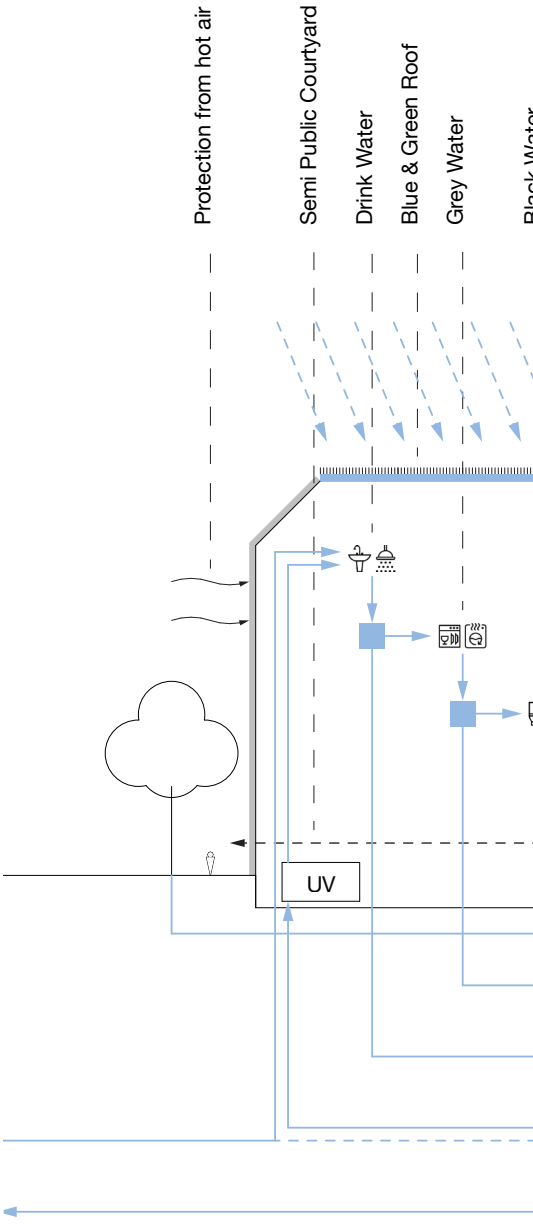
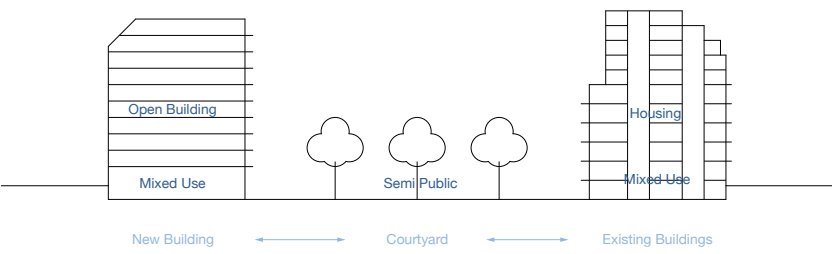
## **PART III: RESULTS**

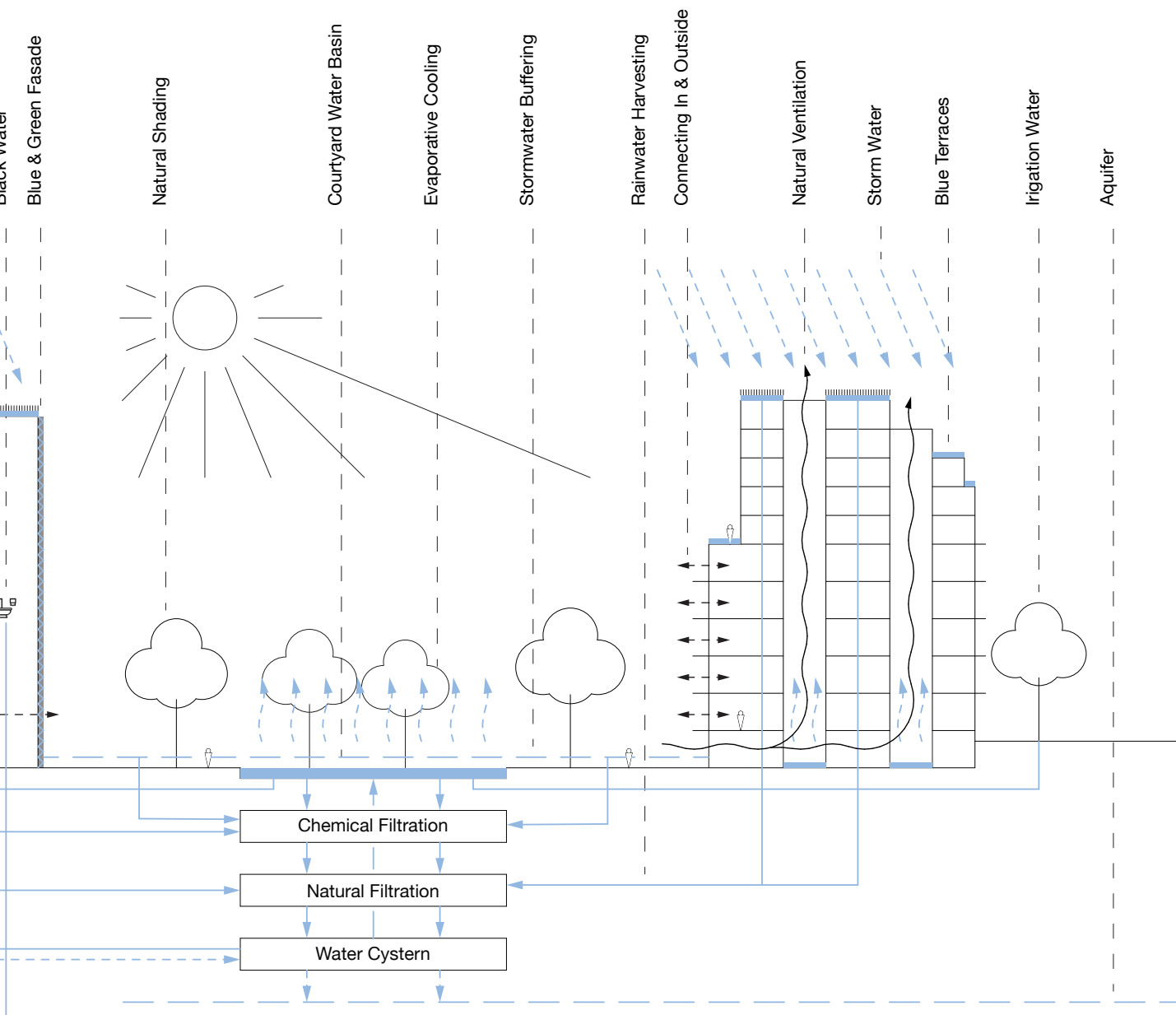
### **The Process, the System & the Design**

This chapter translates the theoretical framework into an architectural prototype: The Lighthouse. It demonstrates how domestic water circularity and bio-based passive design can be integrated into the Eixample grid.

# Initial Design Vision

The project began with a radical vision to redefine urban architecture from a passive shelter into an active, climate-resilient eco-machine. Driven by escalating heat and water scarcity, the foundational concept focused on dismantling traditional linear resource consumption in favor of a decentralized, closed-loop urban metabolism.







## 11<sup>th</sup> Advanced Architecture Contest

Participating in the IAAC's 11th Advanced Architecture Contest (2026) served as a voluntary but pivotal testing ground for the project, ultimately earning 7th place out of 113 global entries. This competition was the catalyst for expanding the core "eco-machine" concept beyond a single building, forcing the design to resolve how decentralized water and heat metabolisms interact across all urban scales. Ultimately, it proved that these localized interventions could successfully scale up to impact everything from interior human comfort to territorial aquifer recharge.

## 1 | Water Infrastructure for the Example Block

### Climate resilient design for urban survival



#### Project Statement

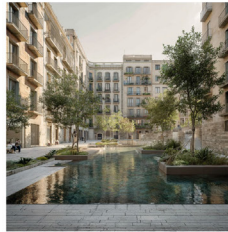
Dense urban housing blocks dominate cities like Barcelona, where water scarcity is increasingly framed as a regional or infrastructure problem. Yet the everyday impacts of water stress are produced at a much smaller scale – within buildings and the spaces between them. This project explores the true courtyard of the urban block as a shared interface between water, climate, and daily life. By harvesting, holding, and carefully expressing water within the block, architecture shifts from a passive endpoint to an active mediator – shaping comfort, resilience, and environmental performance from within the city itself. (Crujeiró)



30752ZAAHY

## 2 | Body Scale: Thermal Comfort as Architectural Material

### Water mediating climate, perception, and well-being



#### Human-Water Relationship

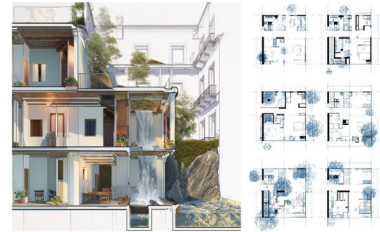
While water scarcity is often discussed as a technical or infrastructure problem, its impacts are first felt by the human body. In dense urban environments, water presence directly influences thermal comfort, perception, and well-being. Through evaporation, shade, sound, and touch, architectural space mediates how water is experienced in everyday life – long before it becomes a question of systems or infrastructure.

At this scale, water is not managed; it is sensed. Architecture shapes its presence, transforming climatic necessity into spatial quality.

30752ZAAHY

## 3 | Interior Scale: Organising Water Use Within the Dwelling

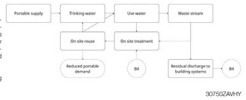
### Separation and reuse embedded in everyday space



#### Domestic Water Organization

In dense Mediterranean housing, kitchens, bathrooms, and service spaces are traditionally clustered around lightwells and interior courtyards. This spatial logic offers an opportunity to rethink water not as a hidden utility but as an integrated architectural element, able to be reused, cooled, and experienced spatially before it leaves the dwelling.

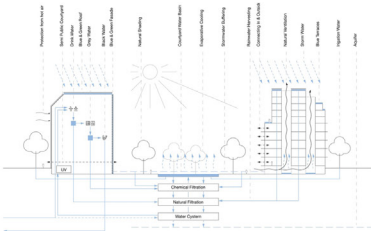
The interior becomes a mediator, quietly reducing demand while maintaining everyday comfort.



30752ZAAHY

## 4 | Building Scale: Integrating Water Infrastructure

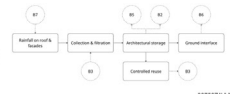
### Filteration, storage, and controlled release



#### Architectural Integration

At the building scale, water is no longer abstract – it becomes structural. Roofs, facades, courtyards, and ground interfaces are reconfigured to collect, filter, and temporarily store water within the architectural section. Rather than being treated as external infrastructure, the building integrates retention and controlled release into its spatial and material logic.

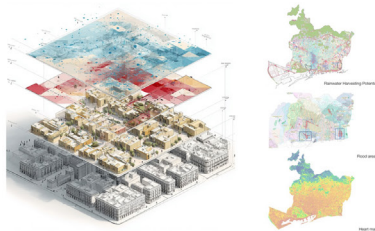
The building acts as a hinge between domestic routines and territorial processes.



30752ZAAHY

## 5 | City Scale: Distributed Urban Water Retention

### Aggregation, delay, and decentralisation



#### Urban Aggregation

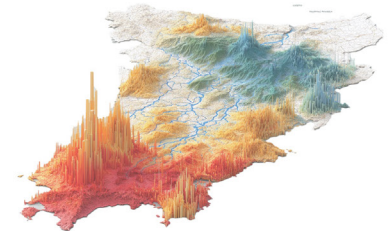
When architectural retention strategies are repeated across multiple blocks, their impact shifts from local intervention to urban system. Individual courtyards and building collectors act as a distributed network of temporary storage, slowing down run-off and reducing pressure on central infrastructure. The city becomes a decentralised buffering bed. Through accumulation and repetition, small architectural actions stabilize urban water availability and strengthen metropolitan resilience.



30752ZAAHY

## 6 | Territory Scale: Aquifer and Groundwater Recharge

### Distributed infiltration and groundwater stabilisation



#### Territorial Hydrology

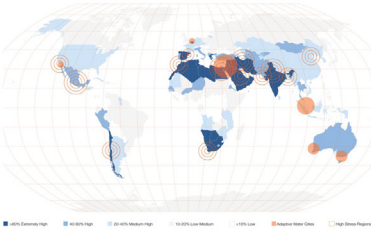
At the territorial scale, buffered and delayed water recharges natural hydrological systems. Distributed infiltration across courtyards and permeable ground surfaces initiates aquifer recharge and stabilises groundwater levels. Rather than accelerating run-off, water is gradually returned to its natural path. Through this shift in timing and distribution, urban architecture contributes to long-term hydrological balance beyond the building and the block.



30752ZAAHY

## 7 | Planetary Scale: Water Stress Within the Global Cycle

### Precipitation, storage, evaporation, and global circulation



#### Global Context

The planetary water cycle operates as a continuous system of atmospheric circulation, storage, evaporation, and return. While the cycle remains constant, its spatial distribution and availability are increasingly uneven under conditions of climate change and urbanisation. Water stress emerges not from the absence of water, but from imbalances in access, timing, and distribution. Architecture does not replace this cycle – it operates within it.



30752ZAAHY

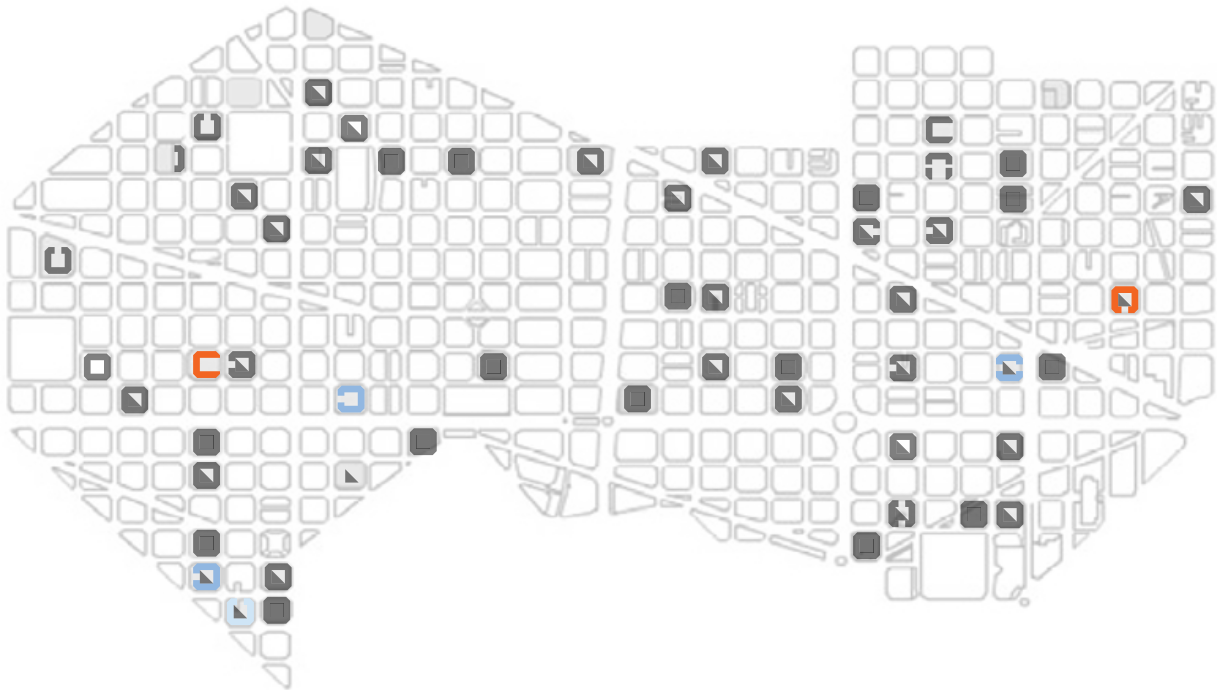
## 8 | Scalar Interconnectedness: From Extraction to Recharge

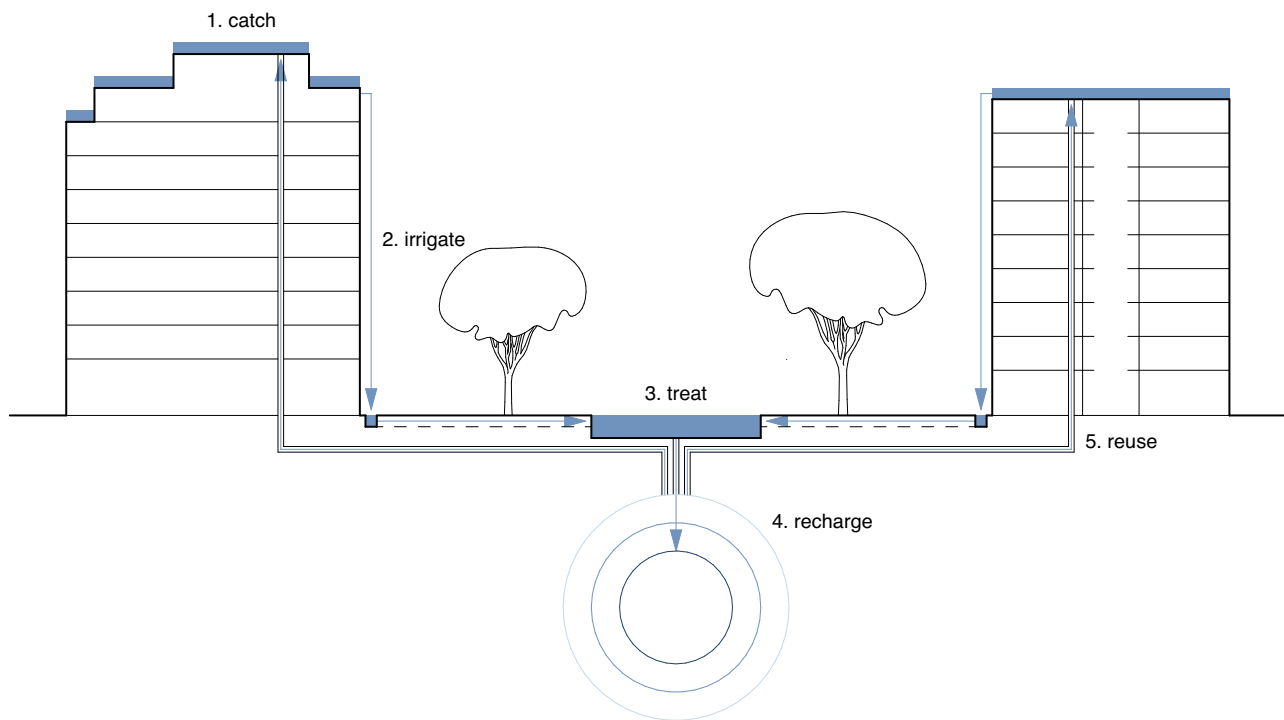
### Linking interior reuse, urban buffering, and territorial recharge across scales



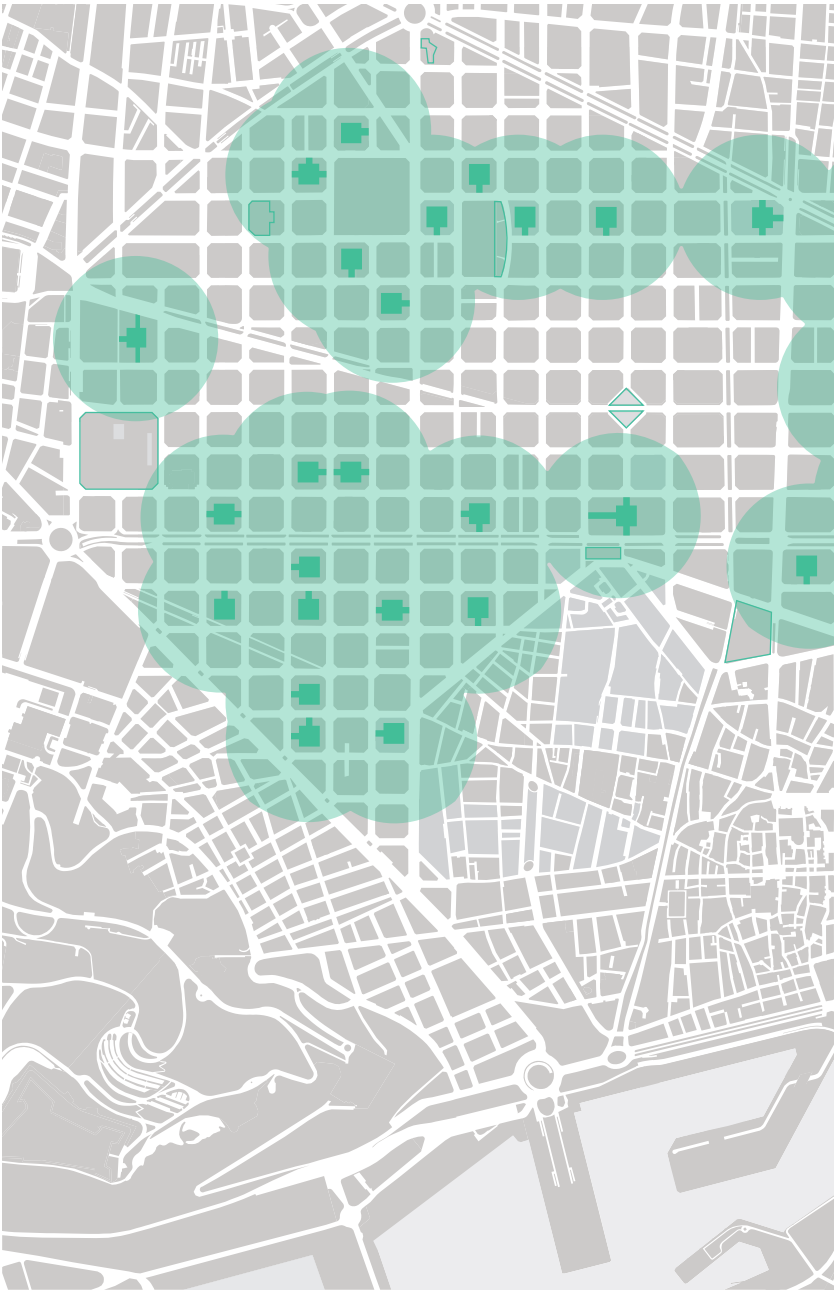
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# Block Refinement & Aquifer Recharge

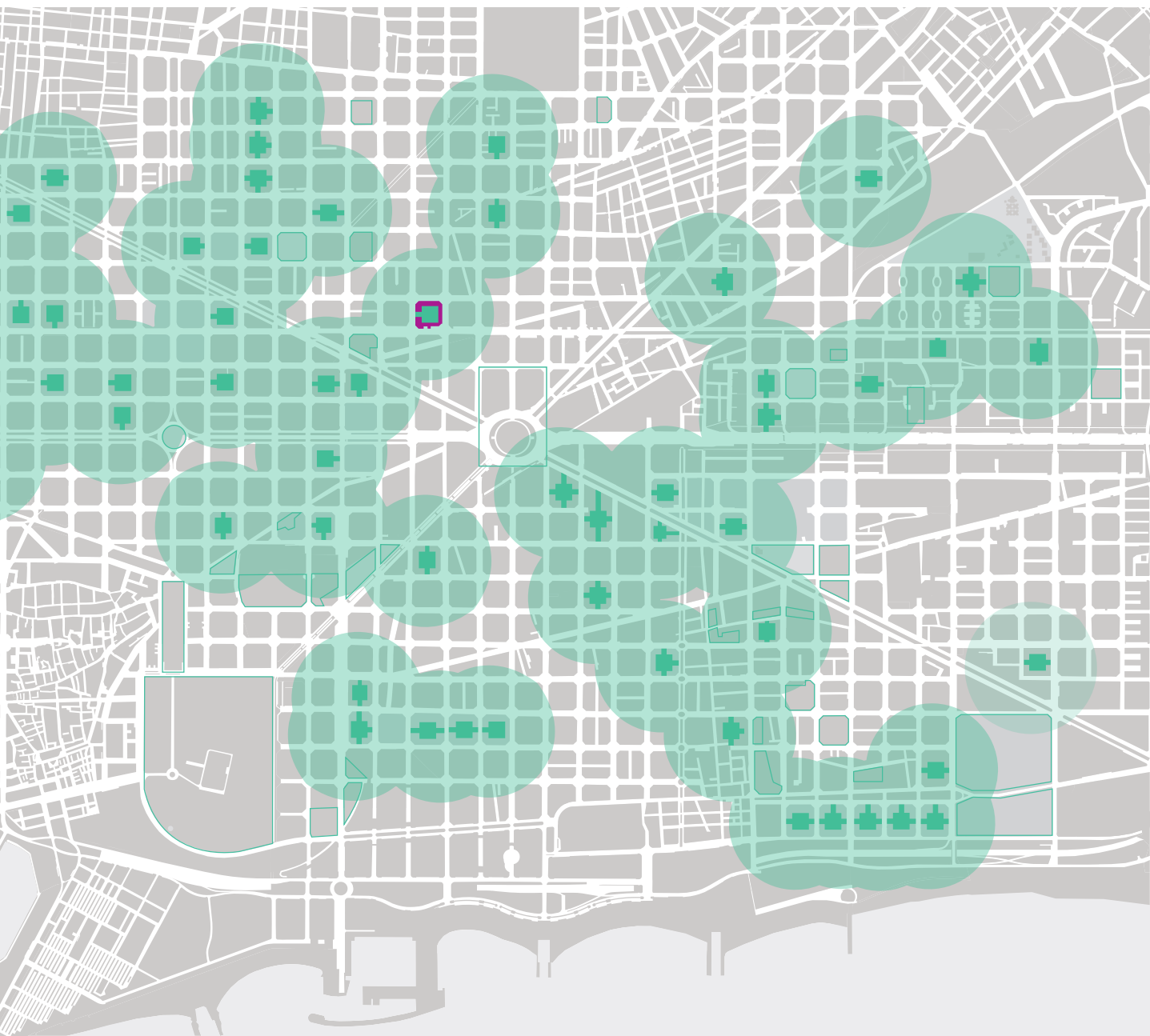




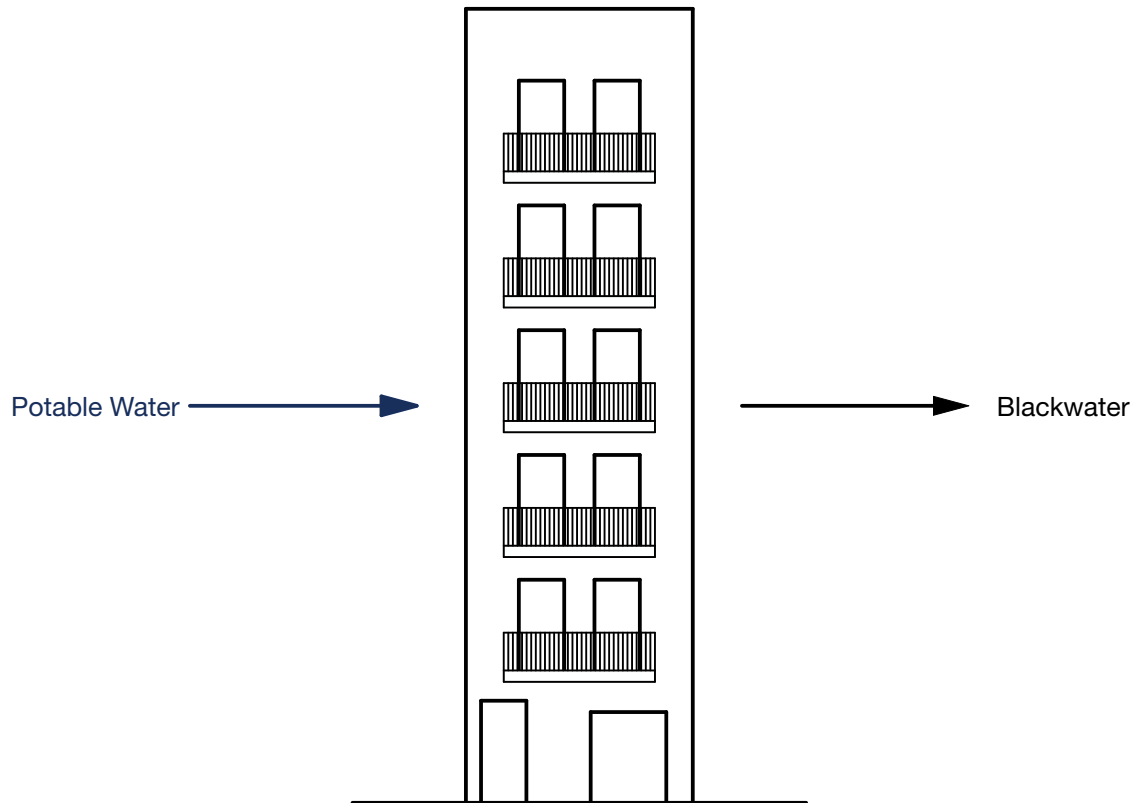
# The Site

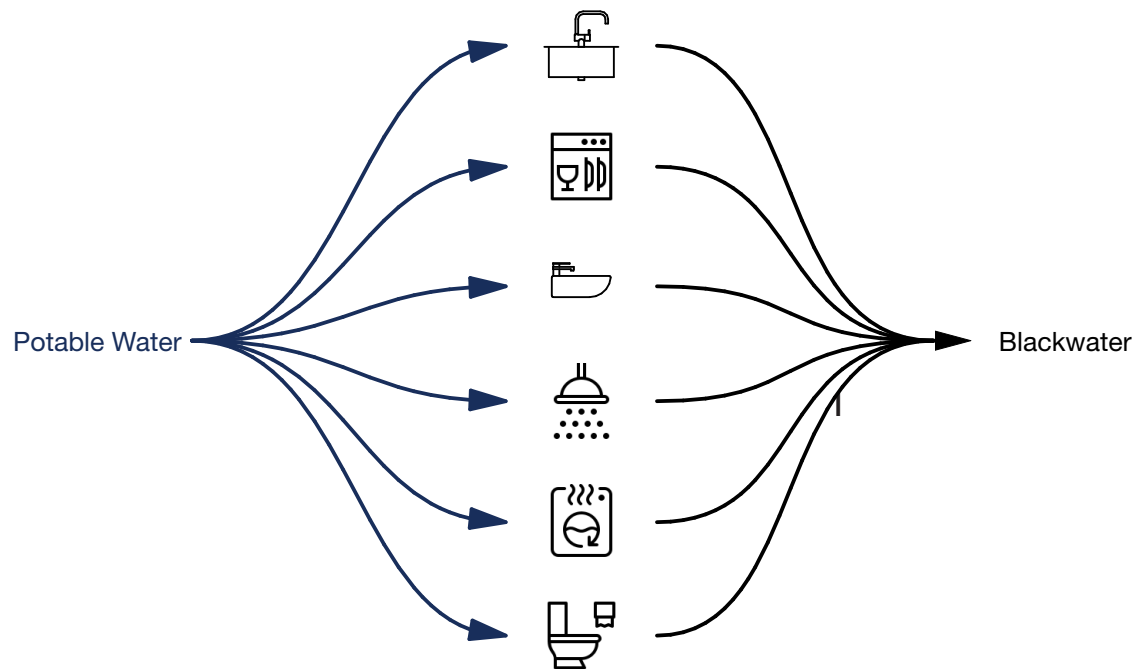




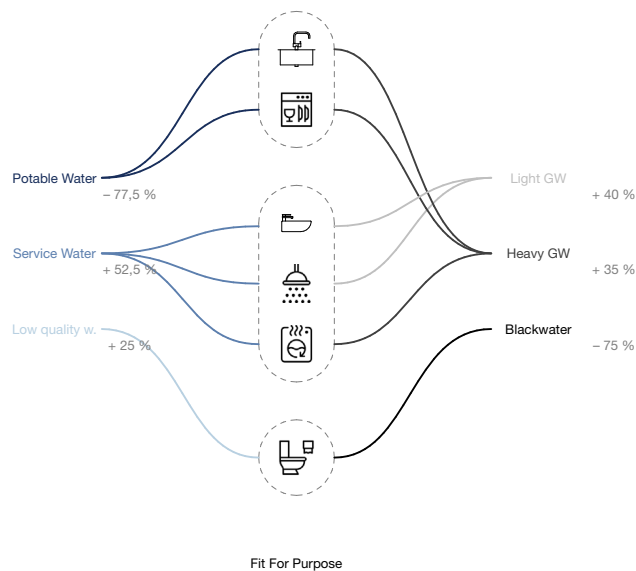


# THE CIRCULAR WATER SYSTEM

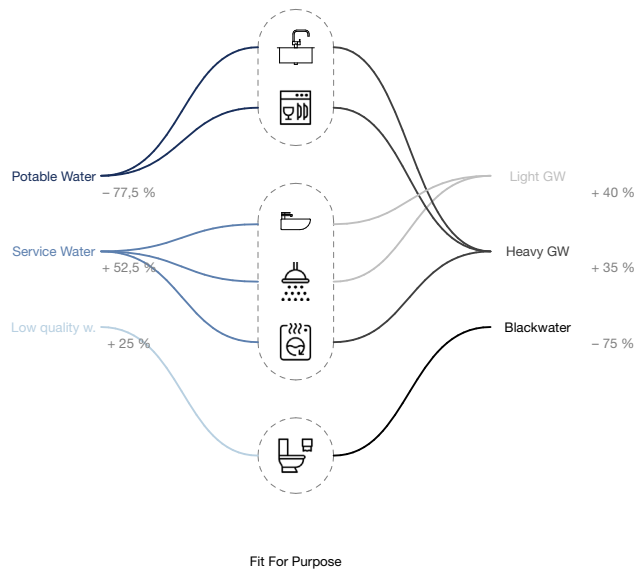




# Phase 1 (Safe present circularity)



## Phase 2 (Climate Crisis 2050 – Circular Future)



This thesis rejects the conservative limits of current municipal water codes. By upgrading rainwater and aquifer yields to near-potable standards via localized Reverse Osmosis, we can safely supply showers and bathroom sinks without touching the failing municipal dams. This project is a prototype designed for the legislation of 2035 or 2050.



# Three Loop Scales

## The Sity System

Potable Water -> Use -> Blackwater

## The Block sycle

Rainwater -> Use -> Filter -> Recharge Aquifer ->

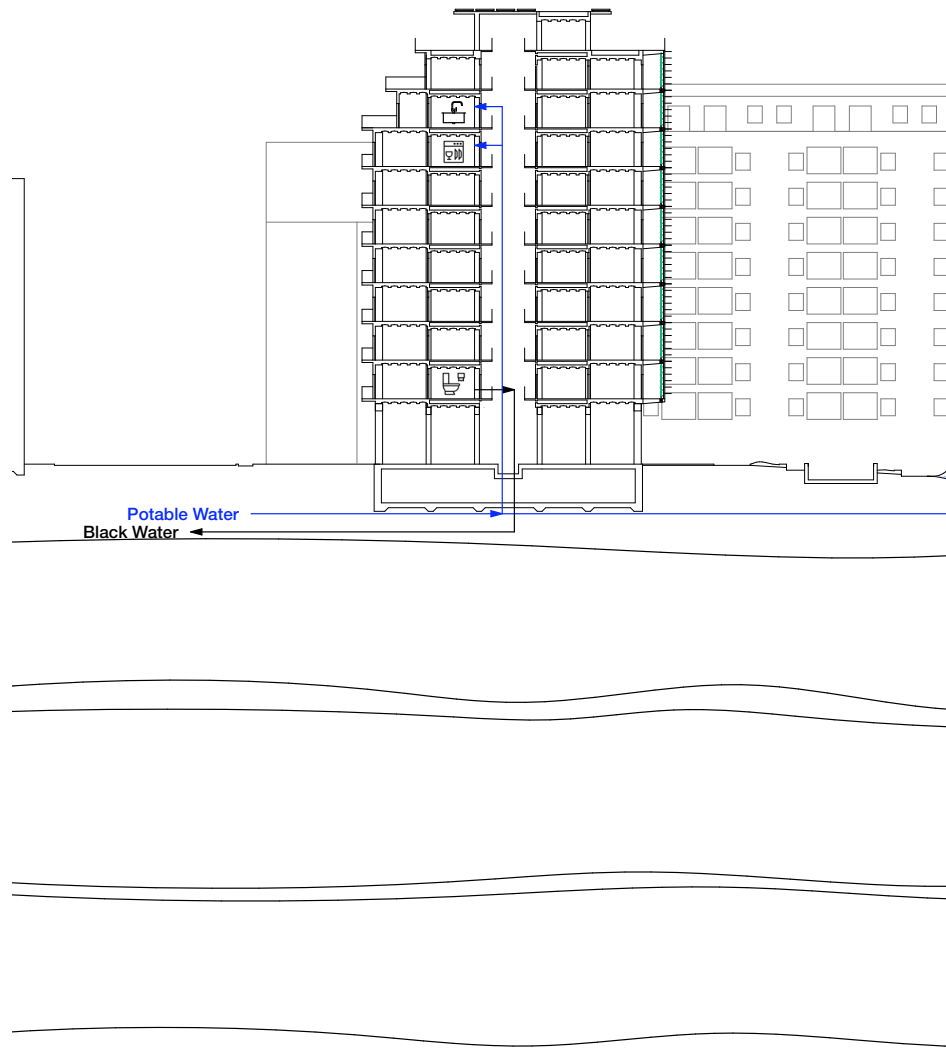
Heavy GW -> Filter -> Recharge Aquifer -> Extract -> Filter -> Reuse

## The Building Cycle

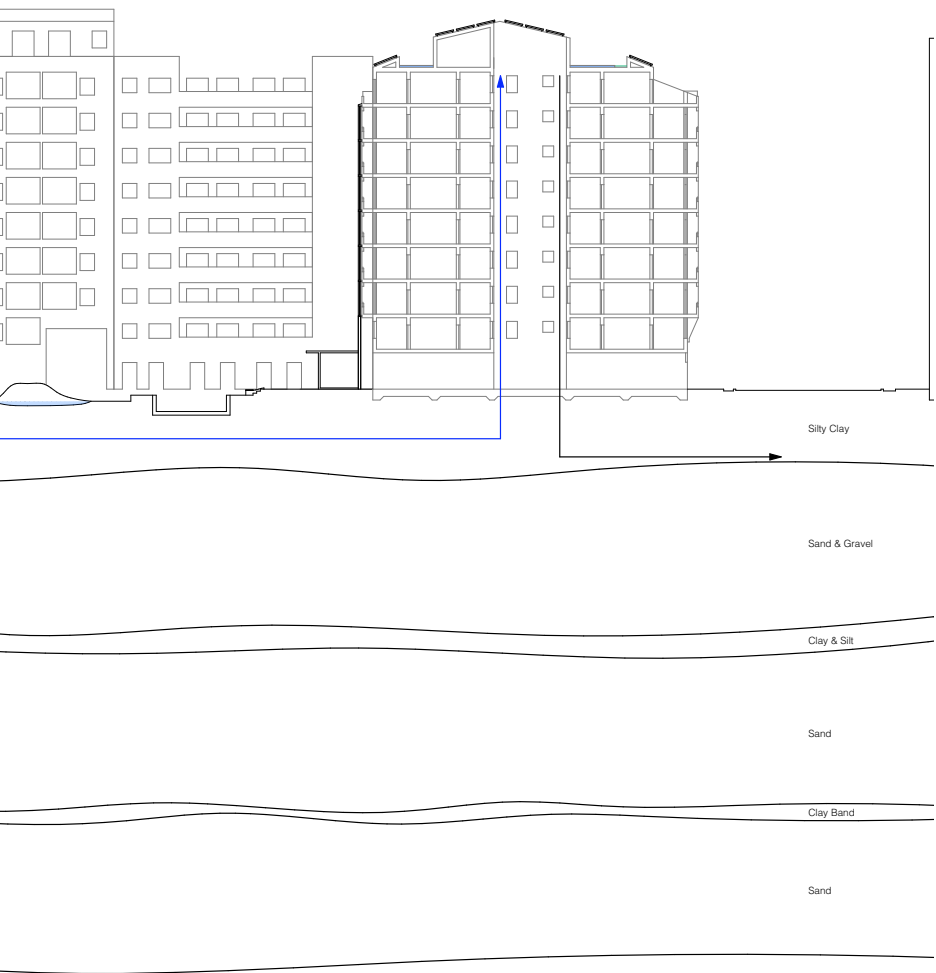
light GW -> Filter -> Reuse

# Circular Connection

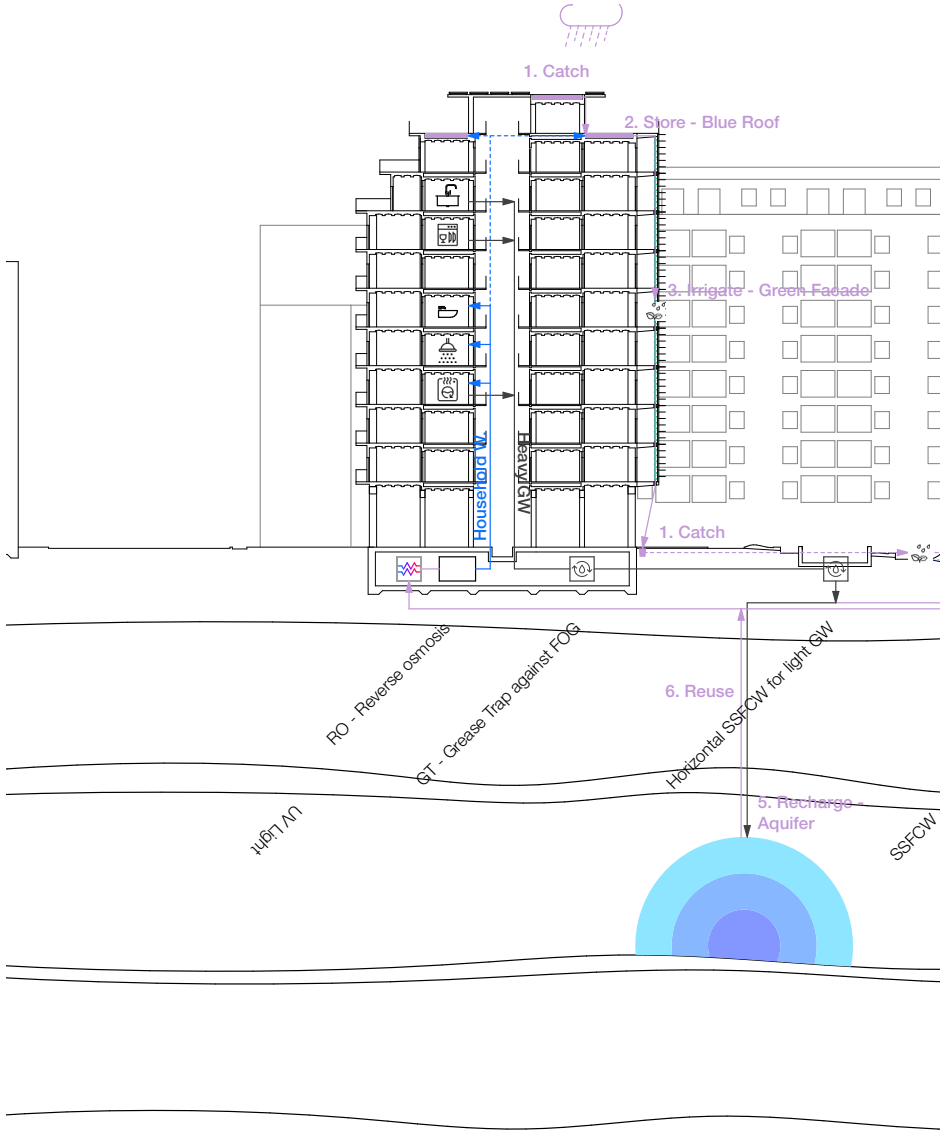
# METABOLIC SECTIONS



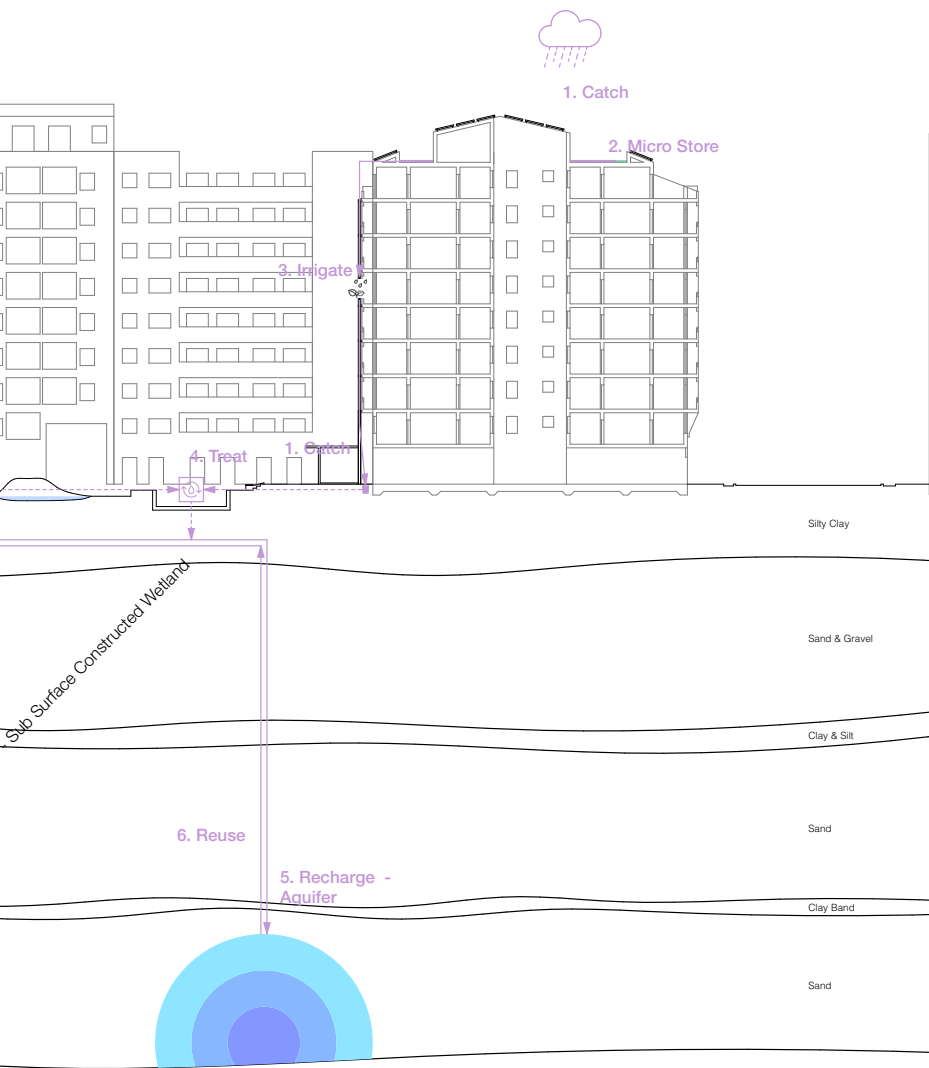
# The City System



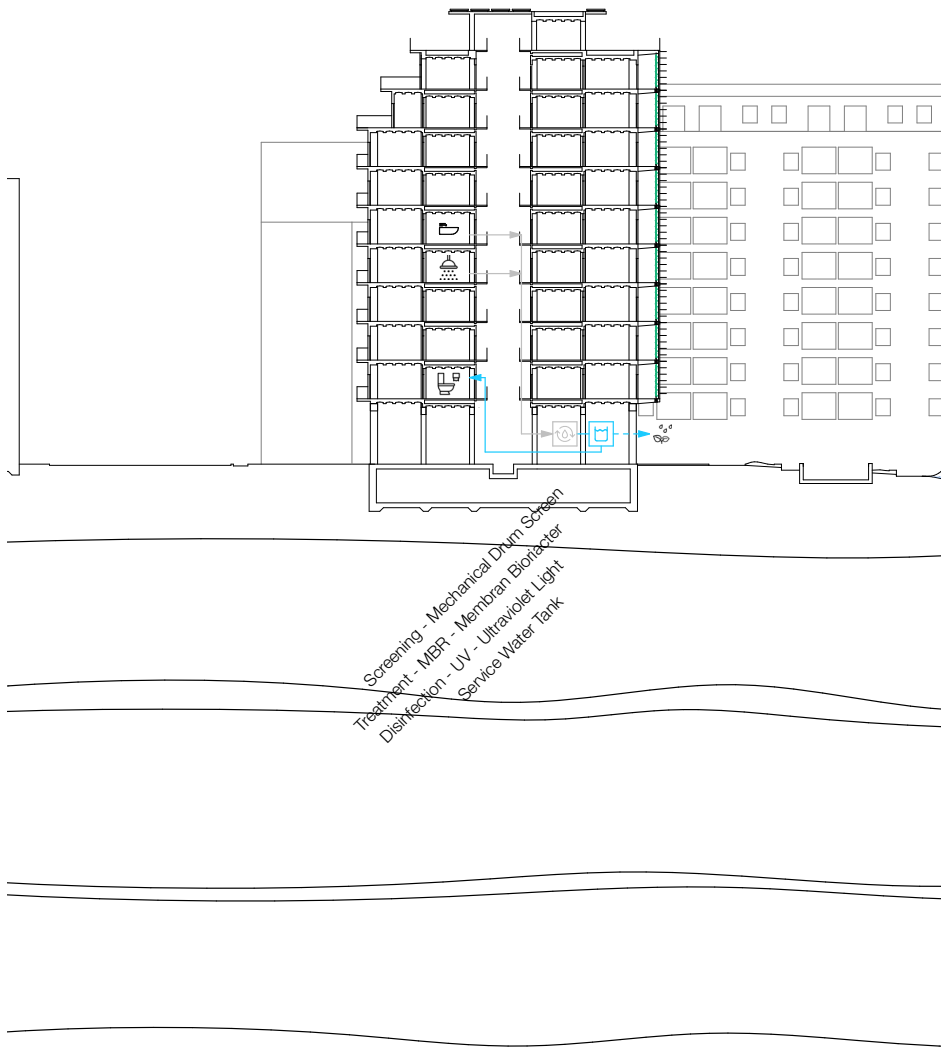
# The Block Cycle

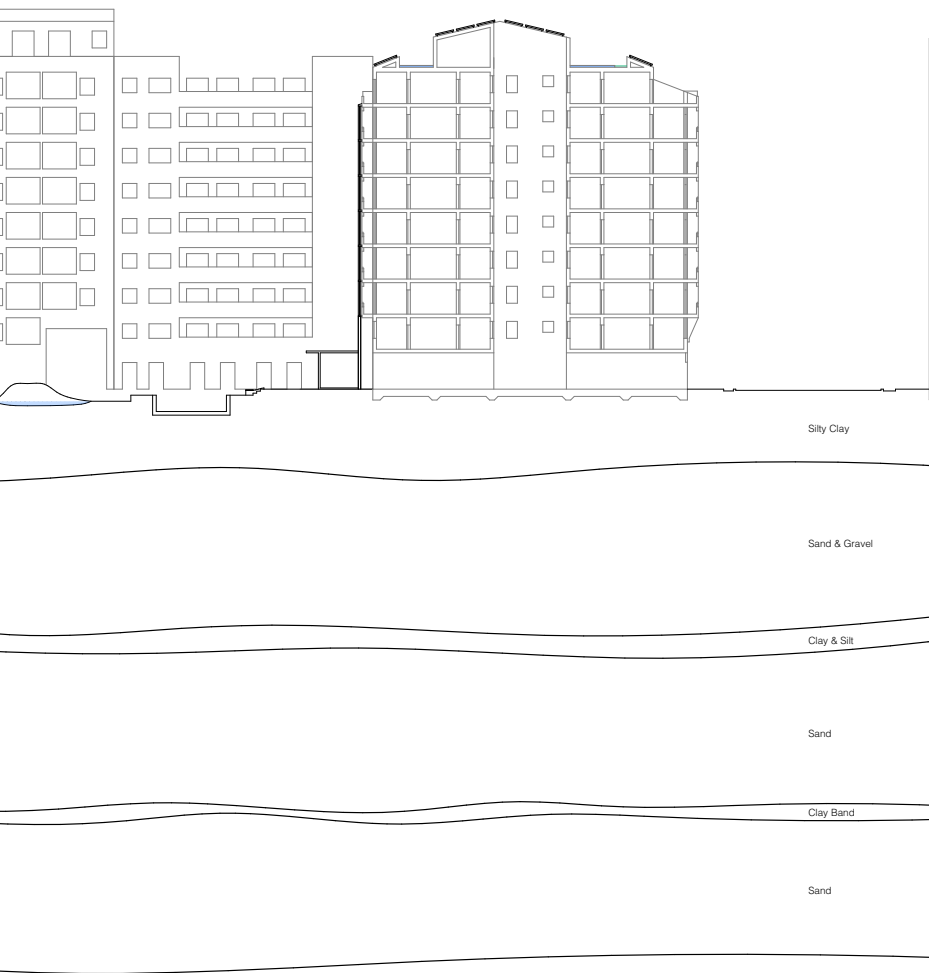




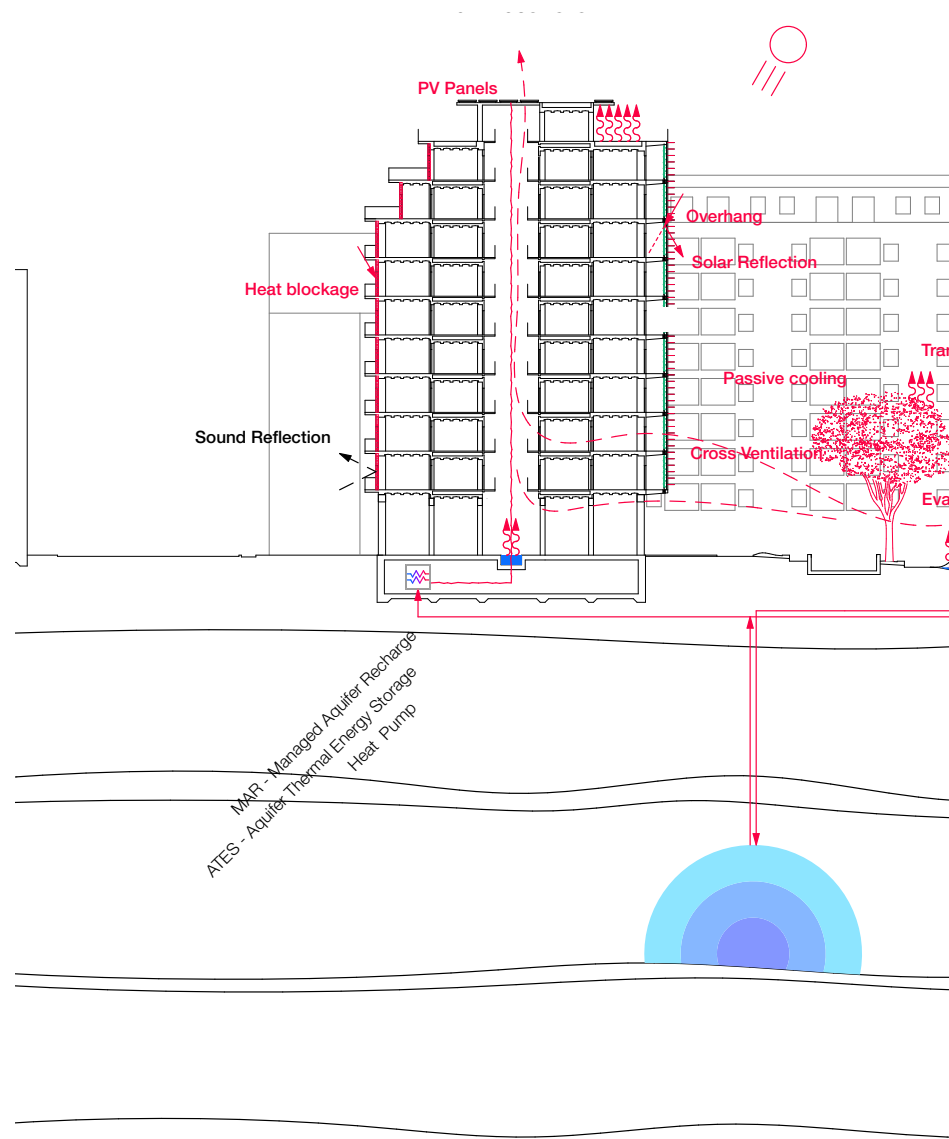


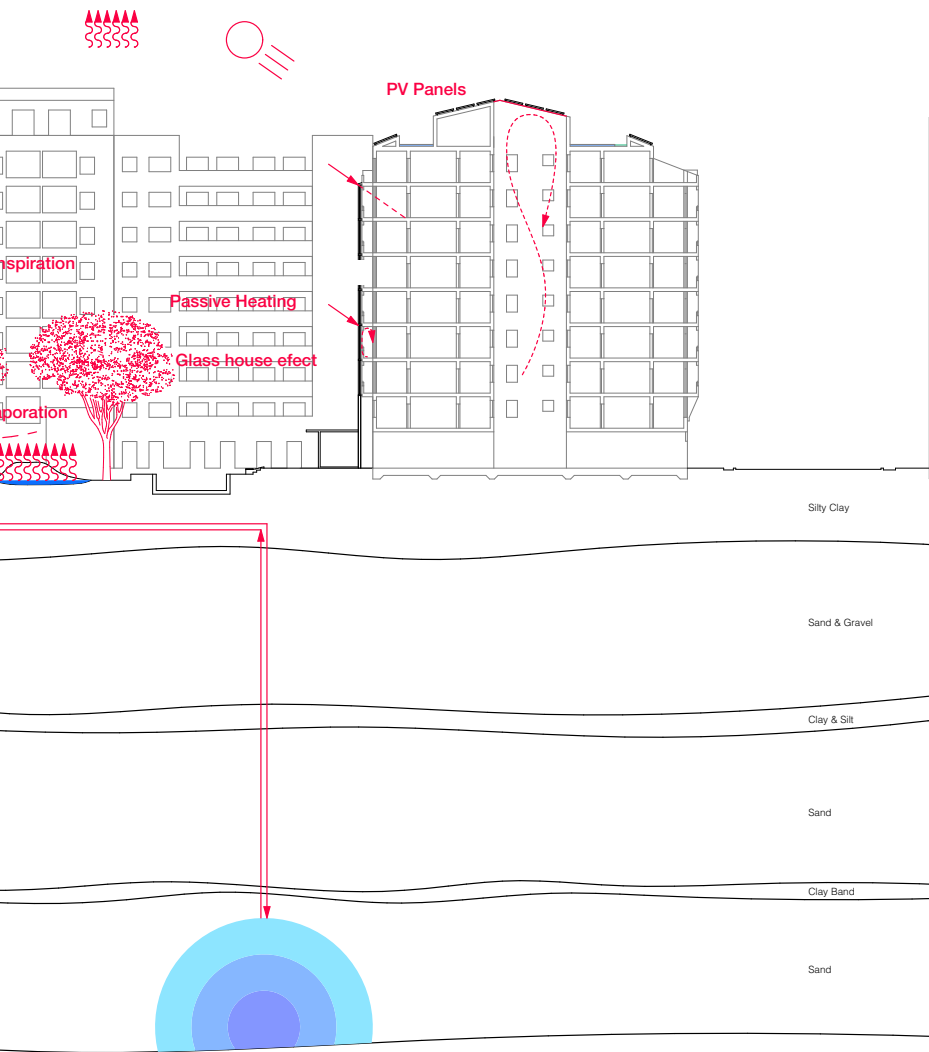
# The Building Cycle





# The Thermal System

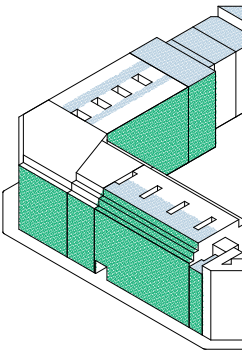
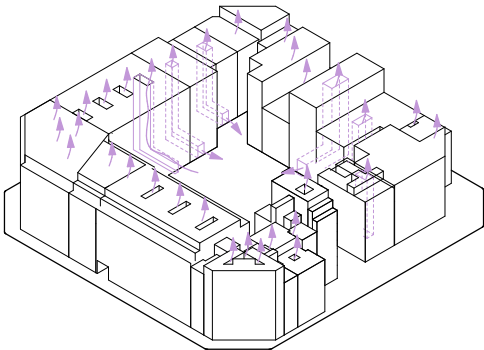


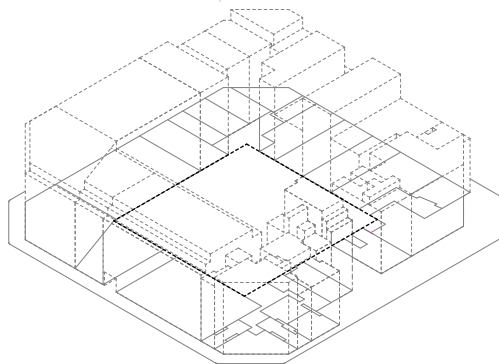
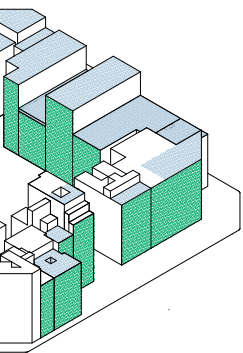




# LIGHTHOUSE BLOCK SCALE

## The Steps









# Elevation

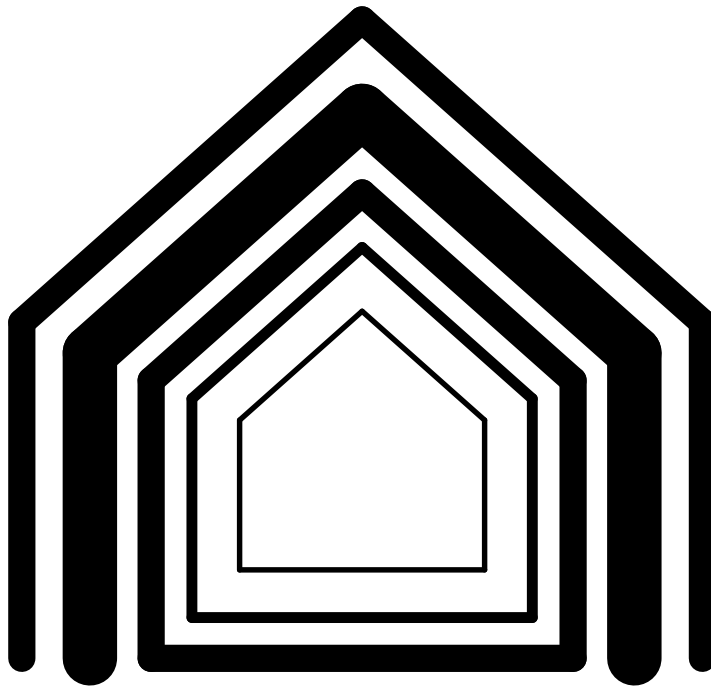






# THE LIGHTHOUSE BUILDING

## The Open Building Princip



Stuff  
7 years

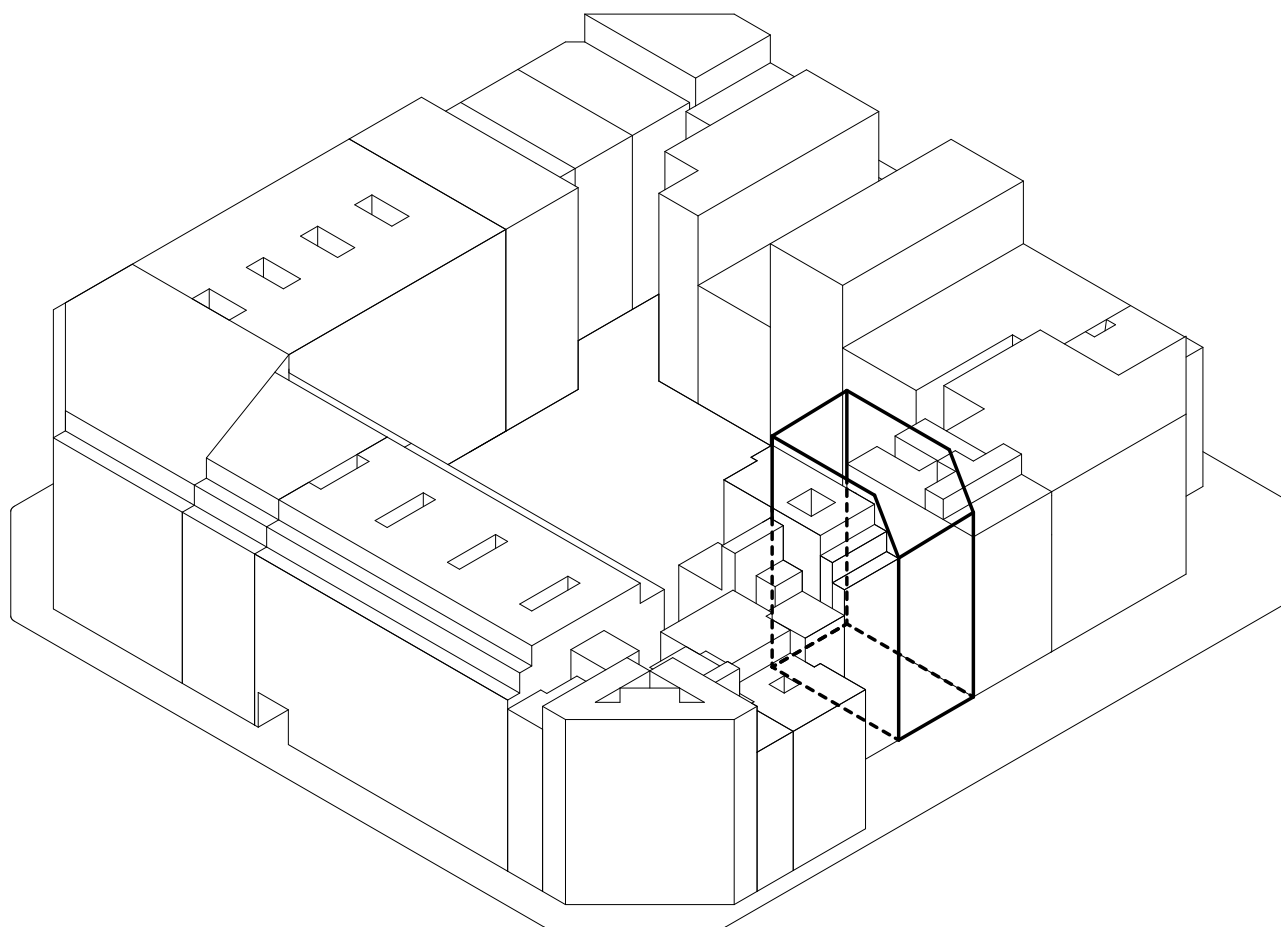
Space plan  
15 years

Systems  
25 years

Skin  
50 years

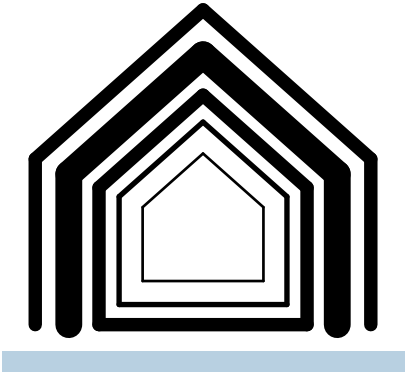
Structure  
200 years

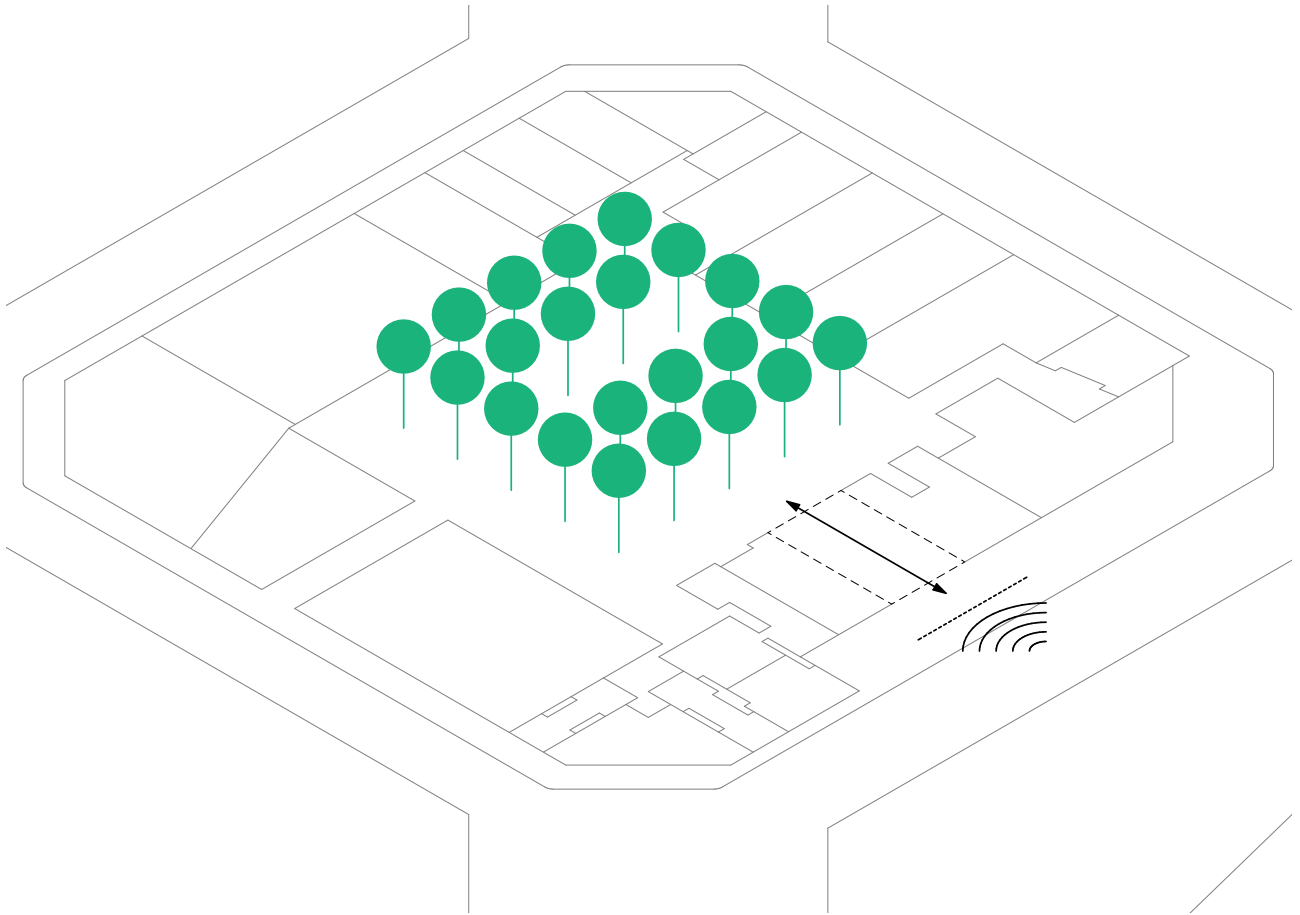
Site  
 $\infty$



# The Site

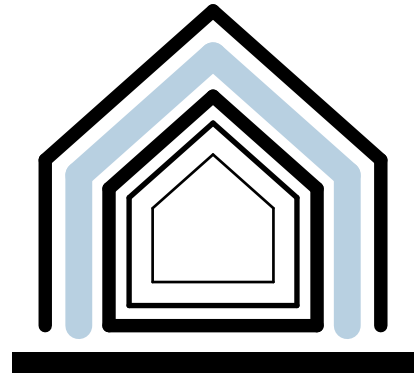
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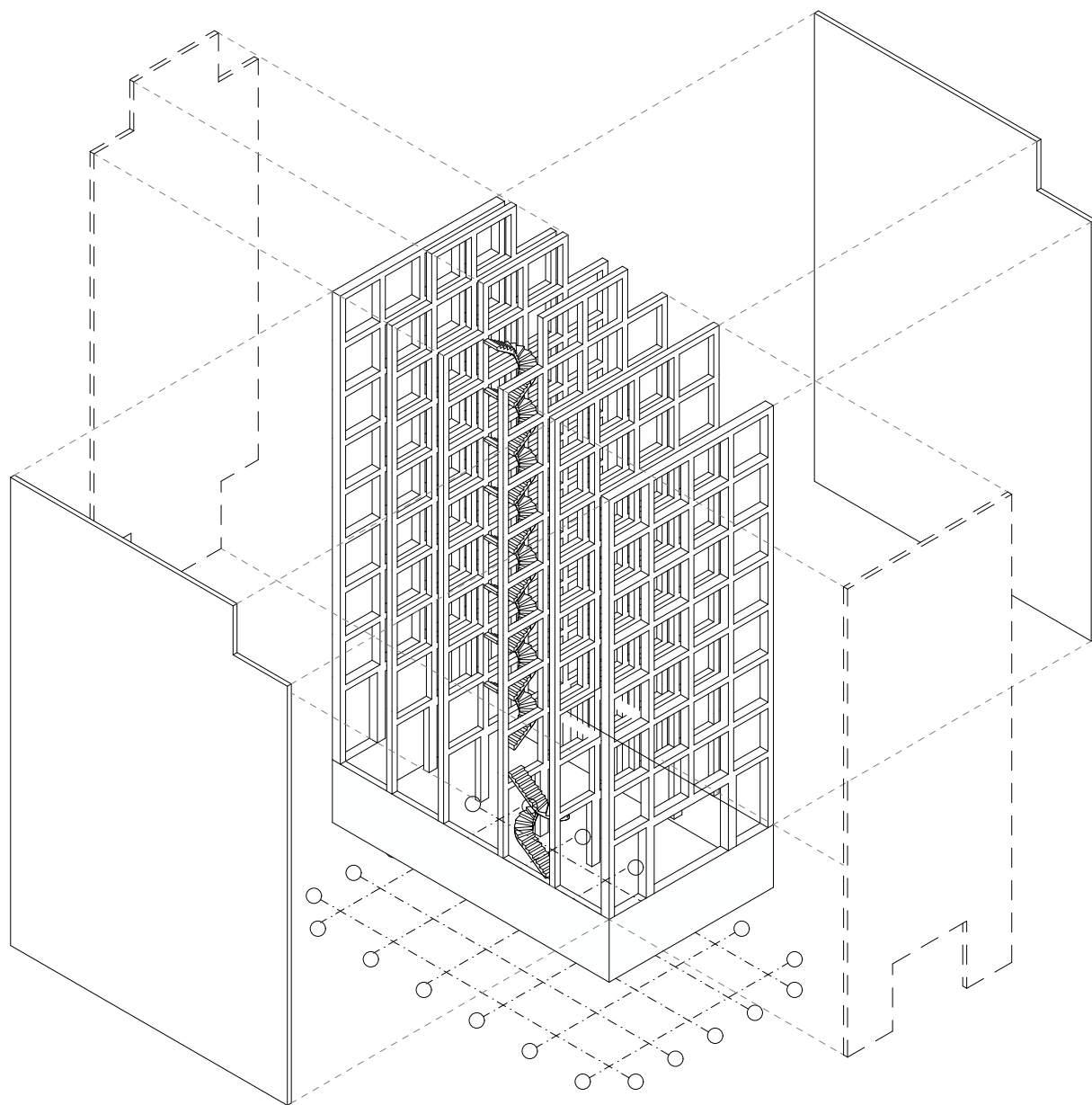


# The Structure

200 years

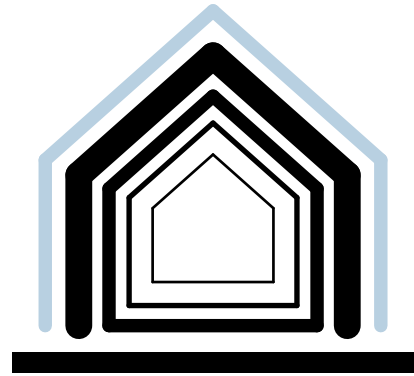


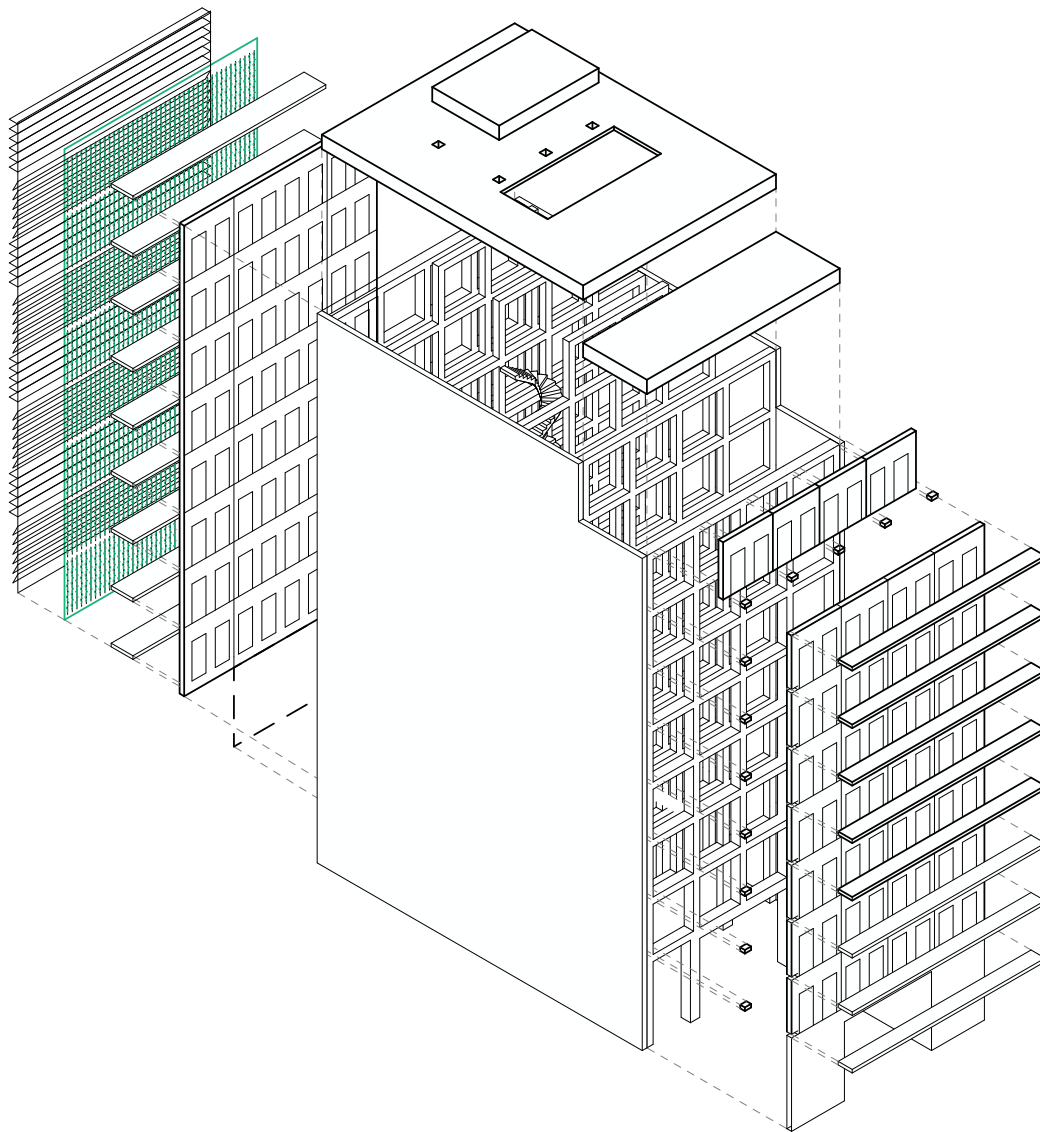




# The Skin

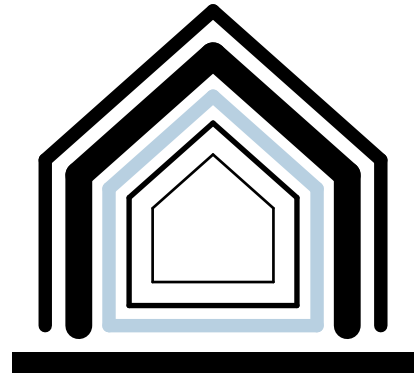
50 years

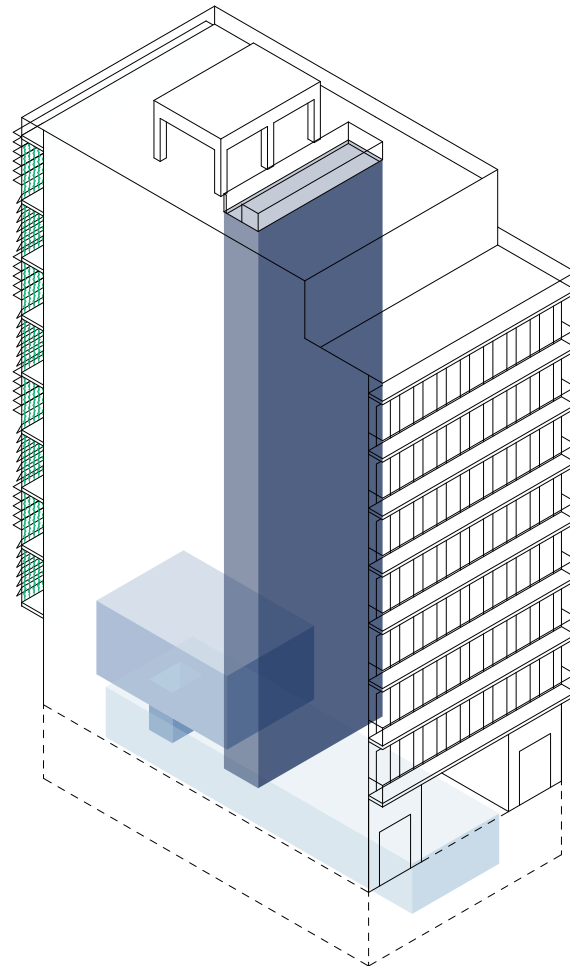




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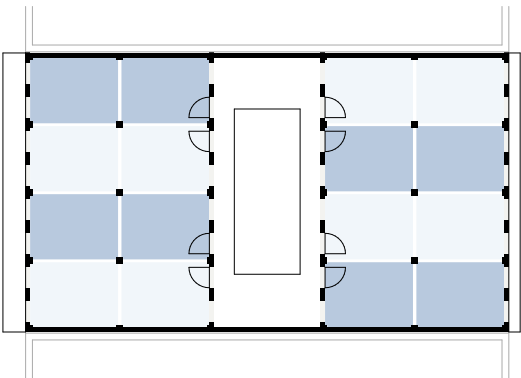
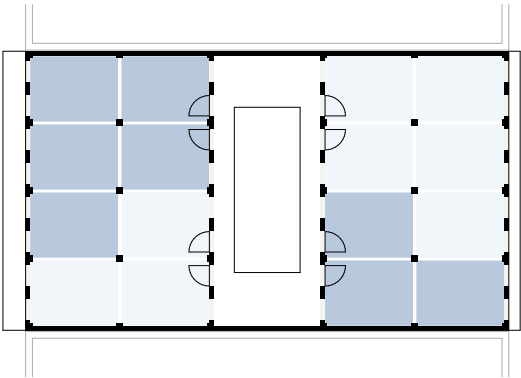
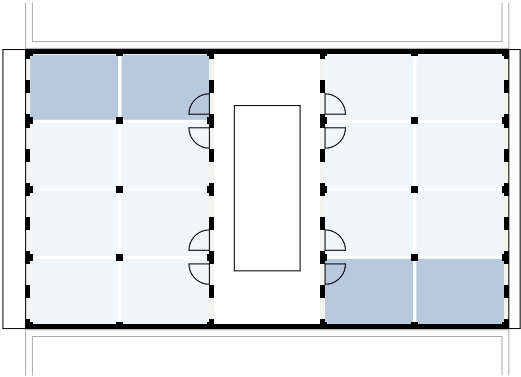
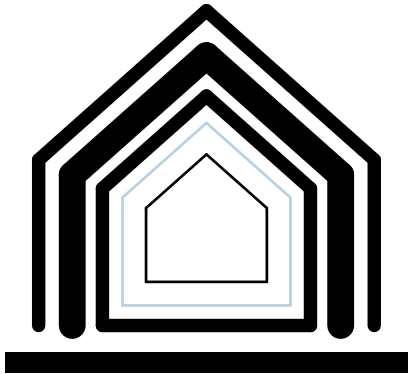
25 years



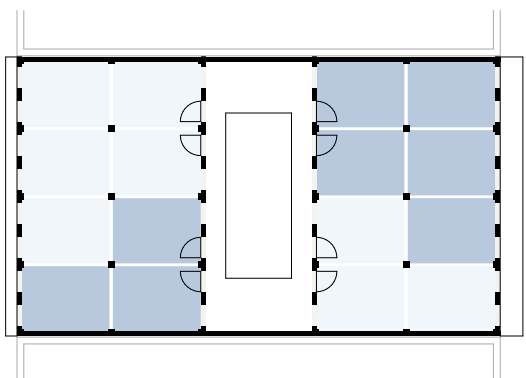
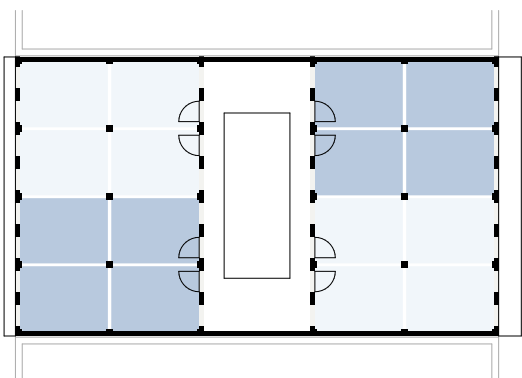
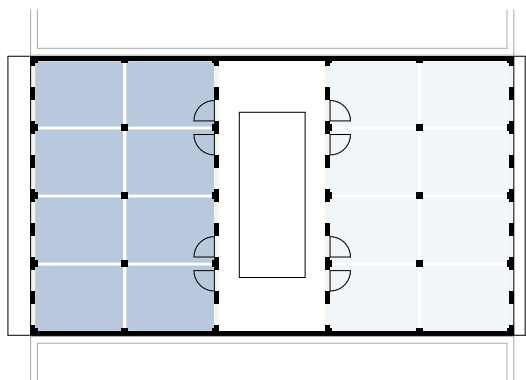
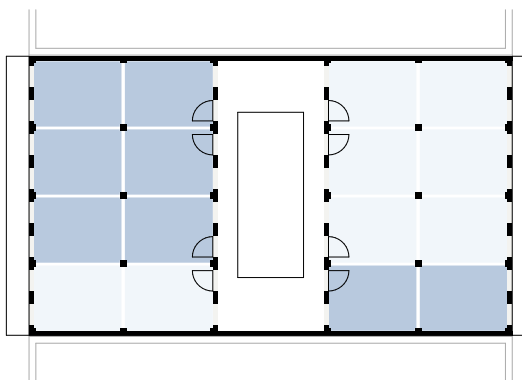
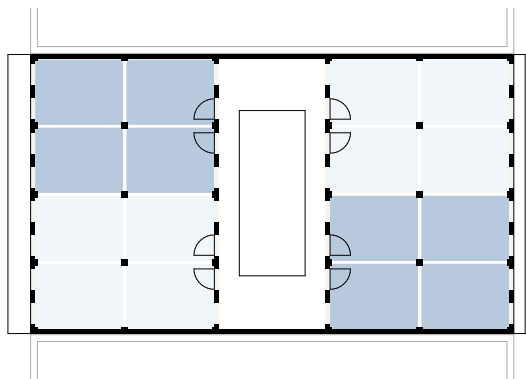
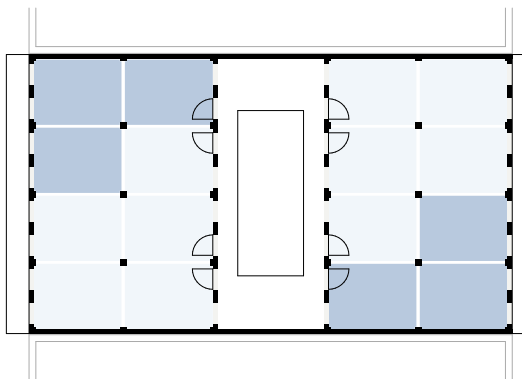


# The Space Plan

15 years

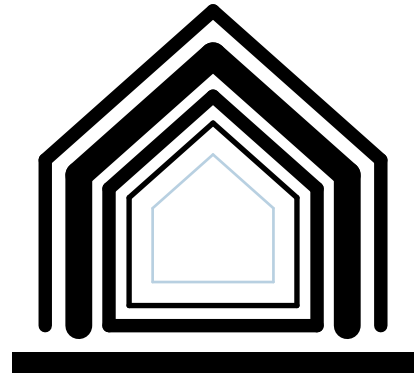






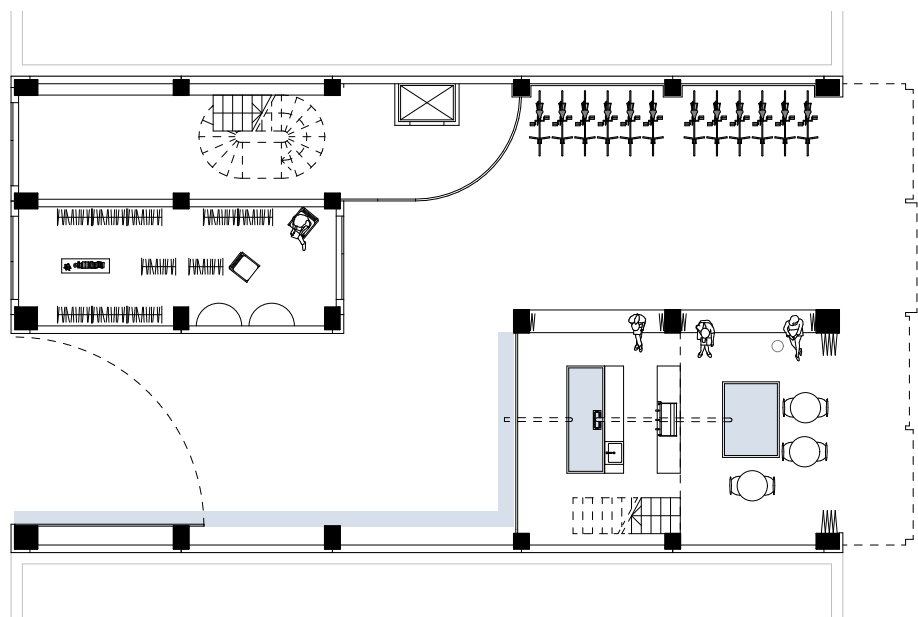
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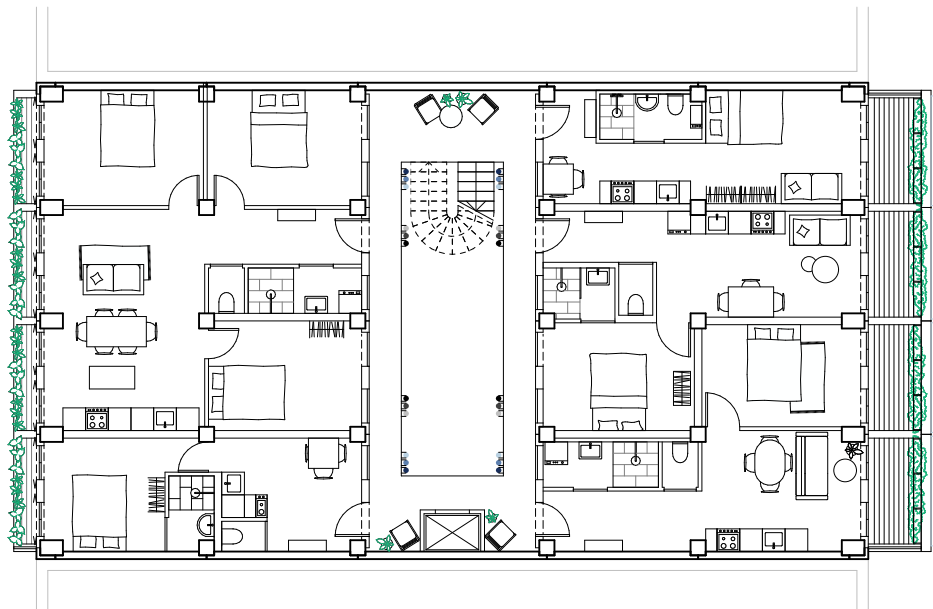
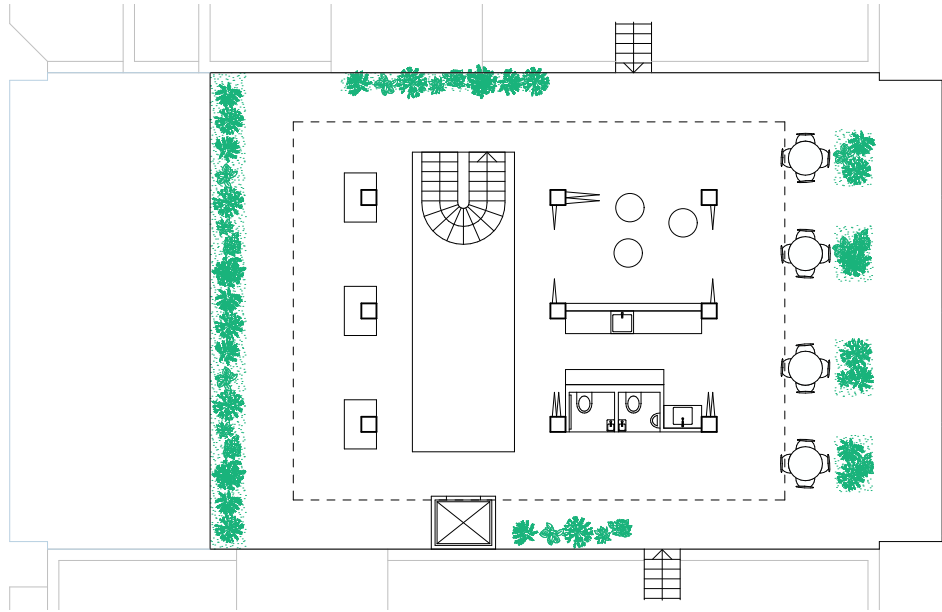
7 years





# Floorplans





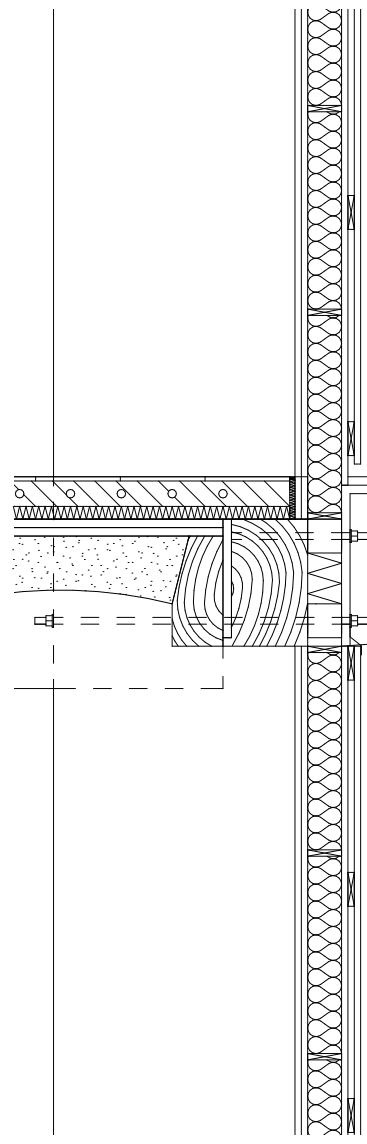
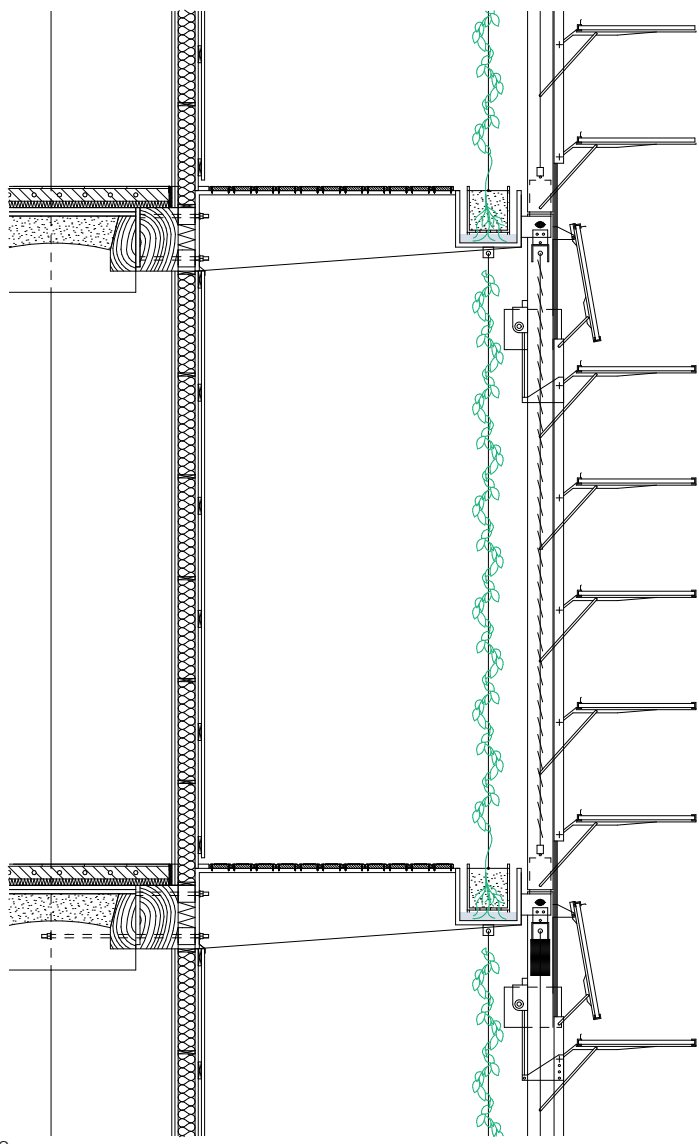
# Section

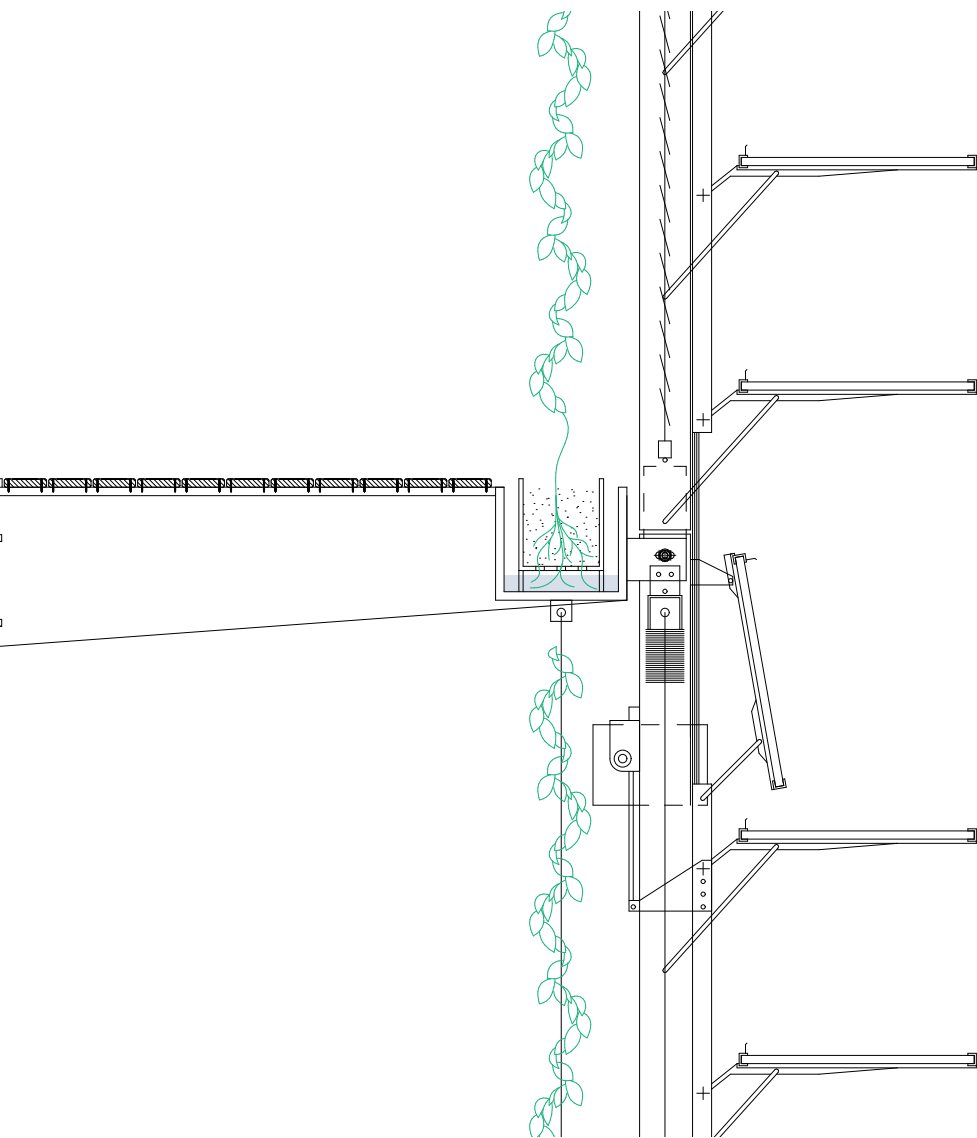






# Detail







# Visuals









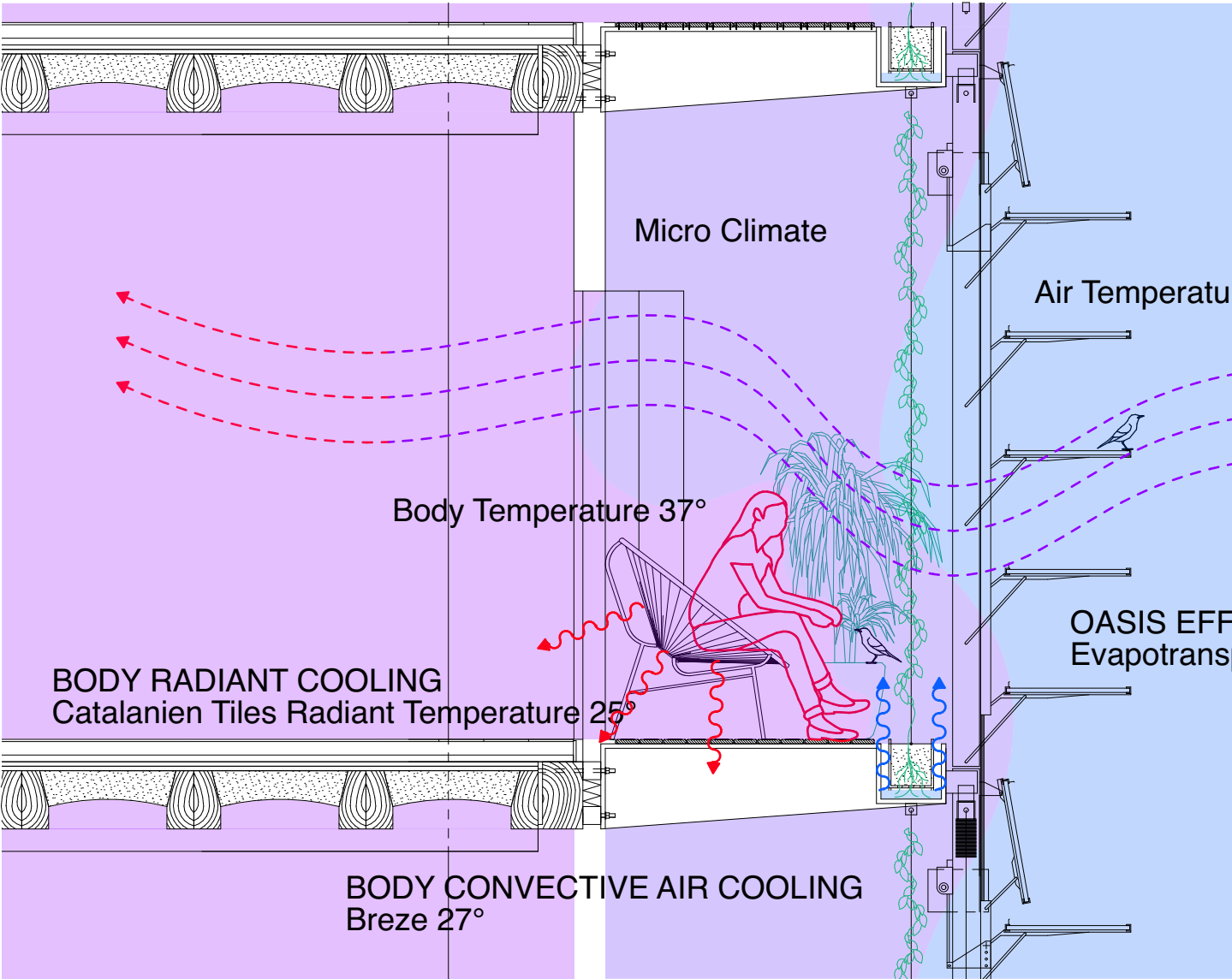
# Model



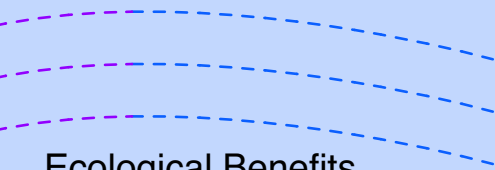




# THERMAL COMFORT & HUMAN SCALE

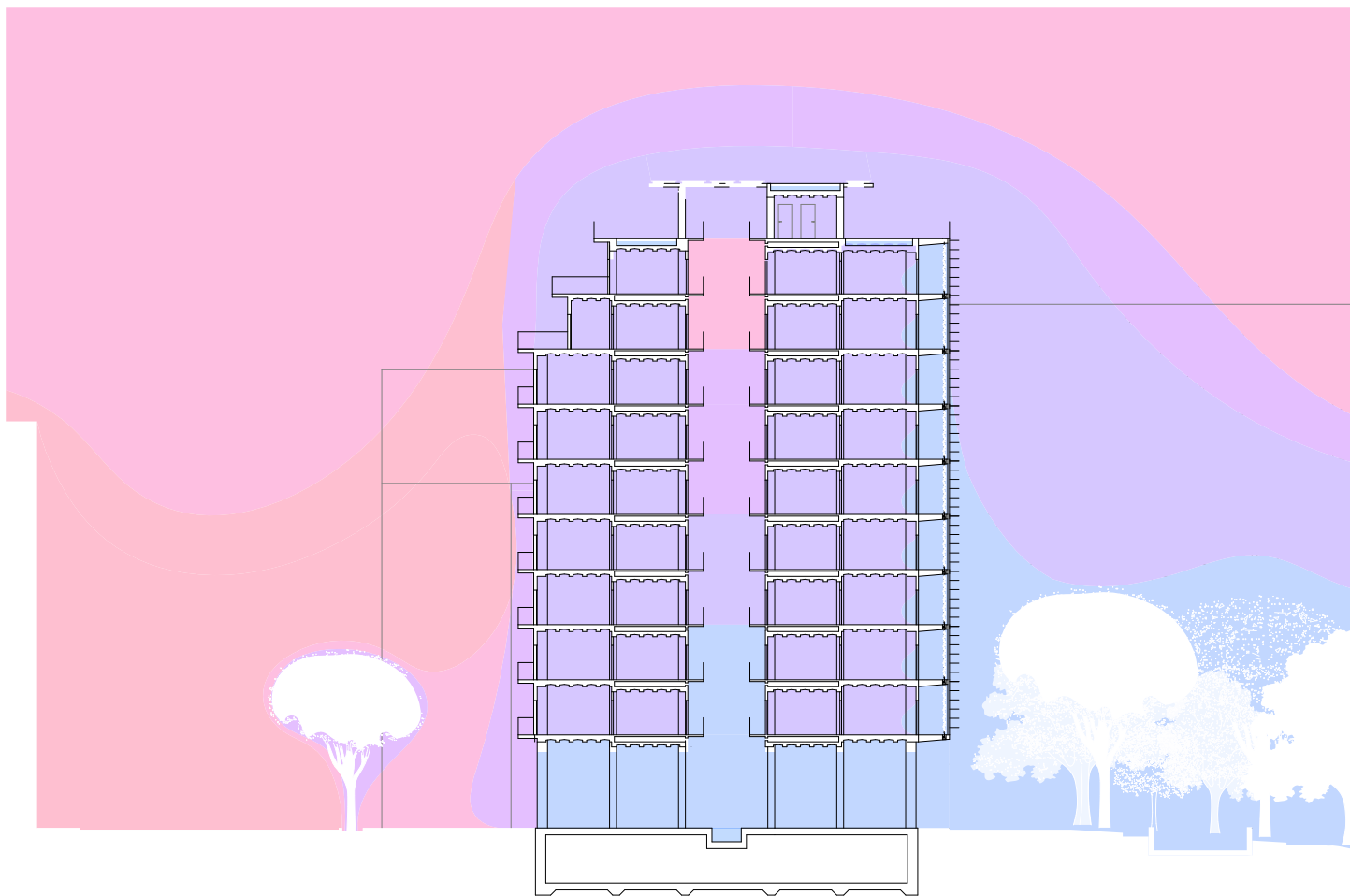


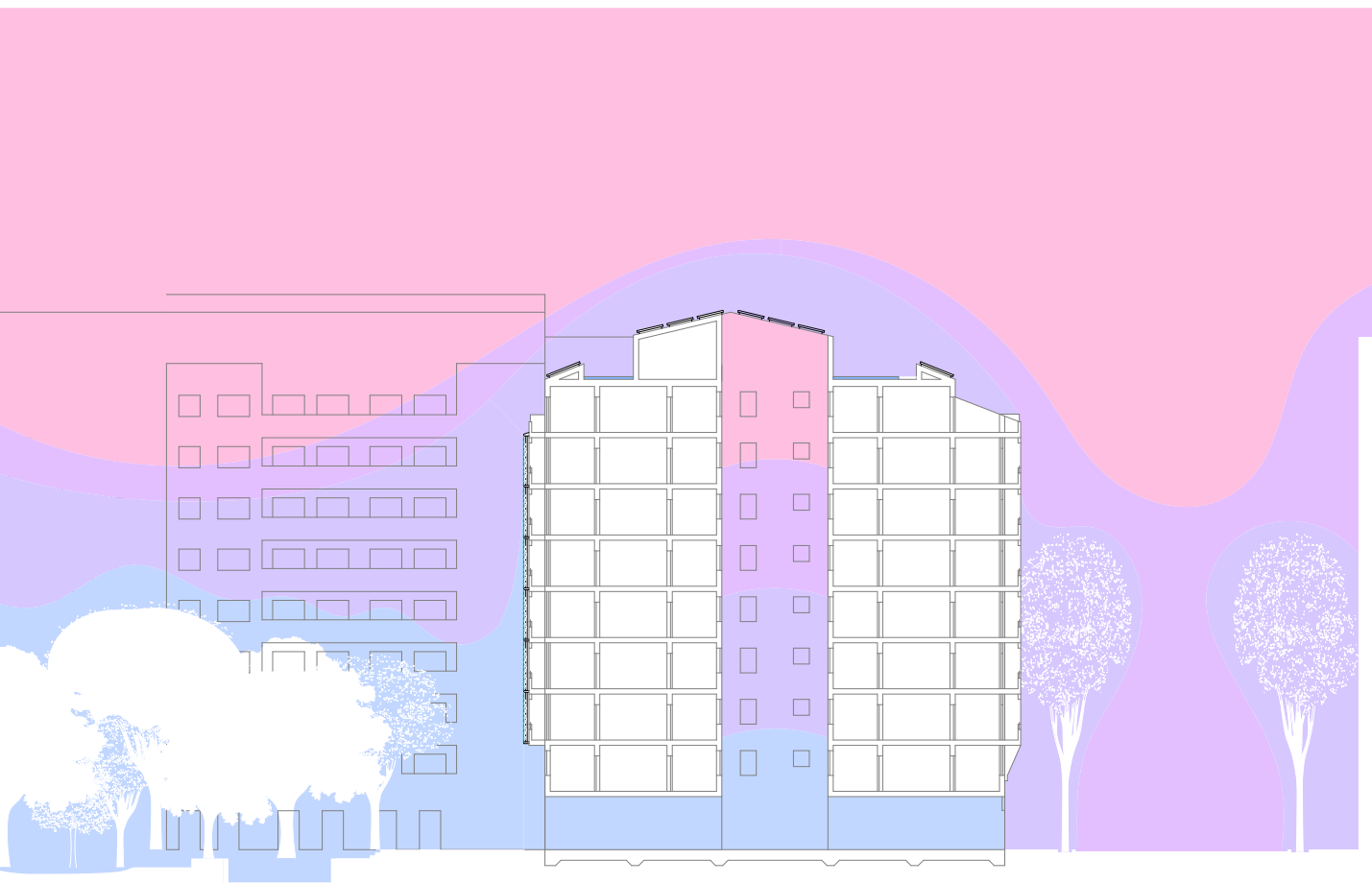
re 27°



Ecological Benefits

ECT  
pirative Cooling









## PART IV: CONCLUSION AND DISCUSSION

# CONCLUSION

## **The Micro-Scale Imperative.**

While Barcelona is actively investing in macro-scale WSUD strategies to restructure its metropolitan networks, this thesis demonstrates that true climate resilience must be anchored at the micro, domestic scale. The project showcases that only a compound approach, synthesizing circular water metabolism with bio-based passive design, can successfully mitigate the intersecting crises of pluvial flooding, water scarcity, and severe urban heat stress. By positioning the Eixample courtyard as the metabolic core of the block, architecture itself becomes the primary climate infrastructure.

## **The Metabolic Core**

While fundamental rainwater harvesting provides baseline microclimatic buffering, true circularity requires the aggressive separation and cascading of domestic water streams. By biologically filtering light greywater for immediate reuse as service water, and utilizing the courtyard's bio-strata to filter heavy greywater for continuous aquifer recharge, the block ceases to be a passive consumer of potable water and a linear producer of wastewater. Instead, the buildings and the courtyard are transformed into active, decentralized nodes of urban water metabolism. Furthermore, this continuous recharge ensures the underground aquifer functions not just as a massive hydrological reserve, but as the critical thermal sink required for the building's ATES system.

### **Thermodynamic Performance**

As the era of limitless energy and reliance on mechanical HVAC systems ends, architecture must return to passive thermodynamic principles. Harvested and reclaimed water serves as the essential fuel for the courtyard's extensive green facades and bio-shading canopies. Through continuous evapotranspiration, these biological layers provide the most sustainable and highly effective form of microclimatic cooling. When combined with strategic architectural shading and solar reflection, this water-fueled bio-infrastructure radically reduces the thermal load on the block.

### **Architectural Synthesis**

Ultimately, this thesis proves that passive design and systemic retrofitting can be seamlessly integrated into historically dense urban fabrics. By retrofitting existing buildings with secondary cooling shells and reorganizing wet cells around bio-filtered light shafts, the historic structures can be fully woven into this circular system. The insertion of the Lighthouse prototype as the metabolic engine, combined with the revitalized courtyard, demonstrates that complex hydrological engineering need not be hidden. Instead, it can be translated into highly livable, deeply sensory architecture that secures long-term thermal comfort and redefines the urban microclimate.

# IMPLICATIONS & RECOMMENDATIONS

## **Resource Scarcity as Design Driver**

An era defined by the mindset of unlimited, frictionless access to potable water and mechanical energy for heating and cooling is coming to a definitive end. Architecture must do more than simply return to proven passive design strategies; it must actively use resource scarcity as a motivation for spatial innovation. By reclaiming control over complex hydrological and climatic engineering, architects can transform hidden technical problems into visible, socially integrated design solutions that actively improve the everyday experience of the city.

## **A Scalable European Blueprint**

The significance of this project extends far beyond the boundaries of a single Eixample courtyard. Because the dense perimeter block is the foundational urban typology of most major European cities, the “Lighthouse” operates not as an isolated, site-specific intervention, but as a highly adaptable radical prototype. It provides a scalable, actionable blueprint that can be multiplied across the continent, equipping aging, climate-vulnerable cities with the decentralized blue-green infrastructure necessary to build enduring resilience against the worsening Urban Heat Island effect.



# REFLECTION

## **The Research Trap and Prototyping Reality**

To be entirely candid, one of the most significant missteps in my process was remaining in the theoretical research phase for too long before initiating concrete spatial design. This hesitation stemmed from the sheer complexity of hydrological systems and my initial lack of expertise in circular filtration methods. The design process was further complicated by a lack of access to advanced simulation software and the inherent difficulty of physically prototyping live water flows. Ultimately, I struggled to accept that architectural design must often proceed alongside systemic unknowns; my desire for complete technical perfection initially paralyzed my spatial output.

## **Catalysts and Breakthroughs**

The critical turning point in the project was the site excursion to Barcelona. Experiencing the Eixample courtyard in person, observing the city's rhythms, and physically visiting built WSUD projects provided a vital, immediate spatial understanding that abstract research simply could not. This momentum was greatly accelerated by expert consultations: meeting Maria de Mar Perez regarding local WSUD strategies, discussing circular filtration mechanics with Lisa Scholten, and gaining insights into Barcelona's specific architectural constraints from Lorenzo Karasz. Finally, discovering Philippe Rahm's Climatic Architecture provided the missing theoretical link, allowing me to fully and confidently integrate the circular water metabolism with passive thermal comfort.



## **A Blueprint for Resilience**

As I conclude both this project and my academic journey, I take away a profound professional realization. My pursuit of perfectionism has always been, and will likely continue to be, my greatest personal battle. However, this thesis taught me that in the face of an accelerating climate crisis, the built environment cannot afford to wait for the perfect solution, because none exists. Future fitting the Example through architecture for urban survival is exactly what our cities need right now, an actionable blueprint for urban resilience.

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