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Master of Science in Architecture and Urban Design (AUD)

# **BUILDING (WITH) A GREEN SOCIAL INFRASTRUCTURE**

**Nature-Based urban regeneration strategies: the case of  
Villaggio dei Fiori, Milan**

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# ABSTRACT

*Keywords: public space, urban regeneration, local mobility, public housing, resilience, NBS, SUDS*

This thesis, through the lenses of sustainability and innovative technological solutions, aims to address the issue of urban regeneration. Specifically, the proposed project focuses on the public housing neighborhood Villaggio dei Fiori, located in the southwest area of Milan, proposing the redefinition of internal mobility and the redevelopment of the neighborhood's public spaces.

Villaggio dei Fiori represents an urban setting with a strong local identity, created to house World War II evacuees with temporary prefabricated housing called "Case Minime" (minimal homes). This area constitutes a portion of the city that has remained immune to the anthropic pressure suffered by the rest of the metropolis and has potentially valuable features: numerous public green areas, a low-density housing fabric, proximity to essential services, and excellent connections to the rest of the city, thanks in part to the new M4 subway line.

However, these strengths are countered by several critical issues: the failure to comply with current regulations on accessibility and building performance, the deterioration of building envelopes, the mismanagement of public housing stock and public spaces (which has led to the abandonment and alienation of many units), the lack of space for slow mobility and socialization, and the presence of disused structures. Added to all of this is the more general need for the city of Milan to provide new public housing and, consequently, the need to propose new housing by densifying the existing housing stock, capable of

accommodating different segments of the needy population. This need brings with it the question of how such densification can integrate with the preservation of the historical memory of the place and the protection of the environmental and social potential highlighted above.

The proposed project develops from the analysis of the current state of the site, with a focus on the historical, political, and urban planning processes that have determined its current conformation, and the study of successful urban regeneration precedents. The investigation then focuses on identifying the main critical issues from environmental, social and mobility perspectives to develop effective and innovative design strategies. The prohibitive cost of operating and maintaining outdoor spaces will also be considered, as well as urban issues that are widespread not only locally but globally, such as the urban heat island effect and vulnerability to extreme weather events such as water bombs.

To make outdoor spaces more livable and resilient, the application of nature-based solutions and sustainable urban drainage systems are proposed. Strategies include depaving interventions, the introduction of more resilient and easily manageable green spaces, and the creation of multifunctional and flexible public spaces that enhance shared areas with the aim of not only solving critical environmental issues, but also fostering the sociality, safety, and well-being of inhabitants.

Another central aspect of the project concerns improving mobility within the neighborhood, with interventions aimed at reducing vehicular traffic, promoting bicycle and pedestrian paths, and integrating with public transportation networks. This approach, based on the study and application of virtuous precedents, aims to foster a more sustainable, accessible, and safe mobility model, improving the quality of daily travel and connection with the rest of the city.

The last proposal concerns the reactivation of urban micro-attractions, i.e., meeting and aggregation places that can boost sociality within the neighborhood and, at the same time, foster an openness to the outside world. The goal is to recover resources already present within the neighborhood and enhance them, generating new opportunities for exchange and participation.

Through this intervention, the thesis explores the possibilities for transforming the neighborhood, treating it in its entirety as an underutilized urban resource, and demonstrates how it can be activated and enhanced to its full potential. The intent is to offer a replicable model of contemporary urban regeneration, capable of integrating sustainability, technology, and social cohesion into a single design approach.

*(Italian version)*

*Parole chiave: spazio pubblico, rigenerazione urbana, mobilità locale, edilizia popolare, resilienza, NBS, SUDS*

*La presente tesi, attraverso la lente della sostenibilità e delle soluzioni tecnologiche innovative, intende affrontare il tema della rigenerazione urbana. Nello specifico, il progetto proposto si concentra sul quartiere di edilizia popolare Villaggio dei Fiori, situato nella zona sud-ovest di Milano, proponendo la ridefinizione della mobilità interna e la riqualificazione degli spazi pubblici del quartiere.*

*Il Villaggio dei Fiori rappresenta un contesto urbano con una forte identità locale, creato per ospitare gli sfollati della Seconda Guerra Mondiale con alloggi prefabbricati temporanei chiamati "case minime". Questa zona costituisce una parte della città che è rimasta immune dalla pressione*

*antropica subita dal resto della metropoli e presenta caratteristiche potenzialmente preziose: numerose aree verdi pubbliche, un tessuto abitativo a bassa densità, la vicinanza ai servizi essenziali e ottimi collegamenti con il resto della città, grazie anche alla nuova linea metropolitana M4.*

*Tuttavia, questi punti di forza sono controbilanciati da diverse criticità: il mancato rispetto delle normative vigenti in materia di accessibilità e prestazioni degli edifici, il deterioramento degli involucri edilizi, la cattiva gestione del patrimonio immobiliare pubblico e degli spazi pubblici (che ha portato all'abbandono e all'alienazione di*

molte unità abitative), la mancanza di spazi per la mobilità lenta e la socializzazione e la presenza di strutture in disuso. A tutto ciò si aggiunge l'esigenza più generale della città di Milano di fornire nuovi alloggi pubblici e, di conseguenza, la necessità di proporre nuovi alloggi attraverso la densificazione del patrimonio edilizio esistente, in grado di accogliere diversi segmenti della popolazione bisognosa. Questa esigenza porta con sé, tuttavia, la questione di come tale densificazione possa integrarsi con la conservazione della memoria storica del luogo e la tutela del potenziale ambientale e sociale sopra evidenziato.

Il progetto proposto nasce dall'analisi dello stato attuale del sito, con particolare attenzione ai processi storici, politici e urbanistici che ne hanno determinato la conformazione attuale, e dallo studio di precedenti casi di rigenerazione urbana di successo. L'indagine si concentra quindi sull'identificazione delle principali criticità dal punto di vista ambientale, sociale e della mobilità, al fine di sviluppare strategie progettuali efficaci e innovative. Verranno inoltre presi in considerazione gli elevati costi di gestione e manutenzione degli spazi esterni, nonché le problematiche urbane diffuse non solo a livello locale ma anche globale, come l'effetto isola di calore e la vulnerabilità agli eventi meteorologici estremi come le bombe d'acqua.

Per rendere gli spazi esterni più vivibili e resilienti, si propone l'applicazione di soluzioni basate sulla natura e sistemi di drenaggio urbano sostenibili. Le strategie includono interventi di depaving, l'introduzione di spazi verdi più resilienti e facilmente gestibili e la

creazione di spazi pubblici multifunzionali e, soprattutto, flessibili che valorizzino le aree comuni con l'obiettivo non solo di risolvere questioni ambientali critiche, ma anche di promuovere la socialità, la sicurezza e il benessere degli abitanti.

Un altro aspetto centrale del progetto riguarda il miglioramento della mobilità all'interno del quartiere, con interventi volti a ridurre il traffico veicolare, promuovere piste ciclabili e pedonali e integrare le reti di trasporto pubblico. Questo approccio, basato sullo studio e l'applicazione di precedenti virtuosi, mira a promuovere un modello di mobilità più sostenibile, accessibile e sicuro, migliorando la qualità degli spostamenti quotidiani e il collegamento con il resto della città.

L'ultima proposta riguarda la riattivazione delle micro-attrazioni urbane, ovvero luoghi di incontro e aggregazione in grado di stimolare la socialità all'interno del quartiere e, allo stesso tempo, favorire l'apertura verso il mondo esterno. L'obiettivo è quello di recuperare le risorse già presenti nel quartiere e valorizzarle, generando nuove opportunità di scambio e partecipazione.

Attraverso questo intervento, la tesi esplora le possibilità di trasformazione del quartiere, trattandolo nella sua interezza come una risorsa urbana sottoutilizzata, e dimostra come esso possa essere attivato e valorizzato al massimo del suo potenziale. L'intento è quello di offrire un modello replicabile di rigenerazione urbana contemporanea, in grado di integrare sostenibilità, tecnologia e coesione sociale in un unico approccio progettuale.

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# 1. INTRODUCTION

## 1.1. RESEARCH QUESTION, AIMS, AND SCOPE

This thesis investigates the application of Nature Based Solutions (NBS) within urban regeneration processes, with a specific focus on public housing neighbourhoods where socio-spatial fragility and environmental vulnerability tend to overlap. The central hypothesis is that, when designed as integrated systems rather than as pure “greening,” NBS are not only feasible in regeneration contexts but also desirable, as they can simultaneously enhance environmental resilience, everyday habitability, and social cohesion.

The research is guided by the following main question:

**How can nature-based solutions be integrated into urban regeneration projects to simultaneously improve environmental resilience and social cohesion in public housing contexts?**

To respond to this inquiry, the thesis develops an investigation culminating in an applied project for Villaggio dei Fiori; a public housing neighbourhood in Milan characterized by a strong local identity, a low-density fabric and dispersed green areas, yet affected by ageing stock, accessibility deficits, underused open spaces, and mobility conflicts.

Beyond demonstrating the desirability of NBS in this context, the thesis also pursues a methodological aim: to outline a design process that is replicable in comparable urban conditions. Replicability is not intended as a formal model to be reproduced, but as a structured workflow based on integral site analysis, performance-oriented objectives and implementable strategies.

## 1.2. WORK STRUCTURE

The thesis adopts a design-led research approach, using the project not as a mere outcome but as a form of demonstration. The central argument is developed through a traceable sequence that connects evidence, site analysis, strategy selection, and expected co-benefits.

To make this process explicit, the thesis is organized into a *Theoretical framework* and a *Project application*, followed by *Conclusions*.

The *Theoretical framework* situates the work within a broader urban debate on contemporary challenges and tendencies affecting cities: climate risks, inequalities, and policy drivers; framing urban regeneration as a socio-environmental process. It then introduces NBS and SUDS as operational approaches, clarifying definitions, mechanisms and co-benefits. Selected precedents are presented as an evidence base, thus providing a scientific rationale for subsequent design decisions.

The *Project application* translates these findings into a regeneration proposal for Villaggio dei Fiori. Starting from a multi-faceted analysis and the definition of design objectives, a concept is then articulated through a strategy set, addressing implementation feasibility and performance assessment.

The *Conclusions* summarize the outcomes in relation to the research question, discuss limits and trade-offs, and outline future directions for further research and potential transfer to similar public housing contexts.



# **2. THEORETICAL FRAMEWORK**

## 2.1. CONTEMPORARY CITIES: CHALLENGES, POLICY DRIVERS, AND REGENERATION RECOMMENDATIONS

Urban regeneration has become the primary arena in which European cities negotiate a triple transition: climate adaptation, decarbonization, and social inclusion. Rather than acting through greenfield expansion, contemporary planning increasingly confronts the inherited city with its sealed surfaces, ageing building stock, and uneven access to welfare, where hazards, exposure, and vulnerability overlap.

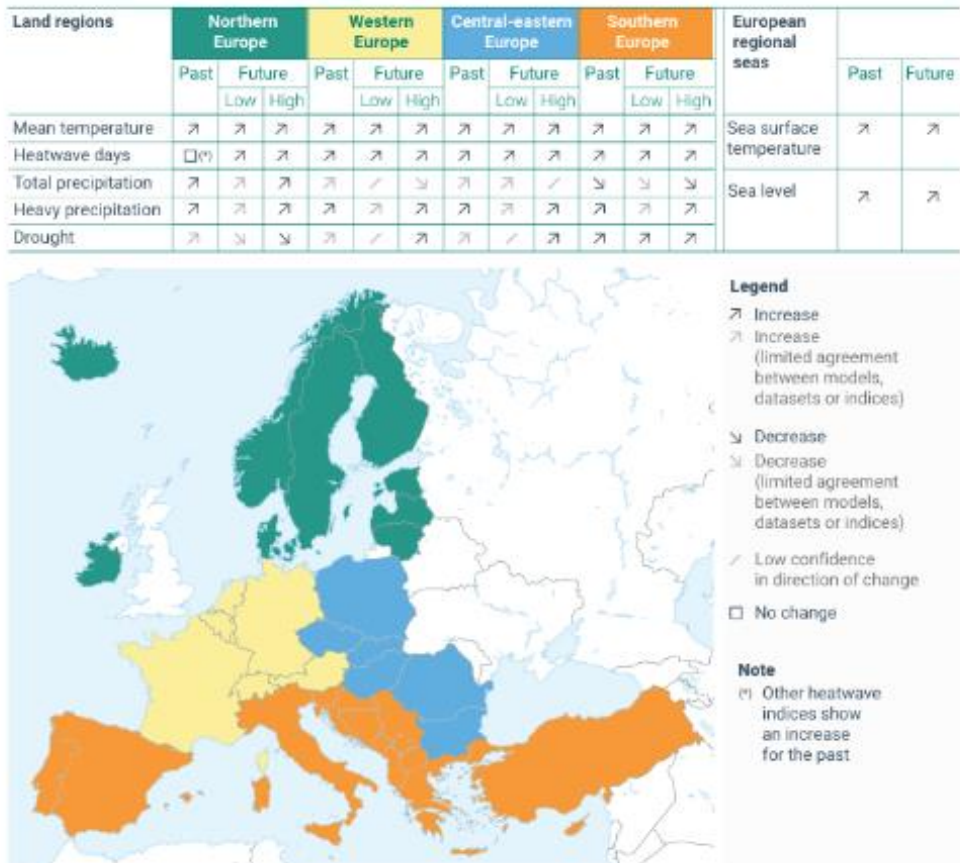


Figure 1 Observed and projected trends in key climatic risk drivers in different European regions. Source: Copernicus Climate Change Service (C3S).

## 2.1.1. Risk convergence, land consumption, and the urgency of the existing city

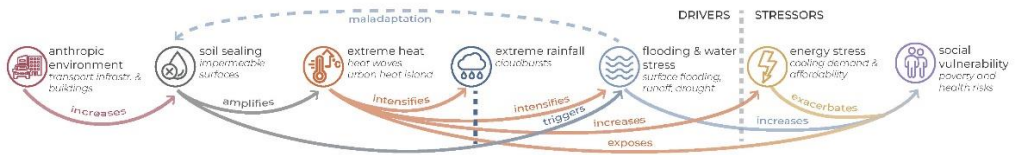


Figure 2 Climate risk convergence diagram.

European assessments describe urban climate impacts as compound conditions: rising heat stress, intensified precipitation, and infrastructural limitations co-produce disruptions that are experienced both as acute events and as chronic discomfort (EEA, 2024).

Heat is especially critical in Europe, where impacts are expected to intensify and interact with demographic ageing and inequality, turning adaptation into a structural public health and welfare issue.

Intense rainfall, in parallel, exposes the mismatch between sealed urban morphologies and drainage capacity: imperviousness accelerates runoff and concentrates peak flows, amplifying pluvial flood risk and maintenance burdens in dense neighbourhoods.

On top of this, the urgency of acting “inside” the existing city is reinforced by land and soil dynamics. Soil sealing reduces infiltration and ecosystem functions and contributes to flooding risk, biodiversity loss, and warming effects (EEA, 2024).

In Italy, national monitoring confirms that soil consumption remains significant and produces measurable ecosystem-service costs (ISPRA/SNPA 2024). For urban regeneration, the

implication is methodological: the city should be treated as an already-built resource, where adaptation and environmental repair occur primarily through reworking streets, open spaces, and underperforming fabrics rather than through further land take.

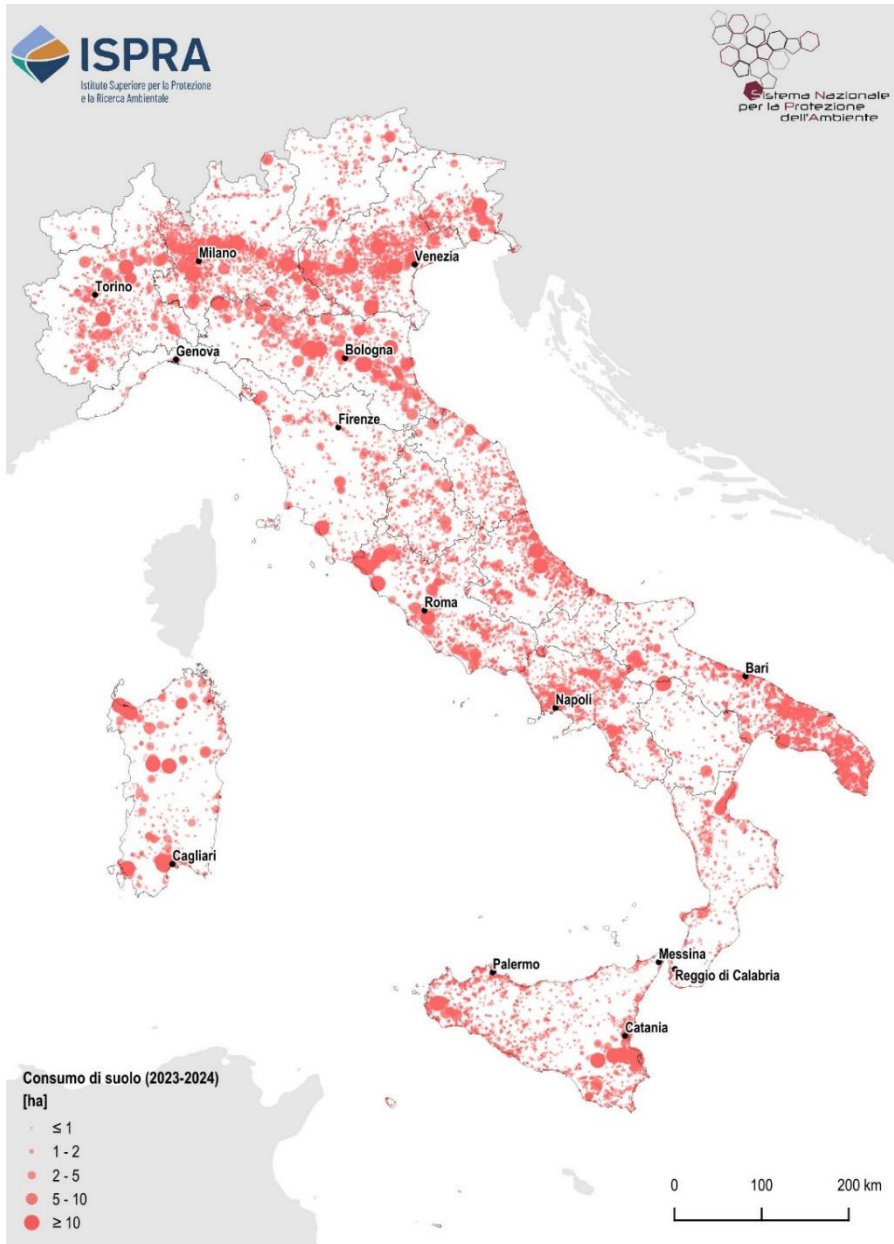


Figure 3 Soil consumption (2023/24) in Italy. Source: ISPRA.

### **2.1.2. Energy transition, renovation urgency, and local self-production**

Further endorsement concerns energy. European policy increasingly positions building renovation as a key decarbonization lever: the revised Energy Performance of Buildings Directive entered into force on May 28<sup>th</sup> 2024 and aims to accelerate renovation (European Commission, 2024). In regeneration settings, nonetheless, energy performance cannot be reduced to a technical upgrade: it intersects with affordability, governance capacity, and equity, especially in public housing. Models of collective self-production are consequently strategically relevant. The European Commission frames energy communities as legal entities enabling citizens, small businesses, and local authorities to cooperate in producing, managing, and consuming clean energy (European Commission, 2024). For design practice, the key implication is that energy strategies gain credibility when they are spatially anchored (e.g., public buildings and shared facilities) and institutionally feasible, rather than treated as abstract technological add-ons.

### **2.1.3. European policy drivers: experimentation, co-design, replication**

These challenges are addressed by European frameworks that increasingly support the use of NBS, pushing cities to treat ecological processes as part of their operational infrastructure.

#### **1. European Commission NBS framework**

At policy level, the European Commission explicitly defines NBS as systemic interventions that deliver environmental, social, and economic benefits simultaneously. This framing is important for regeneration practices because it legitimizes NBS as a category that can be linked to welfare outcomes.

#### **2. Horizon Europe and EU Missions**

Within Horizon Europe, NBS are tested and assessed through funded research and innovation actions. In this context, the value of EU funding is not only financial: it structures NBS as a field where benefits must be evidenced, impacts monitored, and solutions designed for transferability.

#### **3. Climate-ADAPT (EEA)**

The European Environment Agency (EEA) supports NBS diffusion through Climate-ADAPT, a platform that consolidates guidance, examples, and resources specifically for adaptation and resilience. Its role differs from research funding: Climate-ADAPT primarily operates as a translation device: it turns dispersed precedents into structured knowledge, often through documented case studies and key actions, helping local authorities and practitioners.

#### **4. Covenant of Mayors**

The EU Covenant of Mayors supports cities through methodological guidance and resources to plan, implement, and monitor adaptation actions.

This initiative matters for regeneration because it encourages a governance culture in which climate strategies are structured plans that require reporting and coherence over time.

### **5. European Urban Initiative / UIA legacy**

Urban Innovative Actions and its successor framework within the European Urban Initiative support cities in experimenting with bold solutions in real urban contexts, including the thematic area of nature-based solutions. This program family differs from strategic policy frameworks because it explicitly funds prototyping and piloting, allowing urban authorities to test spatial typologies, governance settings, and community engagement models before scaling them into standard practice.

### **6. New European Bauhaus**

Finally, the New European Bauhaus adds a cultural and qualitative layer to European transition agendas by promoting sustainability together with inclusivity and spatial desirability. Its relevance lies in shifting the discourse from “environmental compliance” to public acceptance and everyday value, reinforcing the idea that climate-adaptive spaces must also function as civic infrastructures capable of building trust and belonging.

Overall, European policy drivers provide not a single prescription, but a coordinated ecosystem: definitions and mainstreaming (Commission NBS), research and assessment (Horizon Europe), actionable knowledge (Climate-ADAPT), local planning commitments (Covenant of Mayors) and pilot experimentation (EUI/UIA), complemented by a design-quality narrative (New European Bauhaus). This multi-channel support explains why NBS today can be treated as credible instruments for urban regeneration.

#### 2.1.4. Milan as a project laboratory

Milan represents a particularly coherent local context in which European transition agendas are translated into planning objectives, municipal guidelines, and public works programs. For the purposes of this thesis, the city is treated as a “project laboratory” not because it provides ideal conditions, but because it offers a real institutional environment where climate-adaptive public space, mobility reform and housing-related pressures intersect.

At the strategic level, the **PGT Milano 2030** consolidates a shift from expansionary logics toward regeneration, positioning the urban ground as a key medium for adaptation. The plan frames the city as a *common good*, links environmental performance to neighbourhood liveability, and endorses a transition toward more sustainable mobility patterns and public-space rebalancing (Comune di Milano, 2020). In this framework, NBS are not an external agenda: they align with a planning vision that increasingly treats permeability, canopy coverage, and water management as urban performance requirements rather than voluntary improvements.

Within this horizon, two municipal initiatives are especially relevant to the thesis because they represent operational drivers that directly enable the kind of spatial reallocation needed for the project application.

The first is **Möves** (Active Mobility Guidelines). This program is significant because it frames walking and cycling as structural elements of urban welfare and safety, shifting active mobility from a transport niche to a public-space paradigm. The initiative is also notable for its participatory development process (November 2024 - April 2025), which collected extensive public input and strengthened the political legitimacy of reallocating



The second is **Città Spugna**, announced in January 2026 as a set of twenty-seven interventions aimed at depaving and introducing water-managing surfaces. The program is relevant because it explicitly frames climate adaptation as a distributed, surface-based project. Città Spugna provides an institutional context in which depaving and water-sensitive public space are becoming part of an accepted municipal vocabulary.

At the same time, Milan's laboratory condition also requires critical reading of programs whose outcomes are more ambiguous once the focus moves from announcements to long-term performance.

**Piazze Aperte**, for example, has been widely recognized as an agile tactical urbanism tool for reclaiming space and testing new public-space uses. Still, the tactical nature that makes it scalable also introduces limitations. Several observations raised by monitoring accounts suggest that paint-based interventions can deteriorate rapidly when maintenance is inconsistent, reducing the durability of their spatial message over time and weakening public trust in transformation (Clean Cities Campaign, 2024). This does not mean that tactical urbanism is ineffective; rather, it clarifies that such interventions contribute to a broader agenda only when they operate as a transition phase toward structural retrofits in the composition of the city.

Similarly dual interpretation applies to **ForestaMi**, which frames canopy cover expansion as an adaptation and mitigation tool and mobilizes civic and institutional participation around tree planting (Forestami, 2023). Yet the program's credibility depends not on the number of planted trees, but on survival rates of the plants and long-term maintenance. Press coverage and reporting have highlighted mortality figures in specific seasons, pointing to irrigation and maintenance as the decisive factor

behind whether tree-based strategies translate into climate benefits (Mingoia, 2022; MasterX IULM, 2023). This tension is crucial for the thesis: it shows that urban forestry is not simply a matter of planting targets, but of maintenance regimes, soil suitability, and governance continuity.

In synthesis, Milan offers a favorable policy direction for this research, yet it also demonstrates why execution must be assessed critically. Interventions can be ambitious and still underperform if maintenance and governance remain weak links, or if transformation is communicated as imagery rather than embedded in a strong, incremental organization.

Against this policy background, the following section clarifies the operational definition of Nature-Based Solutions used in the thesis, translating strategic aspirations into measurable mechanisms and design principles.

## 2.2. SUSTAINABLE URBAN REGENERATION PRACTICES: NBS AND SUDS AS AN INTEGRATED TOOLBOX

Urban regeneration today suggests a comprehensive and multi-layered approach, capable of addressing environmental, social, and economic challenges simultaneously. In this context, the concept of sustainability not only implies the application of Nature Based Solutions (NBS) and Sustainable Urban Drainage Systems (SUDS); it extends to a wider range of good practices that integrate ecological, technological, and social dimensions in the design.

NBS and SUDS represent essential instruments within this broader toolbox; they promote ecosystem services, enhance resilience<sup>1</sup>, and mitigate the effects of climate change<sup>2</sup> by managing water, heat, and encourage biodiversity through natural and hybrid systems. Yet, achieving sustainable regeneration also depends on complementary strategies that address issues not related to ecological processes, but equally significant for the livability and functionality of urban environments.

These include interventions such as the reorganization of local mobility networks, the redesign of public spaces for social interaction, the integration of renewable energy systems and implementation strategies to make interventions feasible and resilient.

So, the research adopts an inclusive definition of sustainable urban design practices; it investigates how a combination of NBS, SUDS and other design strategies can generate synergistic

benefits; this perspective will guide the selection and evaluation of the case studies presented in the following chapter.

### **2.2.1. Nature Based Solutions**

Nature Based Solutions are actions inspired and supported by nature which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring diverse natural features and processes into a variety of landscapes through locally adapted, resource-efficient, and systemic interventions (European Commission, n.d.).

NBS are not mere greening; they are interventions expected to deliver performance: cooling and shading, rainwater management, air quality improvement, and biodiversity enhancement. Besides their ecological functions NBS have the capacity of producing additional co-benefits like increased perceived safety and comfort, support physical activity and socialization, added aesthetic value and even energy saving when applied to buildings. In the context of urban regeneration, their relevance lies in the possibility of embedding these functions into shared spaces like streets, courtyards, squares, parks, and public buildings.

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<sup>11</sup> The capacity of a socio-ecological system to cope with a dangerous event or anomalies by reacting and reorganizing in ways that preserve its essential functions, identity, and structure, while also maintaining its capacity for adaptation, learning, and transformation. (Dessi, Farnè, Ravanello, & Salomoni, 2017)

<sup>22</sup> This term refers to a change in the state of the climate that persists for an extended period (decades) and can be identified by changes in the average and/or variability of its properties. Climate change can be caused by internal natural processes or external forces, such as anthropogenic changes in the composition of the atmosphere and land use. (Dessi, Farnè, Ravanello, & Salomoni, 2017).

## 2.2.2. Sustainable Urban Drainage Systems

Within the broader NBS family, Sustainable Urban Drainage Systems are more water-focused solutions that manage rainfall close to where it falls. They can be designed to transport (convention and channeling), slow runoff before it enters watercourses, provide areas to store water (detention), allow water to soak (infiltration) into the ground, evaporate or transpire from vegetation (evapotranspiration) as well as encourage attenuation of contaminants to improve water quality (filtration and fito-depuration). (CIRIA, 2023)

Rather than accelerating runoff into sewer networks, SUDS aim to slow, store, and treat water through distributed surface and subsurface devices such as rain gardens, swales, permeable pavements, tree trenches, or floodable public spaces. In regeneration contexts, this logic is particularly relevant because it can be integrated into incremental street and open space redesign without requiring full replacement of underground networks.



Figure 6 NBS and SUDS concept diagram.

### **2.2.3. Complementary strategies: mobility, materials, and energy**

The effectiveness of NBS in consolidated neighbourhoods depends on complementary practices that enable spatial capacity and long-term feasibility. First, mobility reallocation is treated as a precondition: reducing vehicular dominance and reorganizing parking and street hierarchies creates the space needed for soil volumes, canopy continuity, and permeable surfaces. Second, material strategies, including depaving, reflective or cooler pavements, support both thermal comfort and water management. Third, energy-oriented practices expand the regeneration toolbox beyond ecological processes: renewable self-production and collective models such as Renewable Energy Communities can support decarbonization while addressing affordability and governance feasibility, particularly when anchored to public buildings and managed assets.

## 2.3. EVIDENCE BASE: PRECEDENTS AND TRANSFERABLE DESIGN PRINCIPLES

This section builds the evidence base through which the thesis translates the general claim of sustainable urban regeneration into a set of transferable design principles. Rather than compiling a broad catalogue of “best practices,” the precedents are treated as operational knowledge: each case is read to understand how environmental performance, public space quality, mobility change and long-term impact can be combined.

### **2.3.1. Selection criteria and comparative method**

The case study set was selected according to five criteria. First, contextual relevance: projects implemented in consolidated urban fabrics where transformation is incremental and must coexist with everyday life. Second, multi-benefit orientation: interventions that explicitly connect environmental functions to social outcomes such as comfort, safety, and the activation of public space. Third, transferability: solutions based on robust and reproducible design moves (e.g. depaving, modal filtering, floodable typologies). Fourth, evidence availability: preference was given to projects supported by institutional documentation, professional reports, or peer-reviewed research.

The results are presented as case study boxes and consolidated into a comparative matrix used to extract transferable principles for the project application.

### 2.3.2. Domains and reasons for inclusion

The selected precedents are grouped into four domains that mirror the thesis' integrated strategy set: SUDS as public infrastructure; NBS-driven public space regeneration; mobility transitions as enabling conditions for NBS; and socio-technical governance through energy-oriented collective models.



Figure 7 Mapping of selected precedents.

## **Mobility redesign as enabling condition for NBS**

**1. Carlsberg City District (Copenhagen)** was selected as a large-scale urban transformation where mobility is planned as a multi-modal network prioritizing walking, cycling, and public transport, supported by dedicated infrastructure (bicycle paths, metro and commuter rail stations) and by parking strategies placed underground.

**2. ZOB Europaplatz and Seeterrasse (Tübingen)** was chosen as a precedent for the reconfiguration of a mobility hub as a piece of urban public space. The project integrates barrier-free accessibility, improved station connections, bicycle facilities, and landscape upgrades, showing how mobility infrastructure can be transformed into a civic landscape rather than producing residual, hostile spaces.

## **SUDS as public space and “visible hydrology”**

**3. Waterplein Benthemplein (Rotterdam)** was selected as a paradigmatic dual-use typology: a set of public squares designed to function as an everyday urban space while temporarily storing stormwater during heavy rainfall. Its relevance lies in the explicit coupling of hydraulic function and civic program, and in the funding logic that mobilized water-management resources to finance high-quality public space.

**4. Elsa Eschelsson’s Park (Uppsala)** was selected as a clear example of a rain park where stormwater management is not hidden underground but spatially legible and integrated into everyday recreation. The park’s rain pond and flood-tolerant leisure surfaces

demonstrate how planned inundation can be normalized as part of public life.

**5. Augustenborg (Malmö)** Augustenborg is a vital example because it frames SUDS as a district-scale retrofit strategy linked to neighbourhood regeneration. It demonstrates that distributed, open stormwater systems can address recurrent flooding while upgrading public space and reinforcing local identity.

### **NBS-driven public space regeneration: from traffic space to social infrastructure**

**6. Sønder Boulevard (Copenhagen)** provides evidence for the transformation of a traffic-oriented urban corridor into a continuous green public space that supports daily life and neighbourhood cohesion. Its relevance for the thesis lies in the reconfiguration of a linear public path into a social spine where planting, program, and everyday movement are co-designed.

**7. Gata Grønland (Oslo)** was picked as an explicit experiment in reimagining a main street without cars, replacing asphalt dominance with trees, seating, and biodiversity-oriented features, while increasing the capacity for everyday urban life. The case is methodologically important because it illustrates the role of temporary-to-permanent approaches and the use of public-life experiments to generate legitimacy and acceptance for reallocation.

**8. Sankt Kjeld's Square & Bryggervangen (Copenhagen)** is a direct precedent for integrating climate adaptation into the identity of everyday public space. It demonstrates that cloudburst response can be implemented through ordinary streets and squares,

turning adaptation into an intelligible civic project rather than an invisible technical layer

## **Energy and socio-technical governance: from efficiency to collective infrastructures**

**9. Vauban District (Freiburg)** remains a key precedent for the energy and governance layer: it is widely documented as an eco-district where low-energy building standards, solar technologies, and a car-reduction concept were embedded in the development process, supported by participatory dynamics and district-scale infrastructures. While its socio-technical conditions cannot be transferred directly, Vauban provides a reference for how energy, mobility, and public space can be aligned within a coherent district vision.

**10. Magliano Alpi REC (Italy)** is included to ground the energy dimension in a concrete Italian governance context. It demonstrates that collective self-consumption depends on both technical and geographical aspects and organizational capacity, reinforcing the thesis idea of infrastructure as simultaneously physical and social.



## 1. Carlsberg City District

**Designers:** 1:1 Landskab

**Year:** 2017-2024

**Location:** Copenhagen, Denmark

**Status:** on-going (phased construction)

### **Key design elements:**

- network of connected streets/nodes supporting slow mobility continuity
- integration of “behavioral infrastructure” (thresholds, legibility, continuity)
- phased construction approach

### **Benefits:**

- increased walkability
- cycling continuity
- heightened safety
- unlocked space for canopy coverage

*In the previous page: Figure 8 View of the station forecourt. Source: [landezine.com/carlsberg-city-district-by-11-landskab/](http://landezine.com/carlsberg-city-district-by-11-landskab/)*

## **Spatial strategy**

At Carlsberg Byen, the mobility concept is embedded in an urban heritage realm rather than treated as a separate layer. The station forecourt (Tapperitorvet) is designed as a multi-modal interchange where pedestrian flows, bus lanes, and a bicycle “highway” are spatially legible and mutually compatible. A key spatial move is the use of continuous pavement treatment while still differentiating movement types through subtle cues. This produces a “shared” square that remains coherent as a unit, yet operationally readable as an interchange with distinct corridors for walking, cycling, waiting, and cars.



*Figure 9 Continuity of paving and differentiation through color. Source: [landezine.com/carlsberg-city-district-by-11-landskab/](http://landezine.com/carlsberg-city-district-by-11-landskab/)*

## **Deployed technology**

The project’s primary technology is material coding and wayfinding by paving. Different brick colors delineate pedestrian zones, cycle paths and areas for stopping or bicycle parking; an approach that uses the ground plane as an information system rather than relying on excessive signage. Where level changes

occur, the design deploys plinth-like elements that serve simultaneously as edge definition and seating: a low-tech but exceptionally durable mobility interface.

### **Feasibility logic**

Feasibility is demonstrated through the alignment of mobility performance with heritage-led place quality. By tying materials, colors, and patterns to historic references like the nearby brewery architecture, the mobility system becomes politically and culturally acceptable.



*Figure 10 Materiality of the historic breweries as inspiration for the intervention. Source: [homeofcarlsberg.com/stories/guide-to-carlsberg-byen](https://homeofcarlsberg.com/stories/guide-to-carlsberg-byen)*

### **Transferable lessons**

First, modal coexistence can be achieved through legibility rather than physical separation: colors and patterns on paving can function as a soft modal filter, guiding behavior while preserving spatial unity. Second, interchange spaces benefit from being treated as public rooms: if mobility infrastructure is designed as public realm, it can attract investment, strengthen identity, and reduce conflicts between modes. Third, designing accessibility as a place-making device (plinths that are also seating, ramps that are also urban edges) can raise both functional performance and everyday comfort.



## 2. ZOB Europaplatz & Seeterrasse

**Designers:** bhmp architekten

**Year:** 2024

**Location:** Tübingen, Germany

**Status:** Completed

### **Key design elements**

- Intermodal hub redesigned as civic microclimate with barrier-free continuity
- Unified ground plane + clear wayfinding to reduce conflicts
- Landscape gradient mediating infrastructure and public realm

### **Benefits:**

- accessibility
- orientation
- comfort for waiting/meeting
- green integration (microclimate co-benefits)

In the previous page; Figure 11 Aerial view of the station. Photo credits: Nikolai Benner, Beate Gohs-Haas

## **Spatial strategy.**

The redesign of Tübingen's central bus station precinct is structured around a clear intermodal sequence: bus platforms, station forecourt, bicycle infrastructure, and the lakeside terrace are reconnected into a coherent urban corridor. Rather than expanding capacity through additional traffic space, the project reorganizes movement by defining a comprehensible spatial order; most notably by establishing a new station square and placing cycling as a defining edge condition to the bus station. The "Blue Ribbon" (a high-priority cycle corridor) forms the northern boundary of the ZOB and crosses the bus station at controlled points. This is complemented by barrier-free access achieved through careful manipulation of elevations: the base of the station building is partially filled to enable stair-free entry while respecting monument protection constraints.



*Figure 12 Competition masterplan. Credits: bhmp architekten.*

## **Deployed technology**

Here, mobility is enabled through a combination of architectural devices and surface-based guidance. The Blue Ribbon operates simultaneously as infrastructure and wayfinding: it is explicitly described as a continuous, fast, and safe east–west cycling route, approximately 1.5 km long and 4m wide. It is connected to the new Radstation, that integrates a ramp to an underground bicycle garage and concentrates services like repair, rental, additional parking; thereby transforming cycling from an “add-on” into a fully serviced transport mode.

## **Feasibility logic**

Viability is underpinned by a governance and funding rationale that frames cycling infrastructure as climate policy. The “Blaue Drehscheibe Tübingen” programme identifies the station area as an east–west bottleneck and positions the intervention as barrier removal for pedestrians and cyclists, supported through the federal program “Klimaschutz durch Radverkehr” with a stated funding amount of €4,813,781 and a project period running from 2020 to 2024.


This coupling of spatial redesign with climate-mobility funding reduces implementation risk and helps justify space reallocation.

## Transferable lessons



*Figure 13 View of the Blue Ribbon. Photo credits: Nikolai Benner, Beate Gohs-Haas*

The first lesson is that cycling corridors gain legitimacy when they are spatially explicit and continuous: a named, visually coherent route can function as both infrastructure and behavioral guidance. Second, multi-modality benefits from “service anchoring”: concentrating repair, rental, and secure parking at the interchange increases the practical competitiveness of cycling for everyday trips. Third, accessibility upgrades can be delivered through subtle level reconfiguration that respects heritage constraints, demonstrating that universal design and monument protection need not be in conflict.



### 3. Waterplein Benthemplein

**Designers:** De Urbanisten

**Year:** 2013

**Location:** Rotterdam, Netherlands

**Status:** Completed

**Key design elements**

- Dual-use square: daily public space + stormwater storage
- Clear hierarchy of basins and higher dry zones

**Benefits:**

- peak-flow control
- multifunctionality
- acceptance via visibility
- public-space upgrade

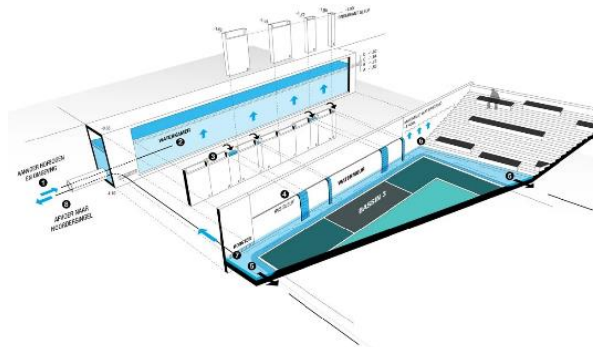
*In the previous page: Figure 14 View of the area with the three squares. Photo credits: Ossip van Duivenbode, Pallesh+Azarfane and Jurgen Bals.*

## **Spatial strategy**

Bentemplein is structured as a deliberately transformable public space that oscillates between the functions of square and temporary storage landscape. The core spatial concept is to make stormwater management visible and socially accepted by embedding storage basins within an everyday recreation setting. This results in a public space that performs hydrologically during heavy rainfall while functioning as a neighbourhood amenity during sunny conditions. The square's hydraulic logic is articulated through three basins with differentiated frequencies of use: two shallower basins capture runoff from the immediate surroundings more regularly, while a deeper basin activates during sustained rainfall.

## **Deployed technology**

The project deploys a surface-based drainage and storage system rather than hidden, pipe-only infrastructure. Water is directed across the square into the basins, allowing users to perceive the dynamics of rainfall and retention. In district-scale terms, Bentemplein is reported as having a storage capacity of 1,800 m<sup>3</sup> and a project cost of approximately €4 million, funded through a combination that includes the City of Rotterdam, water boards, and additional European/Dutch sources (Peinhardt 2021).



*Figure 15 Functioning of the main watersquare. Credits: De Urbanisten.*

## **Feasibility logic**

The feasibility logic rests on multifunctionality as a mechanism for unlocking investment. Rather than justifying expenditure as “drainage infrastructure,” the project makes public spending politically legible by turning storage into high-quality public space. This aligns with Rotterdam’s approach of integrating climate adaptation into placemaking and district strategies. By delivering measurable water management capacity alongside everyday recreational value, the square reframes stormwater spending as a dual-return investment in risk reduction and social infrastructure, improving the likelihood of replication and long-term maintenance.

## **Transferable lessons**

The project demonstrates that SUDS can be most robust when designed as a public program rather than an engineering afterthought. Three specific lessons are transferable: differentiated storage compartments allow a communicative relationship between rainfall intensity and spatial activation, building public understanding while improving performance; visibility can be functional and by making flow paths legible, the design reduces misuse and helps communities anticipate water behavior; and finally, embedding storage within everyday recreation increases acceptance and can broaden funding coalitions beyond utilities to include urban development and public space budgets.



## 4. Elsa Eschelsson's Park

**Designers:** Karavan landskapsarkitekter

**Year:** 2022

**Location:** Uppsala, Sweden

**Status:** Completed

### Key design elements

- Graded topography for controlled floodability
- Flood-tolerant planting
- Active programs integrated into hydraulic landscape

### Benefits

- detention/storage
- water purification
- active public space

*In the previous page; Figure 16 View of the phytodepuration pond. Photo credits: Jann Lipka.*

## **Spatial strategy**

Elsa Eschelsson's Park is conceived as a multifunctional landscape that choreographs water as an experiential and spatial organizer. The park is explicitly structured around three interrelated components: a green area, a stormwater pond and a skatepark. The spatial logic depends on designed overflow: during heavier events, water expands beyond the pond into adjacent surfaces.



*Figure 17 Plan of the park. Credits: Karavan landskapsarkitekter.*

## **Deployed technology**

The project combines above-ground storage, controlled overflow thresholds, and infiltration capacity in vegetated areas. Quantitatively, the pond is reported to store approximately 790 m<sup>3</sup> of water, while the adjoining activity surface can store an

additional 750 m<sup>3</sup> during major events. In operational terms, the design anticipates exceedance: stormwater overflows into green areas during events beyond a 10-year rainfall, and infiltration in lawn areas is presented as a contributor to improved groundwater balance. This layered storage strategy resembles the logic of communicating vessels, where capacity is distributed across connected surfaces.

### **Feasibility logic**

Feasibility derives from the integration of water functions into a publicly valued program, reducing the risk that the water system is later “engineered out” or treated as residual space. By pairing a day water pond with skate/bike and sport-compatible surfaces, the project makes climate adaptation legible as a civic amenity rather than a technical constraint.

### **Transferable lessons**

This project suggests that small-to-medium urban parks can provide substantial storage if multifunctionality is designed from the outset. A key lesson is that the activity surface should not be treated as compromised “flood space,” but as a deliberately shaped secondary basin whose periodic inundation is compatible with use and materials. Additionally, the reliance on controlled exceedance and infiltration points to a pragmatic strategy for climate uncertainty: instead of designing for a single event magnitude, the park performs across a spectrum, with clear spatial signals that communicate when and where water will move.



Figure 18 The skatepark during dry and wet conditions. Photo by Jann Lipka, simulation by Karavan landskapsarkitekter.

A multi-story apartment building with a courtyard. The building has a mix of light-colored and orange-brown panels. The courtyard features a water feature with large rocks and a willow tree. The text is overlaid on the image.

## 5. Augustenborg Eco-city

**Designers:** municipal offices + housing company cooperation

**Year:** 1998–2002

**Location:** Malmö, Sweden

**Status:** Completed

### Key design elements

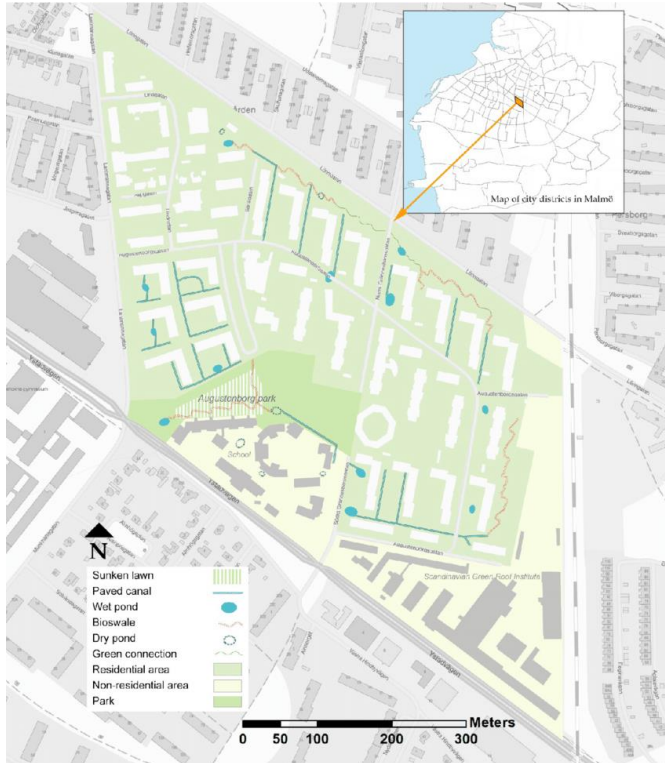
- Distributed open stormwater network
- Courtyard integration: devices embedded in everyday landscapes
- Hybrid logic: storage + visible conveyance + controlled overflow

### Benefits:

- reduced flooding/CSO pressure
- greener courtyards
- scalable network logic

In the previous page: Figure 19 View of one of the ponds. Photo credits: GRaBS.

## Spatial strategy



Augustenborg's stormwater strategy is fundamentally a district retrofit: rather than expanding pipe capacity, the neighbourhood was redesigned to disconnect stormwater from the combined sewer and manage it through an open, visible landscape system. The spatial logic distributes water across canals,

channels, ponds, ditches, and wetlands integrated into courtyards and public green spaces. Importantly, the intervention is described as implemented with residents in situ, meaning spatial transformations were staged and negotiated within an existing social fabric rather than delivered as a tabula rasa development.

Figure 20 Masterplan of the neighbourhood with integrated suds. Source: Mottaghi et al, 2020.

## Deployed technology

The open system is substantial in scale: it includes 6 km of canals and water channels and ten retention ponds. Green roofs are used as distributed source control; more than 11,000 m<sup>2</sup> of green roofs are reported, including both new installations and retrofits on existing buildings. The system is designed so that only

surplus water is directed to conventional sewers and receiving watercourses, and the project reports that flooding problems ceased after implementation (European Environment Agency, 2026).

### **Feasibility logic**

The initiative is framed as responding to repeated flooding and social/economic decline, embedding SUDS within a broader neighbourhood renewal. The financial model is presented as multi-source: a reported total investment around SEK 200 million ( $\approx$ €24 million), with significant contributions from the housing company and additional national/EU funding instruments. This indicates that district-scale SUDS retrofits become feasible when positioned as urban regeneration, capturing housing, public space and environmental budgets simultaneously.

### **Transferable lessons**

Three lessons stand out. First, district SUDS can be socially stabilizing if framed as an upgrade to everyday life: the Augustenborg case emphasizes improved public spaces and resident participation as success factors, which helps explain acceptance and long-term stewardship. Second, an open network can enhance system resilience by attenuating peaks and reducing combined sewer overflow risks, delivering benefits beyond the immediate project boundary. Third, maintenance and safety trade-offs must be designed for: the case explicitly notes challenges such as cleaning, algae, accessibility, and safety near schools, suggesting that successful replication requires maintenance planning as part of the design brief rather than a post hoc operational concern.

## 6. Sønder Boulevard

**Designers:** SLA

**Year:** 2004–2020

**Location:** Copenhagen, Denmark

**Status:** Completed

### **Key design elements**

- Linear Park with episodic micro-programs
- Canopy continuity
- Planting as spatial grammar

### **Benefits:**

- cooling/shade
- spaces for sociality
- perceived safety
- biodiversity support

*In the previous page: Figure 21 View of the linear park. Photo credits: SLA.*

## **Spatial strategy**

Sønder Boulevard exemplifies nature-based urban transformation through reprogramming of a former traffic corridor into a linear civic landscape. The spatial strategy replaces the logic of through-movement by vehicles with a “green belt” that supports slow mobility, informal gathering, and local commerce spillover. A distinctive feature is the deliberate incompleteness of the design: portions of the boulevard are left as unprogrammed fields intended to be filled over time by residents’ initiatives, embedding an incremental process into the spatial framework. This transforms the boulevard into a living social infrastructure rather than a fixed masterplan outcome.



*Figure 22 The Boulevard in the '70s and after the intervention. Credits: SLA.*

## **Deployed technology**

The adopted solutions are primarily ecological and socio-spatial: planting, flexible open areas, and amenities that support spontaneous activities. SLA describes an extensive community participation process as central to the transformation, indicating an engagement-led methodology.

## **Feasibility logic**

Feasibility is built on converting a contested mobility space into a widely shared amenity. By framing the corridor as

Copenhagen’s “outdoor living room,” the project generates broad stakeholder value: residents gain everyday space, local businesses benefit from footfall and spillover, and the city gains a recognizable public-realm asset. The incremental approach further reduces implementation risk because it allows adaptation over time; under-defined areas can respond to emerging needs without requiring major reconstruction, aligning the project with the temporal realities of neighbourhood change.

### **Transferable lessons**

The project suggests that NBS in mobility corridors can succeed when process is treated as a design variable. Leaving space intentionally open-ended can produce long-term adaptability and local ownership. Additionally, the transformation indicates that depaving or reducing vehicle dominance does not require total pedestrianization; rather, it can be achieved through rebalancing and reprogramming, where greening and everyday uses indirectly “filter” behaviors and reduce the corridor’s attractiveness as a shortcut for cars. Finally, coupling ecological upgrades to social life is a feasibility condition: without daily value, green corridors risk being politically fragile.



*Figure 23 The intervention stimulated local economy and socialization. Credits: SLA.*



## 7. Gata Grønland & Kirkegata

**Designers:** SLA (with municipal initiative/experiments)

**Year:** 2022

**Location:** Oslo, Norway

**Status:** Implemented as pilot / experimental intervention

### **Key design elements**

- Street reallocation to prioritize public life
- Tactical-to-permanent logic enabling iteration and acceptance

### **Benefits:**

- walkability
- safer bike movement
- biodiversity
- pilotability/phasing

## **Spatial strategy**

The project's interventions are explicitly framed as public life experiments that test how compact, reversible changes can introduce a radically different form of "city nature" into the dense historic core. The spatial strategy depends on temporary reclamation of street space: where cars and asphalt previously dominated, the streets are transformed into environments prioritizing pedestrians, cycling, informal seating, and biodiversity. In Kirkegata, the experiment creates a 450-meter "urban forest" sequence, turning linear movement into an immersive ecological corridor while maintaining a safe, attractive cycling routes. The experiments' temporality is not incidental; it functions as a governance tool that lowers barriers to implementation by positioning the intervention as a test capable of informing permanent policy.

## **Deployed technology**

The project deploys light but high-impact NBS techniques: temporary depaving or surface takeover, introduction of mature planting and biodiverse species that emulate forest ecologies. SLA describes planting schemes that include edible and fragrant herbs, berry plants and trees up to five meters in Gata Grønland, indicating a deliberate choice for multisensory, biodiversity-oriented palettes rather than conventional ornamental streetscaping. This is coupled with reallocation of street space for outdoor seating and local business activity, linking ecological change to economic and social activation.

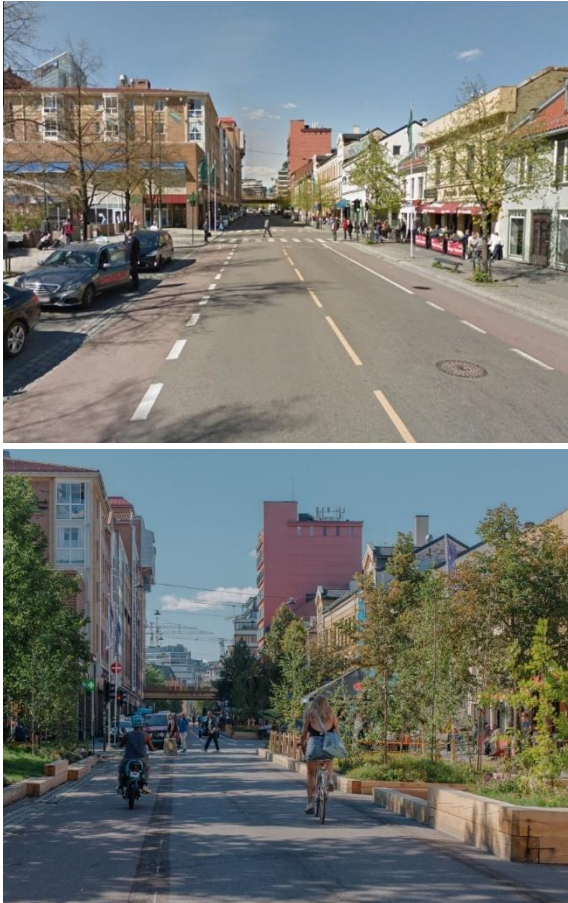
## **Feasibility logic**

Feasibility is achieved through experimental governance and reversible delivery. By defining the interventions as time-bound experiments and aligning them with municipal collaboration, the project reduces political risk and creates a platform for

evidence-based scaling. The compactness of measures also supports feasibility in dense contexts where underground utilities and regulatory constraints often block large-scale depaving or reconstruction.

### **Transferable lessons**

A central lesson is that incrementalism can be strategic rather than timid: temporary pilots can shift both citizen expectations and institutional comfort, enabling more ambitious permanent NBS later. Finally, coupling ecological takeover with improved cycling conditions suggests a transferable model for aligning active mobility with biodiversity goals, avoiding the false trade-off between “green streets” and “functional streets”.



*Figure 25 Before and during the experiment. Credits: SLA.*



## 8. Sankt Kjeld's Square & Bryggervangen

**Designers:** SLA (with municipal/water utility partners)

**Year:** 2017–2019

**Location:** Copenhagen, Denmark

**Status:** Completed

### Key design elements

- Cloudburst adaptation embedded in ordinary streets and square
- Water-sensitive topography
- Biodiversity-oriented planting
- Reorganization of mobility hierarchy

### Benefits:

- flood resilience
- cooling
- biodiversity
- public space quality & identity

Figure 26 Aerial view of Sankt Kjeld's square. Credits: SLA.

## Spatial strategy

This project operates at the intersection of NBS and cloudburst protection, restructuring everyday streets and a square into a connected network of rain gardens and green public spaces. Spatially, the strategy is depaving at scale: SLA reports that two-thirds of the area's asphalt (equivalent to approximately 9,000 m<sup>2</sup>) has been converted into green urban space, explicitly linking surface transformation to both hydrological capacity and public-life improvement. The layout forms a network of green rainwater beds designed to handle intense events while also delivering shade, biodiversity, and traffic reduction benefits as part of the wider Copenhagen Climate District initiative.



Figure 27 The square before and after the intervention. Credits: SLA.

## Deployed technology

The hydrological system is based on nature-based conveyance and filtration, supported by a specific water-quality logic. ACO's case documentation describes a "First Flush" approach in which the initial, more polluted roadway runoff is directed to the sewer, while the subsequent, cleaner "Second Flush" is allowed to infiltrate into green areas; it also states that 30% of rainwater is handled on the surface within green areas, with excess during cloudbursts led onward via sewers to the harbor (ACO; 2026). This coupling of green infiltration with controlled diversion reflects a pragmatic hybrid model: nature-based where feasible,

conventional conveyance where necessary for pollution and extreme peaks.

### **Feasibility logic**

Feasibility here depends on demonstrating that climate adaptation can be co-produced with everyday urban quality. SLA frames the project as simultaneously reducing traffic, air pollution, and urban heat island effects, thereby broadening the coalition of beneficiaries beyond flood management stakeholders alone. The explicit scale (34,900 m<sup>2</sup>) and delivery period (2015–2019) further indicate that the project is positioned as major municipal infrastructure rather than a small pilot, which is essential for transferring the model to other districts with comparable cloudburst risks.

### **Transferable lessons**

First, depaving is most powerful when it is systemic: converting asphalt into a connected green network increases both storage/attenuation capacity and habitat value compared to isolated pocket interventions. Second, water-quality realism matters: the first/second flush logic shows how NBS can be protected from contaminated runoff through selective diversion, improving long-term viability of infiltration landscapes in traffic environments. Third, the project demonstrates that large scale climate adaptation can be communicated as urban upgrading, thereby sustaining political support for substantial spatial reallocation away from cars.



## **Spatial strategy**

Vauban's strategy is district-scale sustainability anchored in community-led development. The neighbourhood is characterized by compact form, multimodal mobility, and a strong reduction of private-car dependence; supported by extensive slow mobility networks and high public transport connectivity. A foundational spatial move is the separation of car parking from everyday life: a central parking facility at the edge of the settlement supports a car-reduced internal street environment. The district is also shaped by cooperative and participatory development models (Baugruppen and community organizations), which influence not only governance but the spatial diversity of housing blocks and shared open spaces.

## **Deployed technology**

Vauban's energy concept combines low-energy building standards with renewable generation and district systems. The GIZ case study reports approximately 2,000 housing units and emphasizes that all housing is low-energy construction, with many buildings based on zero-energy or energy-plus principles (Gorges, 2011). A flagship component in the broader Vauban context is the Solar Settlement: Rolf Disch's documentation reports fifty-nine residential buildings with approximately 445 kWp of PV generating around 420,000 kWh per year (Rolf Disch Architektur, 2018). These figures are significant because they indicate operational energy production at neighbourhood scale rather than isolated buildings.

## **Feasibility logic**

Feasibility is achieved through governance innovation and financing structures that align private investment with collective

performance. The Solar Settlement explicitly describes a dedicated development company and partial financing via “Freiburg Solar Funds”, indicating that renewable energy and plus-energy housing were treated as investable assets rather than purely municipal expenditures (Rolf Disch Architektur, 2018). At the district level, participatory mechanisms and cooperative housing groups are reported as key outcomes of the Vauban process, suggesting that social organization was not ancillary but a delivery mechanism that enabled ambitious standards and shared services.

### **Transferable lessons**

Vauban shows that energy community outcomes can be delivered without a single formal REC entity, if governance, finance, and spatial planning are aligned around collective performance. The combination of strict building standards, district logic, and investable PV delivery suggests that replicability depends less on a single technology than on a coherent institutional package: cooperative development, clear standards, and financing channels that reward long-term performance.



## 10. Magliano Alpi REC

**Designers:** Local REC / institutional-community initiative

**Year:** 2020

**Location:** Magliano Alpi (CN), Italy

**Status:** Operating monitored after piloting

### Key design elements

- Collective self-consumption model
- Governance structure defining roles and benefit allocation
- Performance monitoring (energetic/economic outcomes)

### Benefits

- renewable production
- affordability/economic performance
- collective governance
- replicability

Figure 29 View of the townhall, the first prosumer of the REC. Source: [cermaglianoalpi.it/](http://cermaglianoalpi.it/)

## Spatial strategy

Magliano Alpi's REC is structured around a municipal anchor model: the town hall acts as coordinator and prosumer, using a public building PV installation to catalyze local participation and distribute benefits. The community frames the REC not only as an energy intervention but as a local development model oriented towards sustainability and post-pandemic revitalization, explicitly linked to citizen-prosumer centrality in European energy policy. This institutional anchoring is spatially important because it concentrates generation at a highly visible civic site, strengthening trust and easing recruitment of additional members.

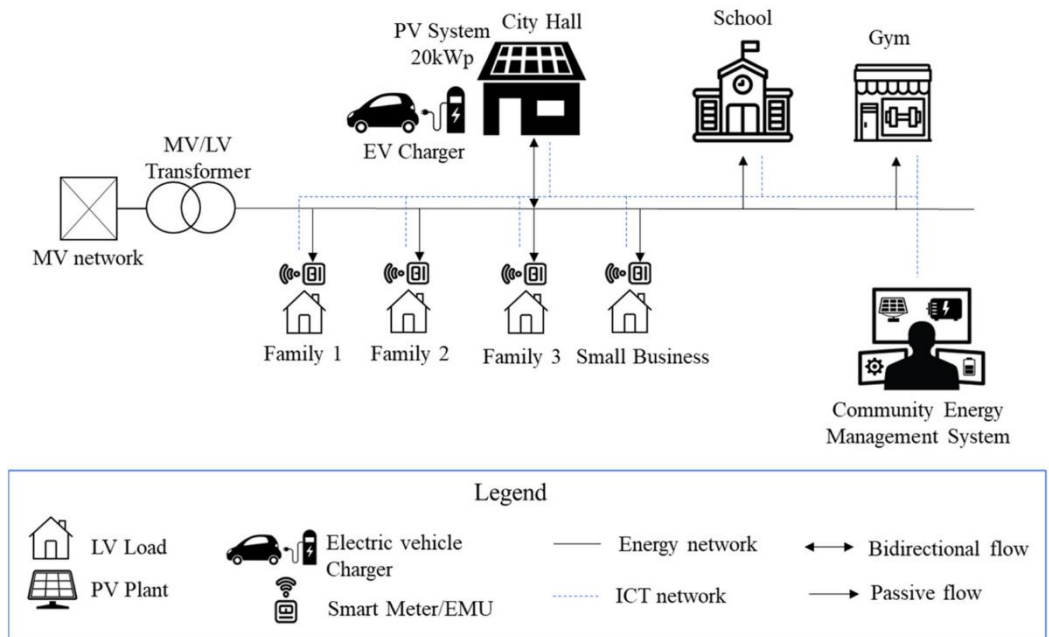


Figure 30 Simplified scheme of the participants of the REC. Source: Ghiani et al, 2022.

## Deployed technology

Technologically, the starting point is simple (PV on the town hall) supported by metering and the national incentive framework for

shared energy. Multiple sources report the initial PV system size as 20 kWp (QualEnergia, 2020; Energy Community Platform, 2026). Performance evidence is available through detailed analysis: Mangialino reports, for an observed year (2021-2022), total electricity consumption of 49,288 kWh, production of 27,137 kWh, and shared energy of 7,797 kWh; highlighting the typical constraint that shared energy is limited by hourly coincidence between exports and imports. The same analysis estimates that load shifting could increase shared energy to 17,000 kWh (+118%), illustrating how operational strategies can materially improve outcomes (Mangialino, 2023).

### **Feasibility logic**

Feasibility emerges from three mutually reinforcing factors. First, the municipality's coordinating role reduces transaction costs for citizens and small users who might otherwise face high administrative burdens. Second, the REC is embedded in a clear regulatory-incentive system that remunerates shared energy, creating a predictable economic rationale for participation. Third, the model is scalable: ENEA reports that additional RECs were being set up locally with the intention to merge communities under updated regulation, indicating institutional learning and expansion rather than one-off experimentation (ENEA, 2022).

### **Transferable lessons**

Magliano Alpi suggests that small municipalities can initiate successful RECs by using public buildings as trusted anchors and by starting with a technically modest but institutionally strong configuration. The performance data underscore a crucial lesson: the success of RECs is not only a matter of installed capacity but of temporal matching; hence, demand-side strategies (load shifting, storage, or coordinated scheduling) can be as impactful as adding generation.

### 2.3.3. Transferable design principles

To enable a structured comparison across heterogeneous precedents, each case study is assessed through five outcome-oriented dimensions:

- A. public space quality and everyday usability;
- B. climate resilience performance (including self-energy production);
- C. mobility and accessibility upgrade;
- D. social activation and inclusivity capacity;
- E. implementation feasibility.

These dimensions are selected because they are transferable across domains (mobility, NBS, SUDS, and energy) and can be consistently observed through project documentation.

Each dimension is scored on a 0–5 ordinal scale:

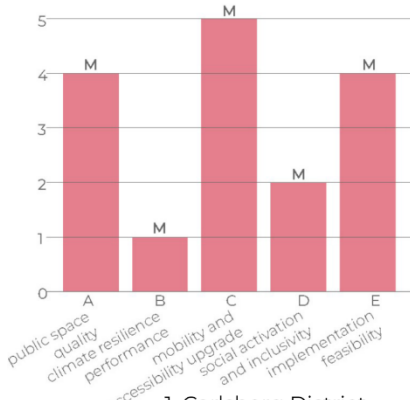
- **0** = not present
- **1** = marginal / not explicit
- **2** = possibly present
- **3** = clearly present
- **4** = important
- **5** = core driver + supported by explicit evidence

To ensure methodological transparency, each score is supported by one of three levels of evidence:

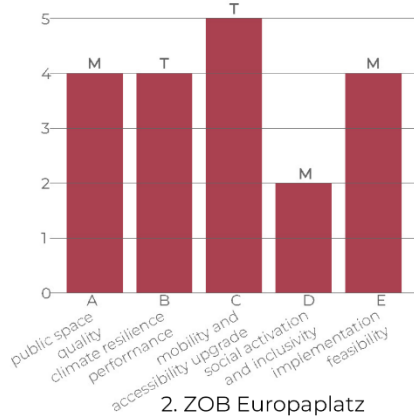
- **Data-supported (D):** the score is grounded in quantitative evidence such as documented storage volumes, energy production values, modal split percentages, or monitored post-implementation performance.

- **Device-supported (T):** the score is justified by the documented presence of technical systems (e.g., bioswales, permeable paving, retention basins), even when quantitative monitoring data are not publicly available.
- **Morphology-supported (M):** the score is derived from spatial transformation and urban form modifications (e.g., pedestrianization, street reallocation, mixed-use activation), where performance outcomes are logically deducible but not numerically monitored.

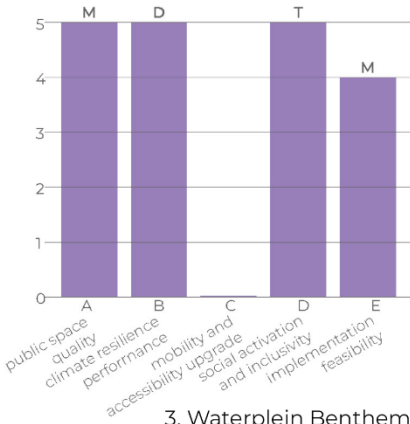
This differentiation allows the comparison to maintain analytical rigor while acknowledging the heterogeneous nature of available documentation. It also clarifies that not all high scores are supported by the same type of evidence, thus avoiding false equivalence between data-driven and morphology-driven performance claims. When a score of 5 is assigned, an evidence tag is attached to the diagram to make the underlying justification immediately legible.



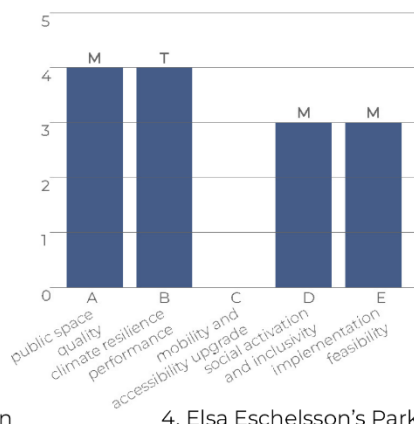
1. Carlsberg District



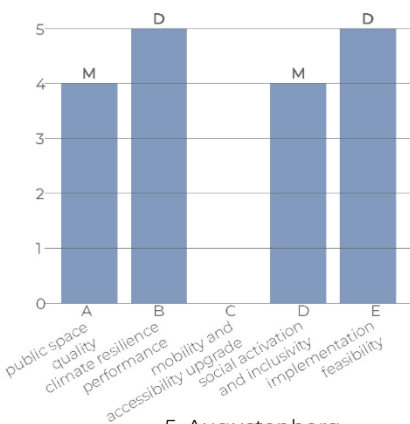
2. ZOB Europaplatz



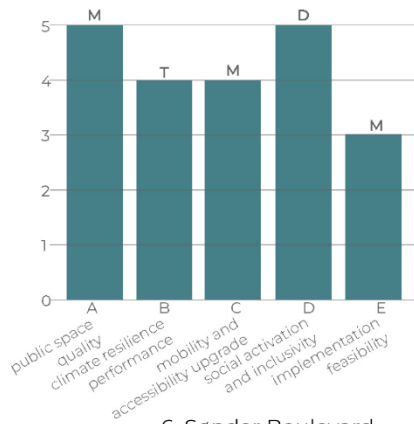
3. Waterplein Benthemplein



4. Elsa Eschelsson's Park



5. Augustenborg



6. Sønder Boulevard

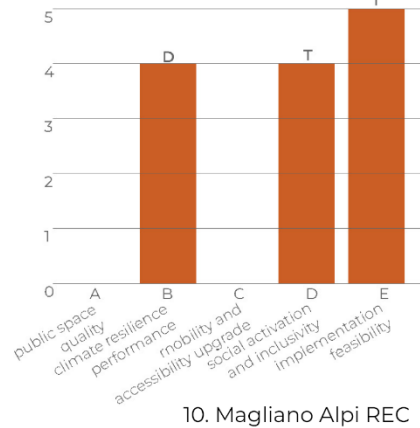
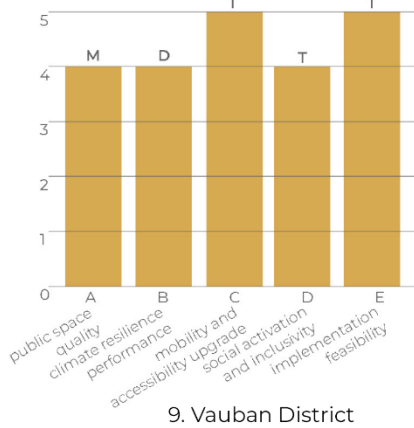
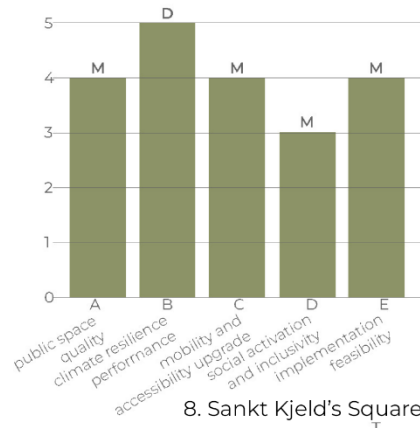
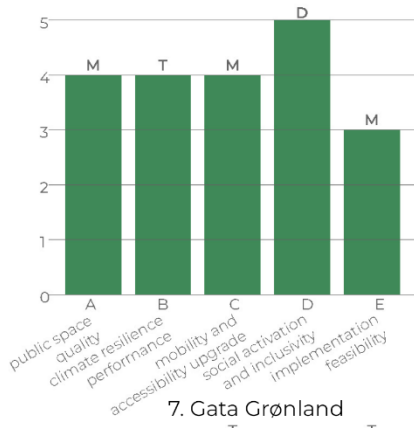


Figure 31 Evaluating diagrams of selected precedents.

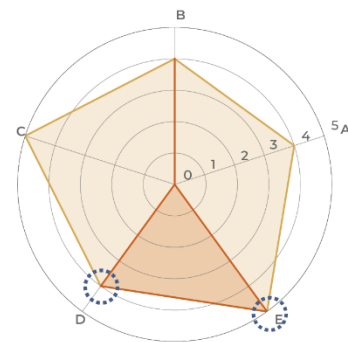
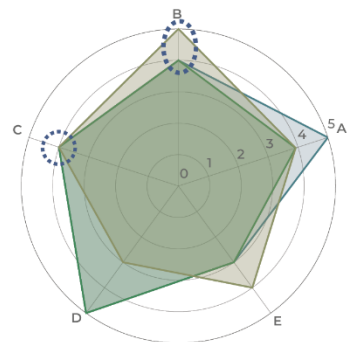
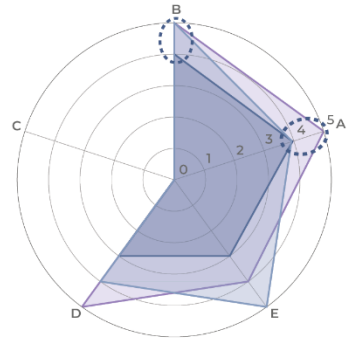
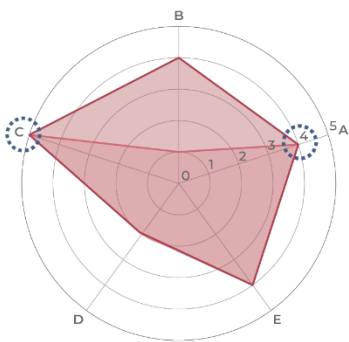
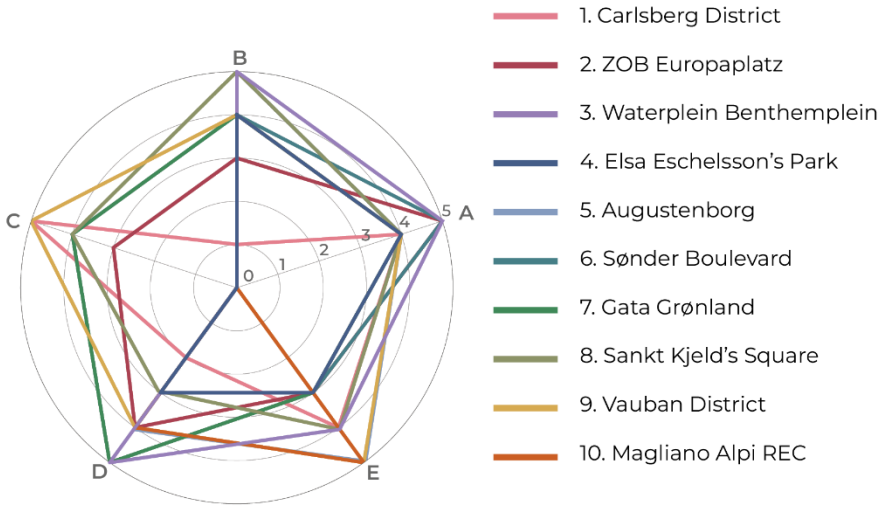


Figure 32 Comparative diagrams overlap the same point-based evaluation of each project to determine patterns.

The comparative diagrams do not aim to rank precedents. Instead, they reveal recurrent patterns: for example, cases that score high in both climate performance and everyday public-space value consistently rely on flexible typologies and on the spatial legibility of environmental functions. Likewise, projects with high feasibility scores tend to embed governance and maintenance logic into design decisions, confirming that deliverability is a core component of contemporary regeneration.

By overlapping all the projects, we can see how we arrive at a perimeter that touches on five points in every field: this indicates how, ideally by absorbing the best practices from each project, we can achieve a result that satisfies all the criteria. So comparative reading is used to deduct a set of transferable principles that function as design rules for the project application. They are not prescriptions, but structured decision frameworks used to justify the strategy set and to maintain coherence across the design process.

1. **Make environmental functions spatially legible.** Water retention and flood management gain acceptance when their role is visible.
2. **Prioritize flexible use typologies.** Floodable parks and squares work better when they remain valuable in dry conditions.
3. **Treat mobility reallocation as an enabling condition for NBS.** Without reduced car dominance, there is limited space for soil volumes, canopy, and permeability: NBS and mobility must be co-designed.
4. **Work as systems, not as isolated devices.** SUDS effectiveness increases when detention, infiltration, and conveyance are designed as connected district infrastructure and no single episodes.

5. **Design with governance and maintenance in mind.**  
Long-term care regimes and actor responsibilities should be treated as design parameters, especially in socially sensitive contexts.
6. **Use phasing and experimentation to build legitimacy.**  
Temporary or pilot transformations can function as proof-of-concept and accelerate acceptance of more structural reallocations.
7. **Anchor collective infrastructures on public assets.**  
Public buildings and municipal initiatives can stabilize implementation and increase social credibility, particularly for energy-oriented solutions.

These principles define the bridge between theory and project application. They provide the methodological foundation through which the Villaggio dei Fiori redesign translates precedent knowledge into an integrated strategy set addressing public space, mobility, climate resilience, and long-term feasibility.



# 3. PROJECT APPLICATION: VILLAGGIO DEI FIORI, MILAN

Villaggio dei Fiori, a public housing neighborhood in south-west Milan, is an anomalous urban fragment and an expression of post-war welfare urbanism: emergency housing that became permanent, a public realm originally conceived as an extension of everyday domestic life and a low density morphology that today appears unexpectedly strategic in a city facing climate stress and renewed pressure for public housing provision.

Its relevance for this thesis lies precisely in its ambivalence: on the one hand, Villaggio dei Fiori is often discussed through the lenses of obsolescent aging stock, fragmented care regimes and gradual erosion of shared open spaces; on the other, it retains a strong local identity and fine-grained fabric that can support Nature-based solutions.

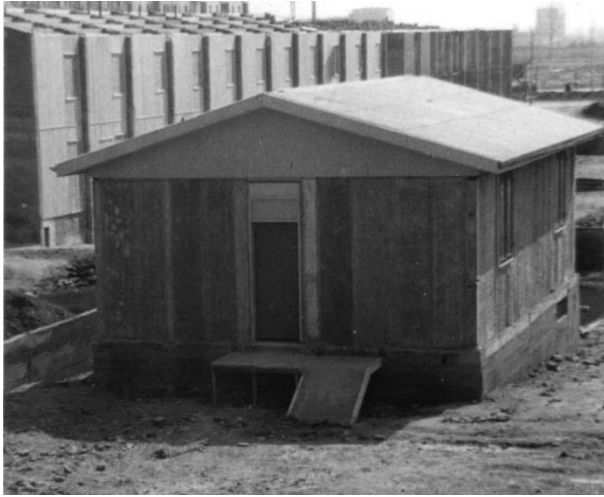
## 3.1. CRITICAL ANALYSIS, CURRENT CONDITIONS, AND FUTURE PRESSURES

### 3.1.1. Origins and transformation



*Figure 33 View on via dei Gigli, 1950-55 circa. Author unknown.*

The neighborhood took shape in the aftermath of World War II, to rapidly house war refugees. A major component of the settlement is the system of *Case Minime*, developed between 1947 and 1953 and attributed to municipal architect Arrigo Arrighetti; they are repetitive two-storey row houses conceived to provide minimum living standards with limited resources.



*Figure 34 Installation of a S.A.F.F.A. house, 1952. Author unknown.*

Alongside Arrighetti's houses, other housing units reinforce the district's character as a living archive of emergency driven construction. Fifty-two single prefabricated houses, most still in use,

were contributed in 1953 by the Swedish company S.A.F.F.A. and placed on land donated to the municipality. The coexistence of these typologies, row houses and detached prefabricated units, produced a hybrid morphology uncommon in Milan: low building heights, a dispersed open space structure, and a neighborhood scale legibility closer to a "village" condition than to the compact city. These traits matter for the thesis because they prefigure the feasibility of ecological retrofitting: a fabric where depaving, canopy continuity, and distributed water-controlling devices can be integrated without large scale demolition. As often happens with facilities created out of extraordinary necessity, the temporary arrangement tended to become permanent: the permanence of families, the difficulty of quickly replacing the housing stock, and the gradual institutionalization of management transformed the temporary arrangement into a lasting system.

In recent decades, the neighborhood's trajectory has converged with dynamics typical of contemporary urban regeneration debates: ageing building stock and residents, difficulties in complying with accessibility and energy performance standards, and the progressive erosion of public space quality due to

improper use and discontinuous maintenance. In Villaggio dei Fiori, these dynamics are particularly visible in the treatment of open space: the growth of private car mobility and the consequent colonization of outdoor surfaces for parking tends to transform courtyards, margins, and small voids into ambiguous leftover spaces, reducing perceived safety and limiting opportunities for daily socialization. This shift produces a silent but powerful transformation: common space ceases to function as an extension of living and becomes a zone of passage or conflict, with direct repercussions on livability and cohesion.

A further historical layer connects the neighborhood to the broader territorial landscape that preceded urbanization and helps explain why a nature-based regeneration framework is coherent here. Street toponyms and surviving references point to a former agricultural matrix organized around *cascine*<sup>3</sup> and a water regime shaped by the interplay of surface canals. *Cascina Corba*, for instance, recalls an important agricultural complex that once stood in the area and was demolished during mid-twentieth-century expansion. More generally, the proximity of Parco Agricolo Sud and the Alzaia Naviglio Grande canal system recall the ecological specificity of the territory, where *fontanili*<sup>4</sup> were a characteristic hydrological feature. This information is not introduced as an exercise in nostalgia, but as a territorial premise: it legitimizes the project's interest in reactivating water retention and ecological continuity as urban repair, reconnecting the neighborhood, conceptually and spatially, to a wider blue/green system.

*Figure 35 Transformation of the area from 1910 to 1972.*

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<sup>3</sup> A typical Lombard agricultural settlement, consisting of buildings grouped around a large courtyard (*Cascina* in Treccani online dictionary).

<sup>4</sup> Water intake, for irrigation purposes, from non-surface aquifers. (*Fontanile* in Treccani online dictionary).

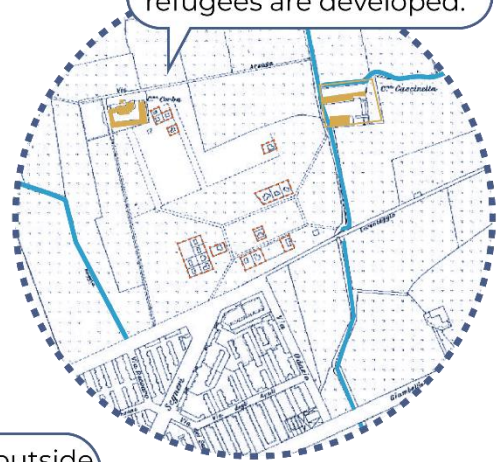
1910



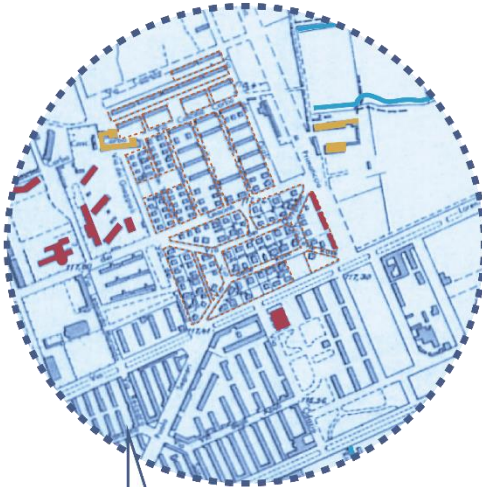
Agricultural area outside the city with a large number of springs and "cascine" farmhouses.

1946

The first housing complexes for WWII refugees are developed.



1956



The Cascine are demolished and the springs buried to make way for the Villaggio dei Fiori. Primary services such as schools, markets, and parks are also built.

1972

Progressive densification of the neighbourhood's surroundings.



- Farmhouses
- Water springs
- Public housing
- Public services

### **3.1.2. Current and future developments**

The mapping of mobility infrastructures, public services, and green-blue infrastructure is not positioned as a mere descriptive inventory; but it operates as a territorial framing device: it clarifies how Villaggio dei Fiori relates to metropolitan connections and ecological corridors, identifies the neighbourhood's role within a broader system of movements, facilities, and landscape structures, and supports a project positioning that is simultaneously local and metropolitan in scale.

Another fundamental aspect for understanding this site is the future projections for the neighborhood.

The opening of the M4 metro line introduces discontinuity that can be interpreted as a new threshold in the neighborhood's trajectory. Improved accessibility is not a neutral condition: it can increase the attractiveness of the area and accelerate transformation pressures, but it can also offer the opportunity to reset the relationship between the neighborhood and the city; strengthening slow local mobility and access to services without dependence on private vehicles. In this sense, public transport can be a device that reactivates Villaggio dei Fiori within the urban system, but only if the quality of public space and internal connections is adequate to support a new regime of daily use.

In addition to transit-related changes, the metropolitan transformation cycle underway and/or planned in the wider area was considered to contextualize the project within an accurate sequence of public works.

First, the construction of the underground parking facility in Largo Brasilia, underway since 2023, signals a reconfiguration of mobility management and surface public space arrangements in the surroundings.

Second, the construction of the new Lorenteggio public library confirms the institutional commitment to public facilities as regeneration drivers, with timelines and funding structures that intersect the broader transformation agenda of the area.

Third, nearby open space projects such as the Parco G129 in Via Giambellino (inaugurated in 2024 and explicitly connected to NBS oriented funding and co-management arrangements), provide a relevant precedent for positioning nature-based public space as both environmental and social infrastructure. The later dedication of the park to Alan (Aylan) Kurdi further shows how public space can become a civic device that links local life to broader narratives of inclusivity and collective memory (ResQ, 2025).

Finally, the San Cristoforo area, strategic due to its relationship with the Naviglio corridor and railway-yard transformation processes, has been the subject of recent upgrades and wider regeneration planning frameworks.

Within this metropolitan context, the thesis' project is positioned deliberately as a strategic insertion rather than an isolated exercise. It interfaces with ongoing construction timelines and evolving public space expectations, while addressing what large scale projects often overlook: the fine-grained, daily life scale of internal routes, thresholds, and micro attractors that determine whether regeneration is experienced as improved wellbeing.



Primaticcio Corba

Quartiere ebraico

Lorenteggio

Inganni La Creta

Gelsomini M4

Segneri M4

Giambellino

San Cristoforo M4  
Mobility Hub













San Cristoforo

Ronchetto sul Naviglio



San Cristoforo M4

 Project area



### MOBILITY INFRASTRUCTURES

-  Railway system
-  Railway station
-  Tram system
-  Tram station
-  Metro system
-  Bus network
-  Bus-stop
-  Bike paths
-  Public bike parking
-  Bike sharing stations
-  Public parking
-  Underground public parking

### GREEN INFRASTRUCTURES

-  Public green spaces
-  Road-side greenery

### BLUE INFRASTRUCTURES

-  Alzaia naviglio grande
-  Lambro meridionale

### PUBLIC SERVICES

-  Public housing
-  Square
-  Library
-  Daily supplies
-  Weekly market
-  Pharmacy
-  Religious buildings
-  Indoor sport
-  Outdoor sport
-  Comprehensive school
-  Kindergarten
-  Elementary school
-  Middle school
-  High school

### PLANNED INTERVENTIONS



-  Areas affected by measures currently being approved and
-  Surface treatment M4

Figure 36 Public services and infrastructures mapping.

In summary, this chapter frames the project by establishing three intertwined premises:

- the neighborhood's postwar housing origins and typological specificity;
- its territorial belonging to a wider blue–green landscape historically shaped by *cascine* and spring-water systems;
- the metropolitan cycle of projects currently reshaping the south-west sector of Milan.

The next section translates this setting into an integrated diagnosis and design objectives, ensuring that subsequent design choices are grounded in an explicit, traceable analytical structure.

## 3.2. INTEGRATED DIAGNOSIS, DESIGN OBJECTIVES AND CONCEPT DEVELOPMENT

### 3.2.1. From site analysis to design objectives

The research continues with a multi-layered site analysis, combining:

- on-site surveys and photographic documentation;
- public documents and maps;
- statistical data regarding demography, mobility, housing stock;
- climatic data like surface temperatures, rainfall quantities, wind patterns, temperatures, etc.

Through this process, the main criticalities, resources, and potential of the area are identified, leading to the definition of a series of design rules forming the conceptual framework of the project.

The structure of the analysis converts heterogeneous observations into projectable variables so that design decisions are anchored to a traceable causal chain. For example, mobility conflicts like spontaneous parking, dangerous crossings, and sub-standard sidewalk widths are mapped together with environmental stressors, including maximum surface temperature classes and areas lacking canopy coverage. This juxtaposition is deliberate: it demonstrates that thermal discomfort is not merely climatic but morphologically produced by impermeable materials, poor shading, and excessive road space.



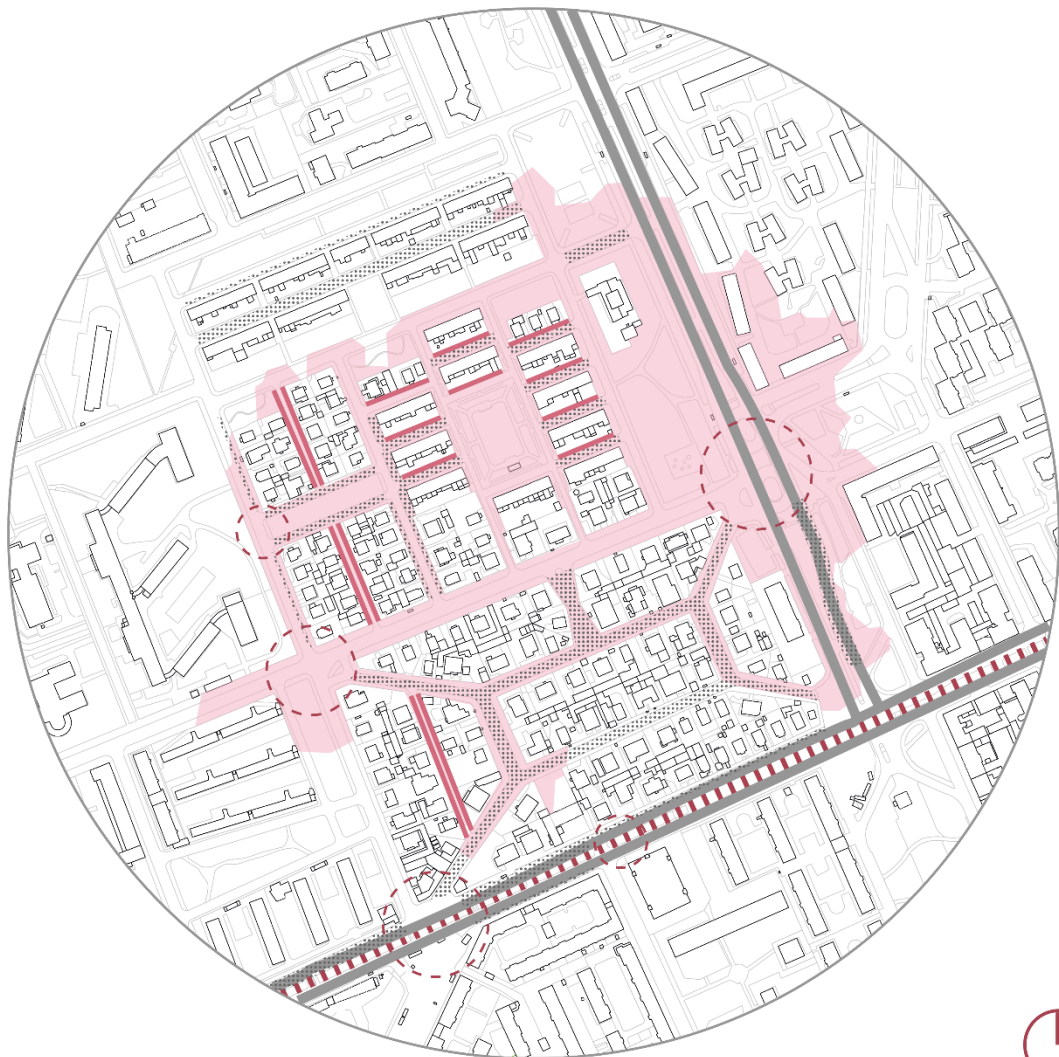
*In the previous page: Figure 37 photographic survey.*

The first thematic section addressed by the analysis is mobility, where one clear issue that emerges is the incorrect allocation of space for movement. During the site inspection, it was observed that the internal roads are oversized in relation to their actual use, while some sidewalks are less than 150 cm wide, making them inaccessible to wheelchair users when partially occupied by elements such as lampposts, parked vehicles, trash cans, and so on.







Another aspect of incorrect space distribution emerges in street parking. Since the area borders municipal parking limits (the boundary of which cuts right through Via Lorenteggio), many residents find themselves having to park close to it, sometimes occupying pedestrian spaces.

Another important aspect is the intersection between slow and vehicular mobility: crossings on the main thoroughfares are unsafe for pedestrians, with poor signage and no speed bumps. Many intersections are also designed to facilitate vehicular traffic, to the detriment of pedestrians and cyclists: the cycle path on Via Primaticcio, for example, is interrupted at the intersections with Via dei Gigli and Via Lorenteggio, exposing cyclists to danger.

Strong elements of mobility, such as the M4 metro line and numerous buses, clash with everyday usage conflicts, generating the need for a complete rethinking of mobility in the area. This gave rise to the idea of proposing a **“pedestrian-centric”** neighborhood that prioritizes slow and public mobility, leaving only the necessary space for vehicular mobility and rethinking a parking system that operates underground.



## MOBILITY ISSUES

-  Spontaneous parking
-  Dangerous crossings
-  Resident parking zone boundary
-  5 min walking distance
-  Narrow sidewalks (<150 cm)
-  High traffic roads

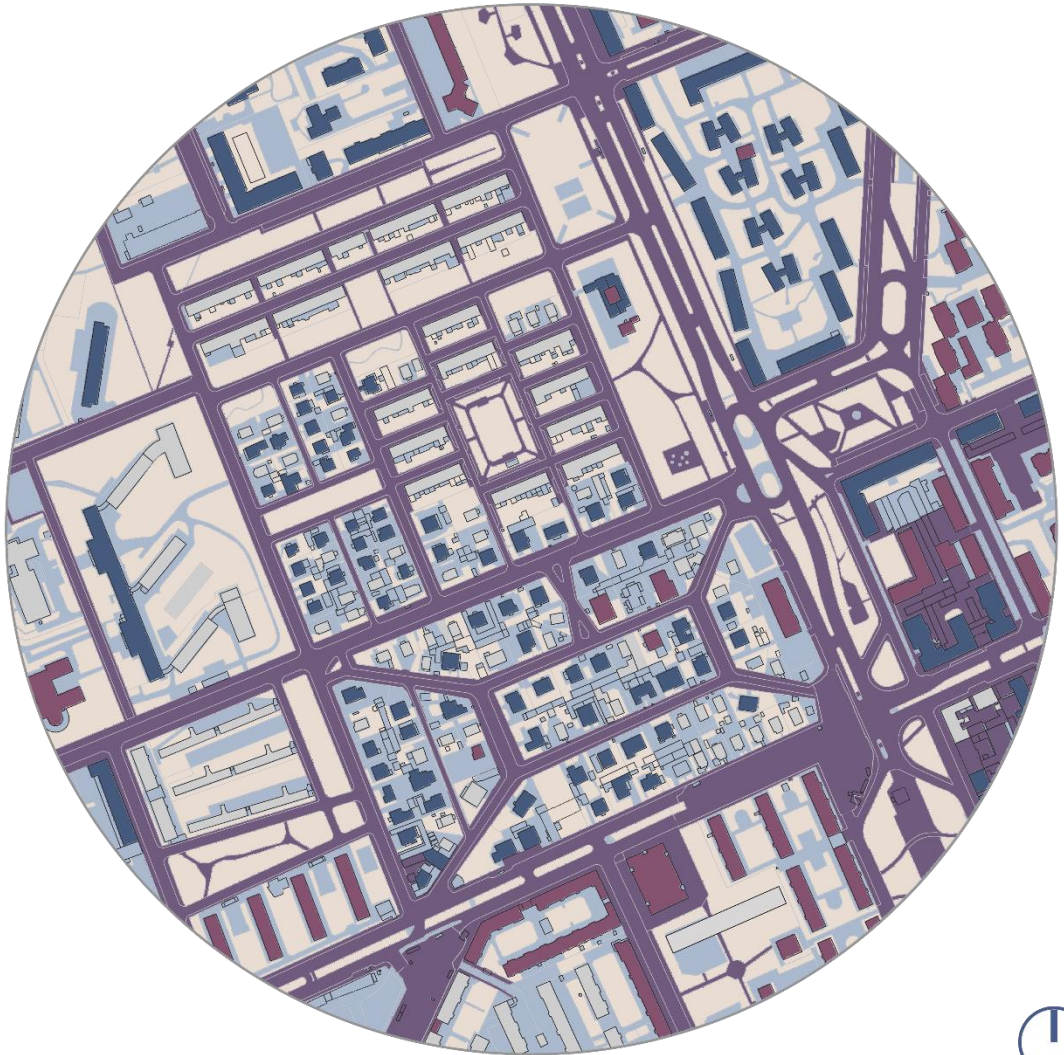


*In the previous page: Figure 38 Mobility issues mapping.*







A second analytical axis concerns water. The drawings explicitly record that Milan relies on a combined sewer system, where stormwater and wastewater share the same pipes; consequently, runoff is contaminated and directly increases the volume that must be treated before discharge. This infrastructural condition shifts NBS from a decorative register to a hydraulic one: each depaved square meter and each infiltration device translates into peak-flow reduction and fewer overload events. The note that many historical water bodies were buried further frames the project as a partial reconstruction of ecosystem services, also considering that climate data show a growing trend in precipitation anomalies, with extended periods of drought interrupted by so-called rain bombs. Infrastructure must consequently be able to respond to discontinuities in water flows: installing multifunctional SUDS solves this problem by eliminating the need to design oversized pipes or risk overflow and consequent street flooding, making the neighbourhood more **climate resilient**.

The sun-path and seasonal shadow studies provide an additional control layer, allowing the identification of year-round exposed surfaces where high-albedo paving and/or tree placement can generate the strongest cooling return per unit of intervention or where the positioning of photovoltaic panels can produce the maximum amount of energy.

A more general zoom-out on the city of Milan shows that areas with more tree cover suffer less from noise and air pollution, providing valuable data to justify and encourage greater green coverage in the area. This is the basis for the project's rule of providing **“restored landscapes.”** Through the careful positioning of shrubs, trees, and herbaceous species, issues related to the microclimate will be addressed.



## MAX SURFACE TEMPERATURE

-  <40 °C (lawn)
-  40-45 °C (light colored metal)
-  45-50 °C (light colored asphalt)
-  50-60 °C (ceramic roof tiles)
-  60-70 °C (dark colored asphalt)
-  >70 °C (bitumen)



*In the previous page: Figure 39 summer max. surface temperature mapping.*

Finally, the built heritage layer combines issues such as the management of public services, their state of conservation, and population trends. The demographic indicators and accessibility deficits establish why comfort, and safety must be treated as primary design criteria: elderly residents and single-person households are disproportionately affected by heat and by unsafe streets. The mapping of public housing stock shows a general state of deterioration, with a trend of abandonment reaching as high as 40% in S.A.F.F.A. homes. The housing stock is old and energy-inefficient, does not comply with current energy and accessibility regulations, and presents a major problem: once an apartment is vacated by its occupant, it cannot be reallocated but remains vacant.

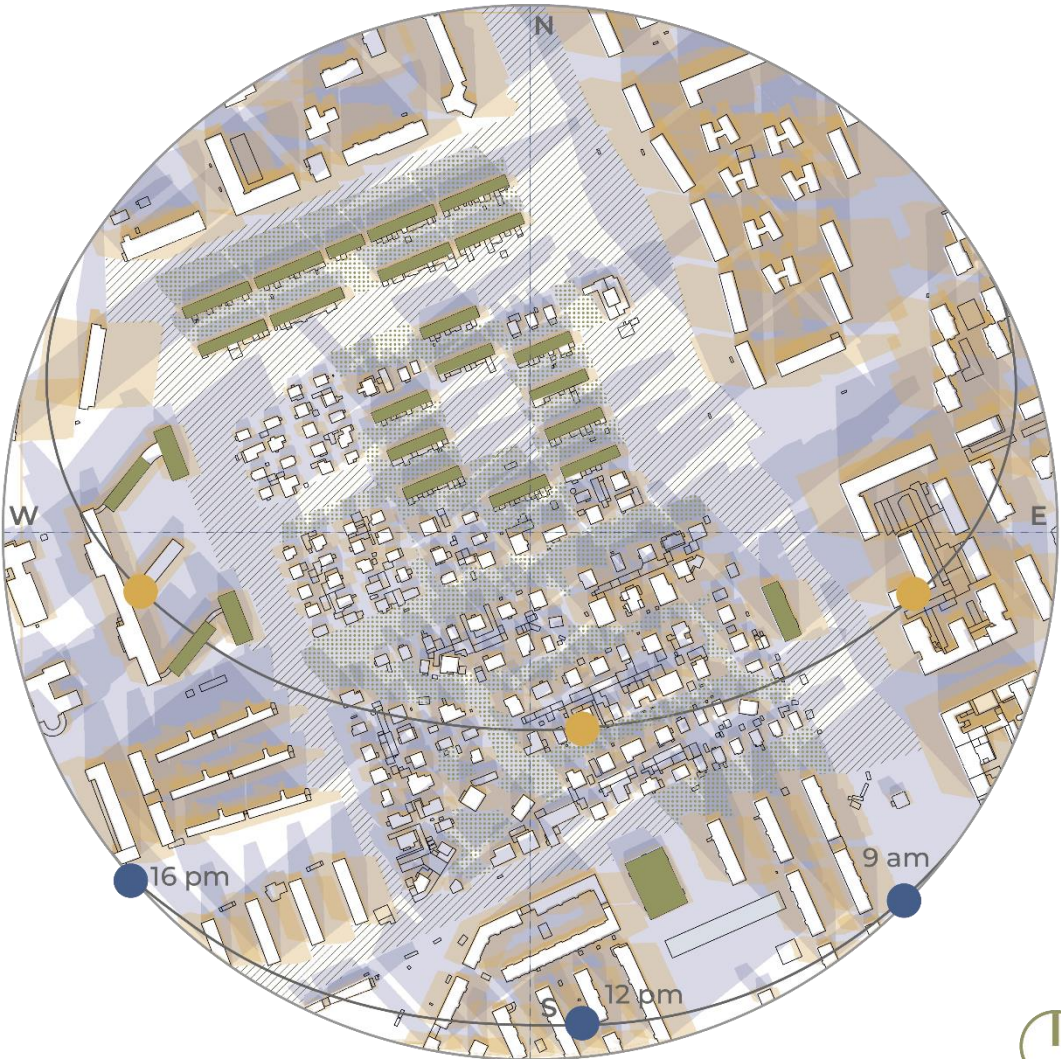
This gradual abandonment creates a contradiction with the trends in demand for public housing: more families are applying, and these families are increasingly large.

This mismatch between housing supply and demand provides an opportunity to review the built heritage in conjunction with solutions for public space: a distribution of space can be rethought that does not favor one or the other but is synergistic, whereas the housing supply increases, green spaces and services also increase, thus proposing a **“sustainable density”**.

In summary, solutions are selected and applied to solve real and tangible problems. The assessment helped identify key areas to work on, and the design objectives express the guidelines that the project aims to follow to address these areas.

*In the next page: Figure 41 sun path analysis.*

*In the second next page: Figure 40 public housing management and state.*



## SHADOWS

- Summer solstice
- Winter solstice
- Possible roofs for PV (public)
- Areas in need of summer canopy cover
- Areas year-round exposed





## MANAGEMENT



MM



ALER

## STATE OF CONSERVATION



Abandoned



In need of renovation

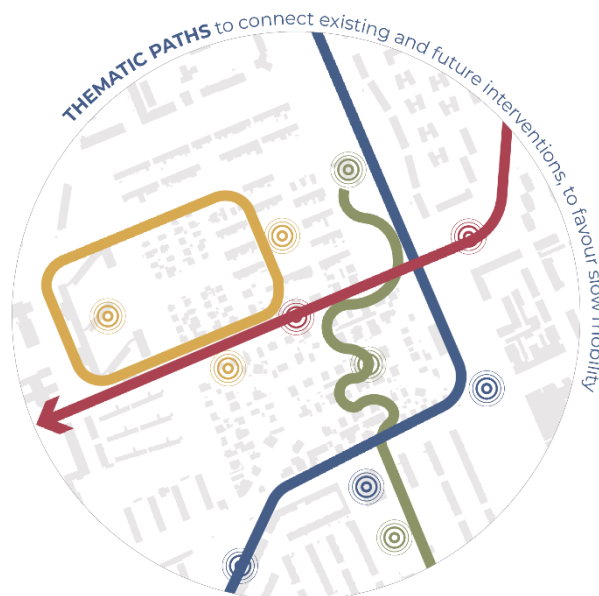


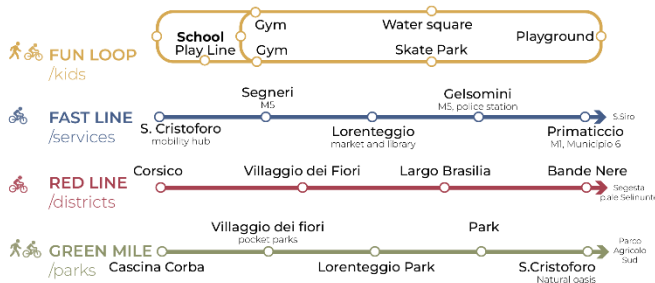
Self-construction



### 3.2.2. Concept: *building (with) a green social infrastructure*

The next step is to translate the design objectives into spatial forms that not only meet those rules but also comply with current regulations and the required environmental performance. The spatial approach is divided into three separate but synergistic architectural gestures: Thematic Paths, Urban Confetti, and 3 Landscapes. The three proposals, unrelated, are in fact linked by a close relationship of interdependence. Lines, points, and bands intersect: the paths create continuity within the area and with the surrounding districts, connecting the confetti, designed as episodes within the neighborhood. The green bands create legible borders, dividing the neighborhood into three distinct microclimatic zones and serving them according to their distinct needs.

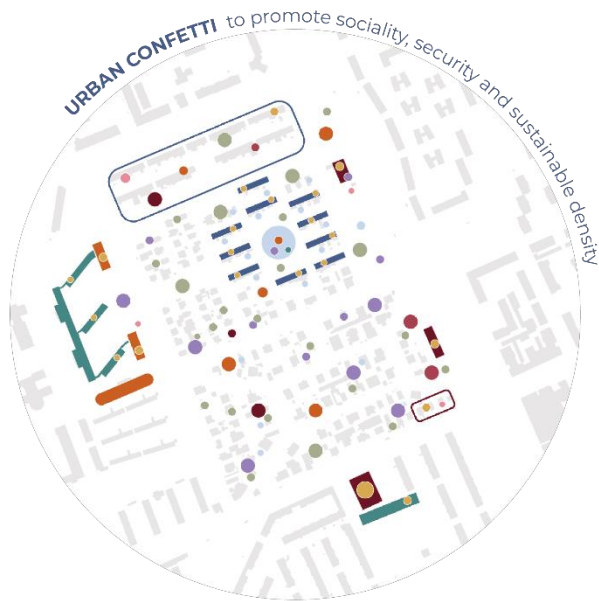




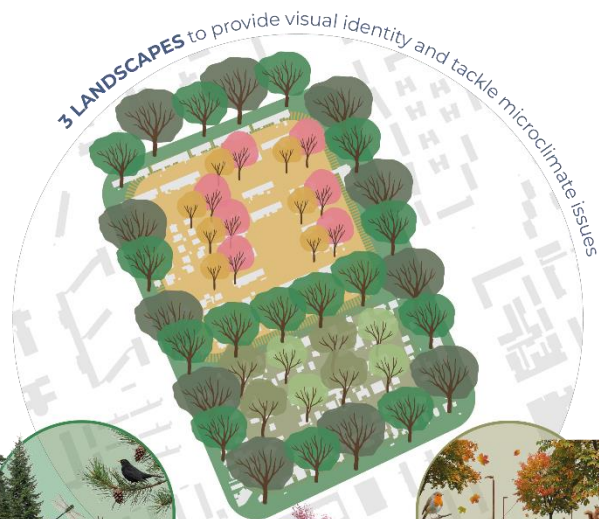
*In previous and next page: Figure 42 the three design pillars.*

The first proposes the development of four thematic routes operating as a “planning grammar”: they structure slow mobility by ensuring that NBS are continuous rather

than episodic and connect services inside and outside the neighborhood, reducing the need for car use. Each route is designed to cater to a specific type of user, so the itineraries are not only intended to connect places but to serve those who use them, considering their distinct needs. The fast line runs along a north-south axis, following the main arteries of the area. It is designed for commuters and those who need to reach key public services such as the town hall, metro, police station, market, library, and San Cristoforo interchange station, where a bike hub is planned to complement the renovated Piazza Tirana. The red line follows the same logic but with an east-west orthogonal development, connecting Corsico with San Siro, passing through the heart of the neighborhood. The Fun Loop and Green Mile are designed as recreational cycle and pedestrian paths: the former forms a ring within the neighborhood and connects childcare and sports facilities such as the Narcisi Institute, playgrounds, and the skate park; the second connects the new Cascina Corba Park with the Parco Agricolo Sud, passing through local parks such as Lorenteggio, Giambellino 129, and the future natural oasis of S. Cristoforo.



- Slow mobility services
- Commercial/services
- Car parking
- Play/sport
- Energy production
- Green areas
- Culture/learn
- Public housing
- Water services
- Meet/socialize



**LANDSCAPE 1**  
Large roadside trees to protect pedestrians from sun and wind, providing a natural filter against traffic noise and pollution from major city arteries. A fitodepuration pond for rainwater detention and cleaning.



**LANDSCAPE 2**  
Fruit trees and colorful flowers to attract pollinators, a strong aesthetic appeal, and seasonal shade modulation.



**LANDSCAPE 3**  
Neighborhood streets with small deciduous trees and rain gardens to control rainwater and limit spontaneous parking and vehicular space, encouraging slow mobility.

The 'urban confetti' approach complements the network logic through punctual interventions: corners, pocket parks, event platforms, and small sport devices that increase everyday sociality and passive surveillance, particularly around schools and public housing entrances. In regeneration contexts, this micro-scale repertoire supports incremental implementation and allows testing and adaptation without waiting for a single, high-budget delivery. The spaces for these micro-interventions arise from the demolition of the S.A.F.F.A. houses, in combination with existing neighborhood services. A second design move concerns programmatic centrality. The reactivation of Cascina Corba as a neighbourhood center and as an operational base for the energy community is not an accessory program; it provides institutional support for stewardship, maintenance, and community governance, which are decisive for the long-term success of NBS.

The three landscapes propose three different urban landscapes. The first features large roadside trees to protect pedestrians from sun and wind, providing a natural filter against traffic noise and pollution from major city arteries. The second, near the Case Minime, features fruit trees and colorful flowers to attract pollinators, a strong aesthetic appeal, and seasonal shade modulation. The last consists of neighborhood streets with small deciduous trees and rain gardens to control rainwater and limit spontaneous parking and vehicular space, encouraging slow mobility.

The strategic outcome is a regeneration model in which mobility reform, public-space activation, and NBS form a single system: street sections are freed for soil and water, ecological devices are anchored to civic programs, and new housing can be added without sacrificing microclimatic comfort or hydrological resilience. *In the next page: Figure 43 strategic masterplan.*



Extension of the bicycle network to connect existing routes and division in leisure and fast tracks.

Construction of 250 new Housing units (19,500 m<sup>2</sup>), 7500 m<sup>2</sup> proximity services, 700 spots of underground parking

Reactivation of Cascina Corba as a neighborhood center, with meeting and event spaces and offices for the Energetic community

Setback of the school wall, redefining public access and bettering street security.

FUN LOOP

Maintenance of the historic "Casa Minimere" core with energy and accessibility improvements.

New floodable plaza, pedestrianization of street fronts.

New underground parking in via Giacinti (90 spots), design of hybrid street.

Underground parking

PUBLIC SCHOOLS

Demolition of Saifa houses and introduction of a widespread park.

reconstruction of public housing units and design of a play line in via dei Giacinti

Construction of commercial spaces.

Gelsomini M6 station

M GELSOMINI

Lorenteggio public library and park

Segneri M4 station

M SEGNERI

PUBLIC LIBRARY

CHURCH

Park Aylan Kurdi

Construction of a bike hub with parking, bike rental and repair, and a charging station with self-generated energy.

MOBILITY HUB

M SAN CRISTOFORO

S. Cristoforo natural oasis.

ALZAIN NAVICLIO GRANDE

GREEN MILE (16 km)

## 3.3. TOOLKIT AND PROJECT IMPLEMENTATION

As before, the project develops synergistically around four main themes: mobility, water management, NBS and landscape, and renewable energy. This division continues in the explanation of the specific strategies used, inspired by the case studies.

### 3.3.1. Mobility, accessibility, and security

Mobility is treated as an enabling system for nature-based regeneration, translating strategic goals into an implementable toolkit that can be deployed gradually and recombined according to local conditions.

The explicit distinction between temporary/reversible measures and permanent/high-impact interventions expresses an adaptive planning logic: pilot actions such as weekly closures, removable modal filters, painted bike lanes, and colored crosswalks can test public response and recalibrate street hierarchies before committing to full reconstruction. This approach is especially pertinent in public housing contexts, where disruption must be minimized and where legitimacy is built through early benefits.

Safety is addressed through a set of speed-management and crossing devices: 30 km/h zones, speed bumpers, elevated and illuminated crosswalks, pedestrian islands and “Dutch style” intersections are aimed at reducing conflict points. Importantly, these measures are coupled with Nature-Based Solutions (NBS) and microclimate design: street greening and green curbs are paired with pigmented or high-albedo surfaces to lower

temperatures, while permeable paving and textured materials support evaporative cooling and reduce ponding.

The toolkit also addresses uncontrolled parking, the structural cause of degraded public space, by combining physical deterrents (bollards, planters, and urban furniture) with alternative supply through underground parking.

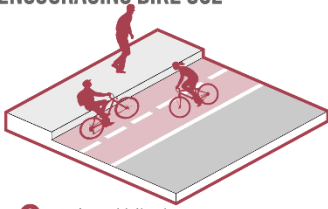
Finally, the inclusion of bike sheds, charging points, and links to existing cycle routes frames active mobility as a daily infrastructure rather than a leisure add-on.

In sum, it is demonstrated that NBS effectiveness depends on governance of the street section: only when traffic is slowed and space is reclaimed can water devices, shade trees, and social 'stopping places' become durable components of urban regeneration.

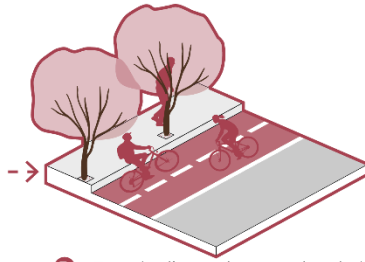
*In the next page: Figure 44 mobility toolkit.*

*In the second next page: Figure 45 via Giacinti section.*

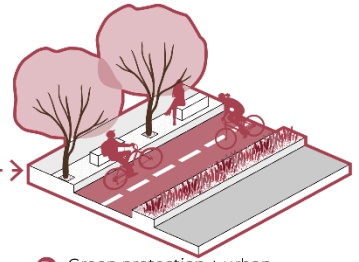
## ENCOURAGING BIKE USE



**A** Painted bike lanes

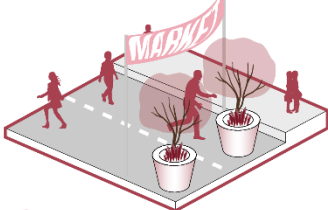


**B** Tree shading + pigmented asphalt

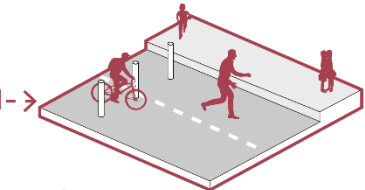


**B** Green protection + urban furniture

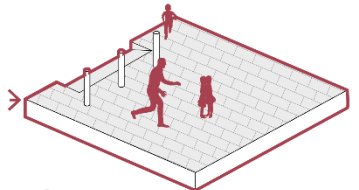
## DISCOURAGING CAR USE



**C** Weekly closures



**C** Removable modal filters

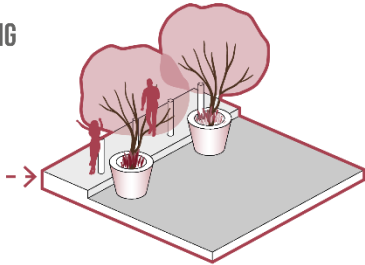


**D** Pedestrian zone with permeable high albedo paving

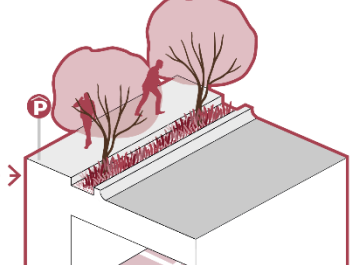
## PREVENTING SPONTANEOUS PARKING



**E** Removable road bollards + dedicated parking

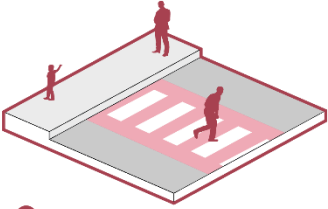


**E** Permanent road bollards + mobile vases

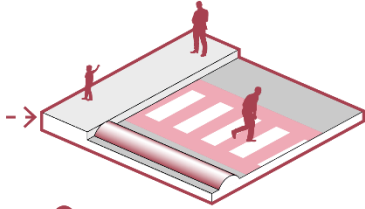


**F** Street greening + underground parking

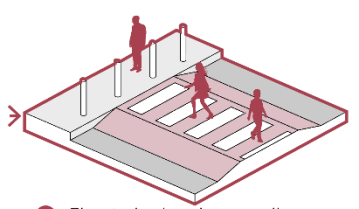
## ENSURING SAFE CROSSINGS



**H** Colored painted crosswalk



**G** Speed bumpers



**H** Elevated colored crosswalk + safety posts + lighting

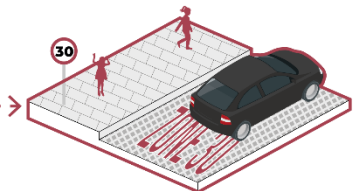
## SLOWING TRAFFIC IN SENSIBLE AREAS



**C** Zone 30 km/h



**J** Lane reduction

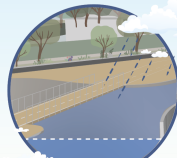


**I** Textured pavement

TEMPORARY/REVERSIBLE

LOW IMPACT/TRANSITIONAL

HIGH IMPACT/PERMANENT

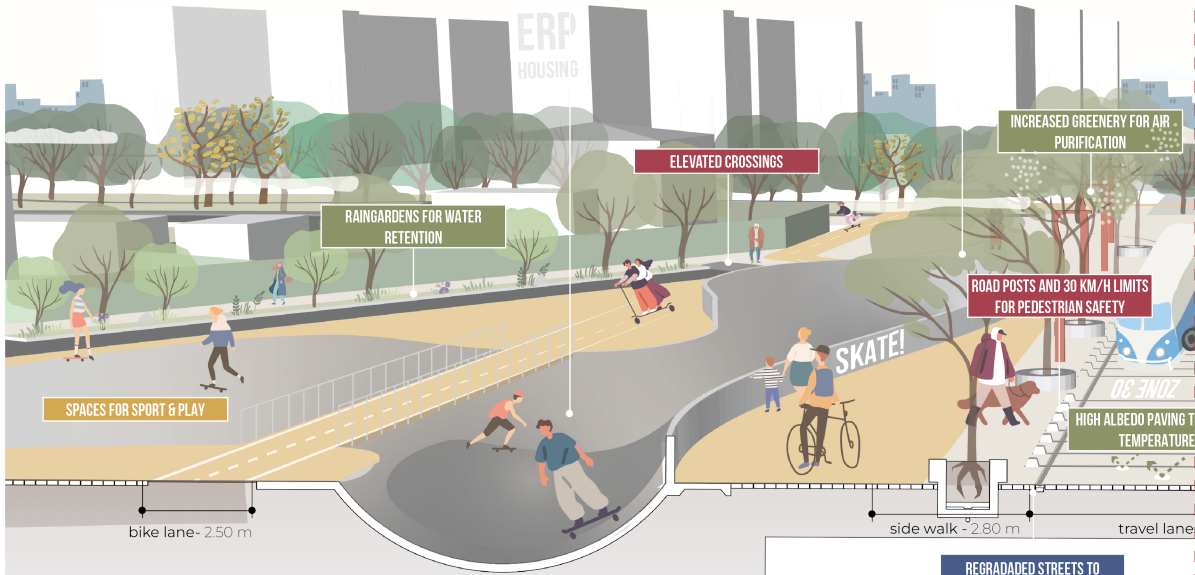


FLOODING PREVENTION  
EMERGENCY BASIN

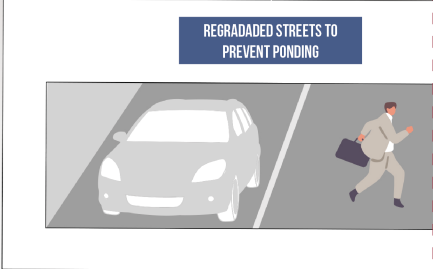


COOLING EFFECT THANKS TO  
SHADING & TRANSPIRATION

ROAD CLOSURE  
REDUCTION  
SO



- MOBILITY, ACCESSIBILITY & SECURITY
- ENERGY & COMMUNITY WELL-BEING
- NATURE BASED SOLUTIONS
- RAINWATER MANAGEMENT & CONTROL



REDUCES EMISSIONS AND INCREASED QUALITY

TO REDUCE S



STIMULATING LOCAL ECONOMY WITH SPACES FOR EVENTS

WALL SET BACK FOR SAFETY OF STUDENTS OUTSIDE THE SCHOOL

SECONDARY GYM ENTRANCE TO ENSURE CONTROLLED EVENING ACCESS

EXPANDED SIDEWALK

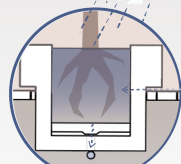
MULTIUSE URBAN FURNITURE

SPACES FOR SOCIALITY

road - 6.50 m    bike lane - 2.50 m    sidewalk - 5.50 m

PERMEABLE PAVING FOR EVAPORATIVE COOLING & WATER INFILTRATION

UNDERGROUND PARKING TO GAIN PUBLIC SPACE



WATER INFILTRATION

### **3.3.2. Sustainable Urban Drainage Solutions**

The project's resilience agenda is translated into a legible hydrological sequence, detailing how Sustainable urban Drainage Systems (SuDS) can operate as district infrastructure in a context where stormwater is otherwise conveyed into the combined sewer.

The toolkit is divided according to the type of action (detention, infiltration, purification, etc.) and capacity, with a distinction between normal rainfall and extreme weather events. In low-rain events, roof gutters and surface channeling direct water to storage tanks and planted devices, keeping runoff out of the sewer while supporting irrigation and evaporative cooling. The same components are designed to scale under high-rain conditions by activating secondary flows and emergency pathways, so that excess water is guided towards detention volumes rather than ponding in streets or overwhelming pipes.

The watersquare is presented as the key multifunctional node of the system. Its section clarifies thresholds, drainage grates, and maximum water levels, demonstrating how an everyday public plaza can temporarily transform into a controlled basin during cloudbursts without becoming unsafe or unusable. This dual programming is central: the space produces daily social value while providing risk-mitigation capacity that would otherwise be hidden in underground infrastructure.

Complementary devices such as bioswales, raingardens, permeable paving, planters, and pocket-park depressions perform interception and infiltration along the street network, distributing hydraulic responsibility.

Beyond quantity control, phytodepuration is introduced as a water-quality bettering strategy. By integrating vegetation and

substrate capable of filtering pollutants, the project addresses the fact that, in a combined system, stormwater is contaminated. The ecological treatment step is therefore conceived as both a technical function and a habitat generator, linking runoff management to biodiversity.

Overall, the toolkit demonstrates an applied research principle: SUDS effectiveness depends on redundancy and spatial continuity, so multiple small devices are coordinated with a few larger basins to deliver water control and safe public space across the regeneration process.

*In the next page: Figure 46 Watersquare section.*

*In the second next page: Figure 47 SuDS toolkit.*



NEW PUBLIC HOUSING

BIOSWALE

ACCESSIBILITY FOR PEOPLE WITH DISABILITIES

NEW NEIGHBOURHOOD CENTRALITY

- MOBILITY, ACCESSIBILITY & SECURITY
- ENERGY & COMMUNITY WELL-BEING
- NATURE BASED SOLUTIONS
- RAINWATER MANAGEMENT & CONTROL

+0.15 m

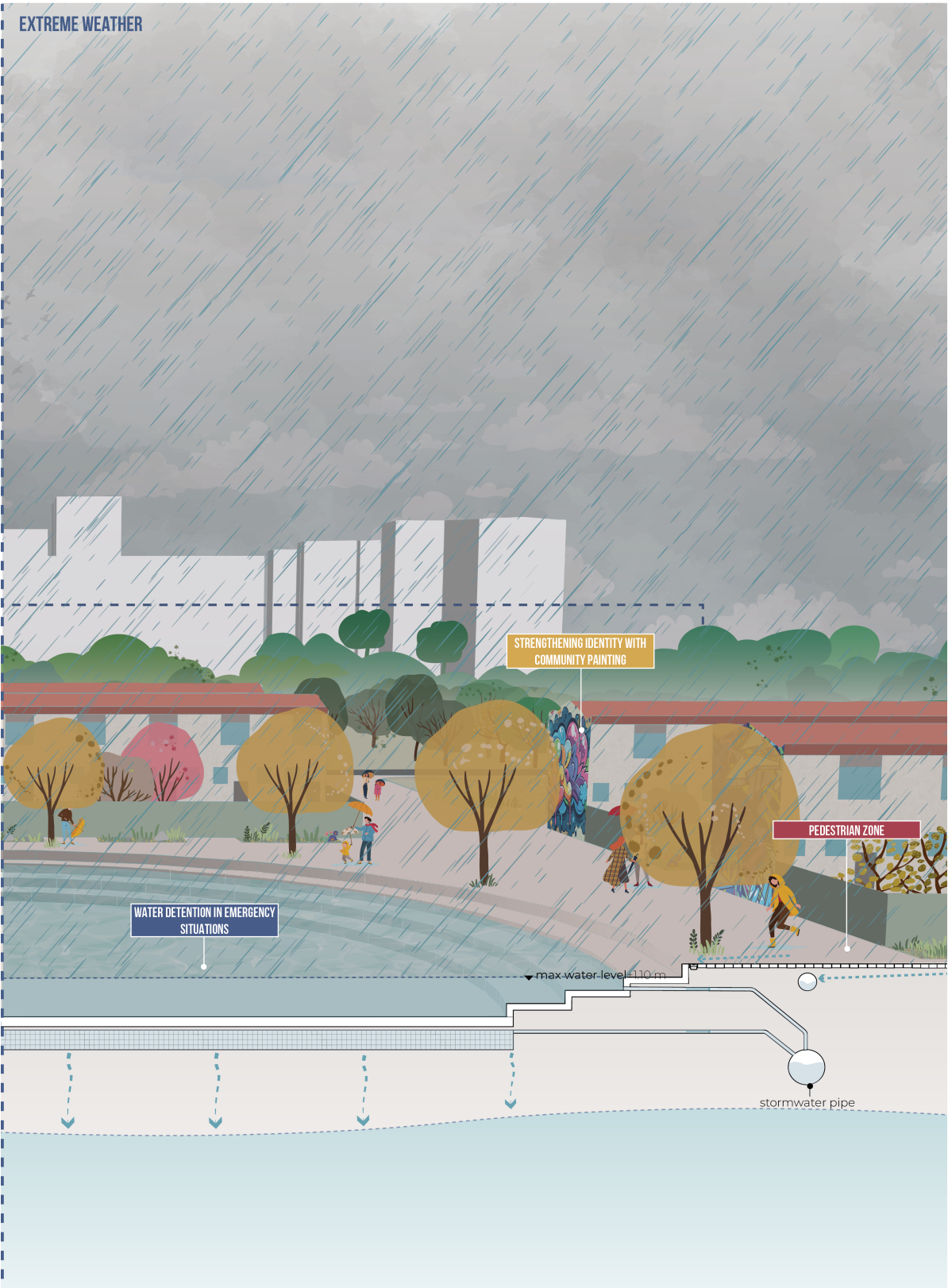
-1.50 m

water chamber

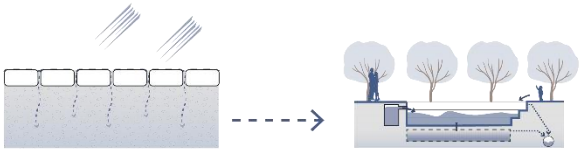
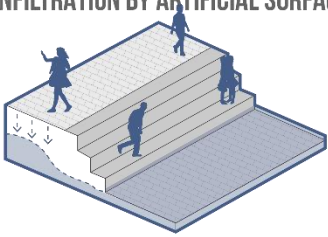
steel slit

drainage grates

EXTREME WEATHER

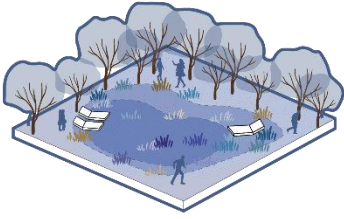


**INFILTRATION BY ARTIFICIAL SURFACES**



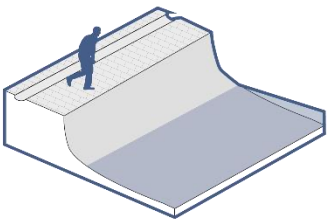
**A** Permeable paving **B** Water square  
 LOW RAIN VOLUME HIGH RAIN VOLUME

**INFILTRATION BY NATURAL SURFACES**



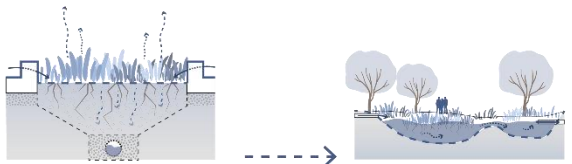
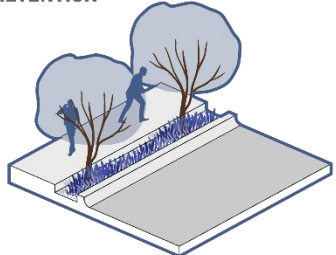
**C** Street greening **D** Pocket Park  
 LOW RAIN VOLUME HIGH RAIN VOLUME

**DETENTION BY ARTIFICIAL SURFACES**



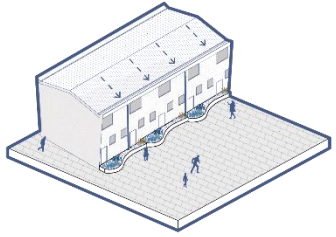
**E** Surface drain **F** Emergency detention basin  
 LOW RAIN VOLUME HIGH RAIN VOLUME

**RETENTION**



**G** Raingarden **H** Fitodepuration pond  
 LOW RAIN VOLUME HIGH RAIN VOLUME

**INTERCEPTION AND CHANNELING**



**I** Planters **J** Bioswale  
 LOW RAIN VOLUME HIGH RAIN VOLUME

### 3.3.3. Nature Based Solutions

The landscape project is conceived as evidence-based infrastructure rather than ornamental planting. Species and typologies are selected with feasibility in mind: maintenance demand, biodiversity index, water tolerance, growth time, and suitability for Lombardy soils; with a preference for native and naturalized essences. This methodological framing is crucial for regeneration contexts, where long-term performance depends on survivability and manageable upkeep as much as on initial visual impact.

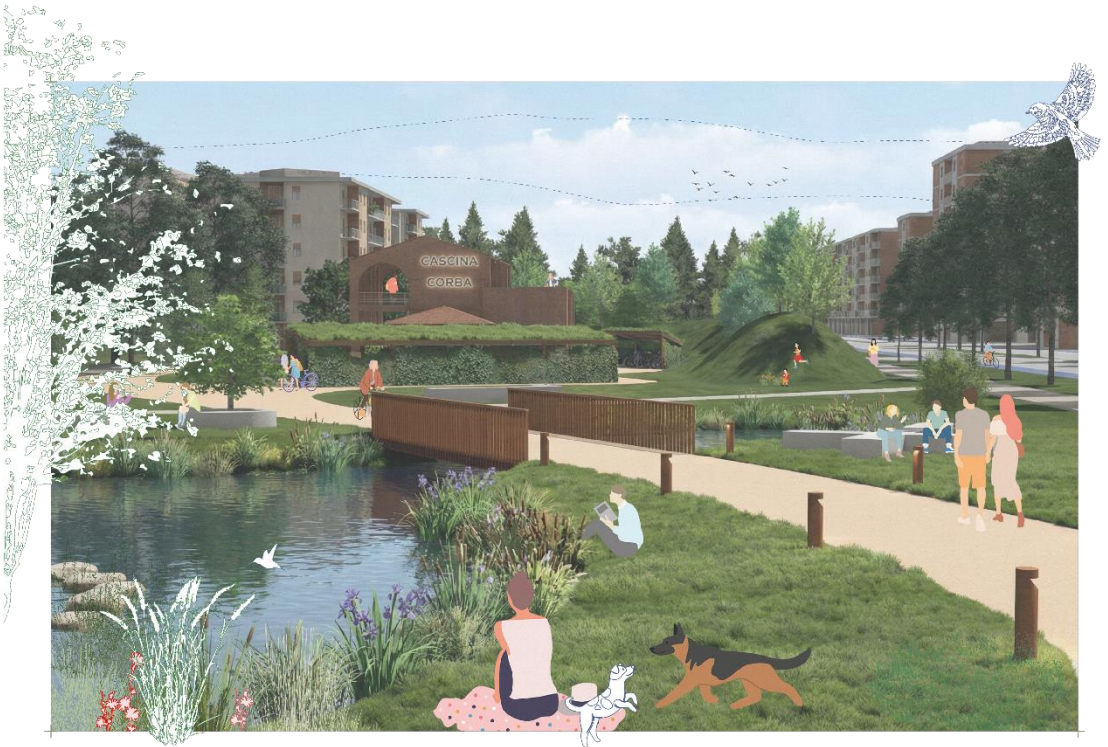
The three proposed 'landscapes' function as a typological system that calibrates ecosystem services to different urban conditions. Landscape 1 deploys large roadside trees and evergreen masses to create constant shade and 'cool routes', while acting as a filter against traffic noise and pollution; its associated wet component supports detention and phytoremediation.

Landscape 2 introduces fruit trees and flowering species near residences to combine seasonal shade modulation with a strong aesthetic identity, reinforcing place attachment and supporting pollinators.

Landscape 3, focused on neighbourhood streets, uses smaller deciduous trees and raingardens to manage runoff, reduce surface temperatures, and spatially limit spontaneous parking, thereby enabling safer slow mobility.

Thanks to the accurate placing of planting, comfort is translated into a spatial composition tool: gradients of exposure and shade guide movement, invite stopping, and extend the usability of open space across seasons, with the proposal of sunny and cool "rooms."

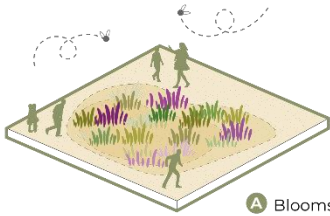
Importantly, wetland and aquatic plants are justified through ecological feedback: by creating habitat for mosquito predators, they mitigate a frequent social concern linked to standing water, thus strengthening acceptability of blue-green solutions. Edible herbs and blooming perennials further connect biodiversity to everyday experience, making ecological functions perceptible to residents. Overall, the thesis' central argument is supported: Nature-Based Solutions are effective when their design is simultaneously technical and social; grounded in measurable ecosystem services while producing legible, attractive spaces that residents can recognize, care for, and defend over time.



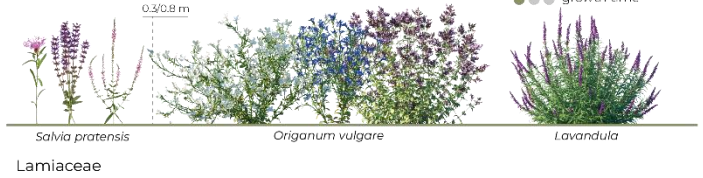
*Figure 49 View of the Cascina Corba Park.*

*In the next page: Figure 48 NBS toolkit and selected planting species.*

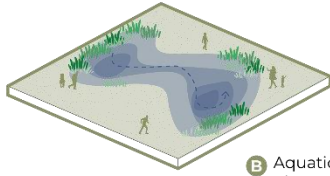
**XS POLLINATION, BIODIVERSITY**



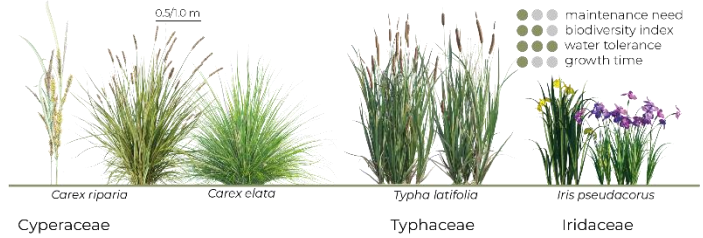
**A** Blooms



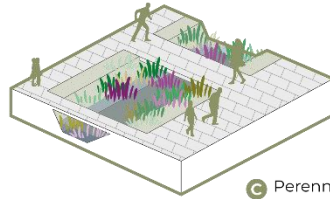
**S PHYTOREMEDIATION, INSECT CONTROL**



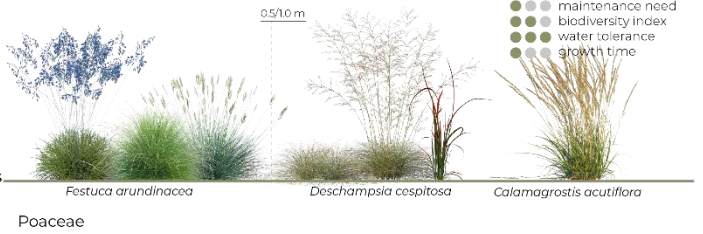
**B** Aquatic plants



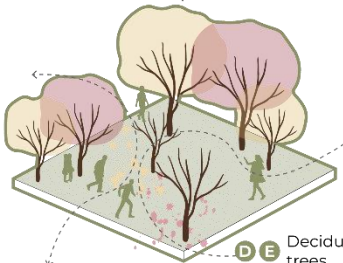
**M HYDRO MANAGEMENT**



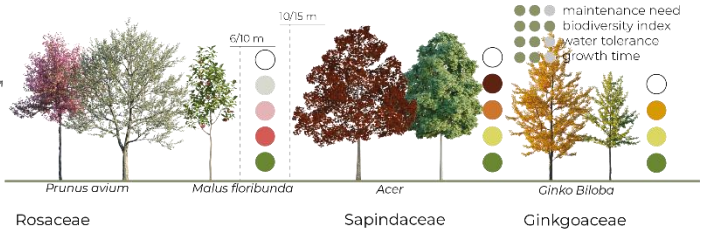
**C** Perennial herbaceous plants



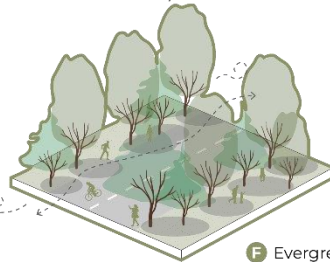
**L SEASONAL SHADE, AESTHETICS**



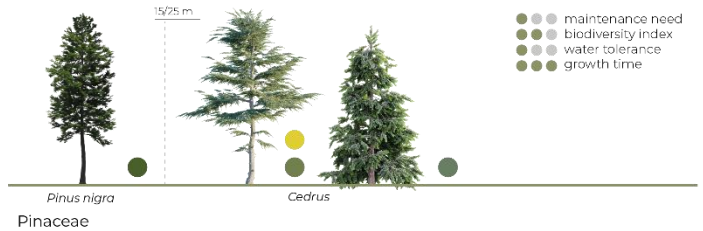
**D E** Deciduous trees



**XL CONSTANT SHADE, COOL ROUTES**



**F** Evergreens



### **3.3.4. Renewable Energy Community**

The regeneration framework extends to socio-technical governance through the establishment of a Renewable Energy Community (REC) anchored in the district's public assets. The definition is operationally grounded: buildings can share energy via the public grid provided they belong to the same primary substation, and the exchange is virtual rather than physical. This technical constraint functions simultaneously as a spatial planning parameter, encouraging the clustering of municipal buildings and public housing into an energy-sharing constellation capable of generating measurable environmental and social benefits.

The project's logic is articulated across three nested scales: building, neighbourhood, and district network; each of which produces quantifiable outcomes that together constitute the community's overall energy performance.

#### **Building Scale**

At the envelope scale, retrofit solutions for the Case Minime were selected according to two governing criteria: cost containment and resident continuity. All interventions are designed to avoid the displacement of occupants during construction, a condition that determines both the technical choice of components and the sequence of works.

The exterior wall receives external rock-wool insulation, reducing thermal transmittance from 0.77 to 0.27 W/m<sup>2</sup>K, a reduction of approximately 65%. The roof assembly, which required asbestos encapsulation rather than removal (permitted under DM

06/09/1994), achieves a transmittance of 0.22 W/m<sup>2</sup>K against an existing value of 1.32 W/m<sup>2</sup>K, representing an improvement of over 83%. The floor separating heated living space from the unheated technical compartment below is insulated on its underside without affecting the interior layout, reducing transmittance from 2.60 to 0.26 W/m<sup>2</sup>K, an improvement of 90%.

*Table 1 Case Minime envelope performance before and after intervention.*

<b>Building Assembly</b>	<b>Existing U-value (W/m<sup>2</sup>K)</b>	<b>Retrofitted U-value (W/m<sup>2</sup>K)</b>	<b>Improvement (%)</b>
Exterior wall	0.77	0.27	65%
Roof	1.32	0.22	83%
Floor to unheated space	2.60	0.26	90%

Taken together, these interventions substantially reduce heat loss through the three primary transmission paths, lowering winter heating demand and improving summer thermal comfort without mechanical cooling. The combined effect positions the retrofitted units significantly closer to current Italian energy performance requirements (D.Lgs. 192/2005 and subsequent amendments) while maintaining the architectural character of the existing housing stock.

A rooftop photovoltaic system is modelled using the PVGIS-SARAH3 database. The system yields an annual energy production of 40,276 kWh against an annual household consumption of 74,287 kWh for a single residential building. This corresponds to a maximum renewable energy coverage of 84.21% of the annual energy requirements of one Case Minime unit, a figure that already signals the viability of the approach before any collective sharing mechanism is considered.

The avoided carbon emissions attributable to the PV panels of a single retrofitted unit amount to 8.66 tCO<sub>2</sub> per year, calculated using the ISPRA national emission factor for the Italian electricity mix (approximately 0.215 kg CO<sub>2</sub>/kWh in 2024–2025). To

contextualize this figure: the avoided emissions per unit are equivalent to the carbon sequestered annually by approximately 400 trees. Scaled across the multiple residential blocks within the REC perimeter, the aggregate avoided emissions represent a significant contribution to the district's decarbonization trajectory.

*Table 2 Data of modelled PV system for Case Minime.*

<b>PV System Parameter</b>	<b>Value</b>
Installed capacity	30.6 kWp
Technology	Crystalline silicon
System loss	5%
Slope / Azimuth	12° / -22°
Annual PV energy production	40,276 kWh/year
Annual energy consumption (per unit)	74,287 kWh/year
Renewable energy coverage	84.21%
Avoided CO <sub>2</sub> emissions (per unit)	8.66 tCO <sub>2</sub> /year
CO <sub>2</sub> equivalent (trees)	~400 trees/year
Emission factor (ISPRA 2024–25)	0.215 kg CO <sub>2</sub> /kWh

Monthly irradiation profiles confirm a marked seasonal asymmetry: in-plane irradiation peaks in summer months (exceeding 200 kWh/m<sup>2</sup> in June–July) and reaches a minimum in December–January. This pattern is fully reflected in the monthly energy output curve, which peaks above 5,000 kWh in summer and falls below 1,000 kWh in the winter trough. The mismatch between peak production and peak heating demand constitutes the primary challenge to self-sufficiency and motivates the design of a diversified procurement strategy for the winter months.

## Neighbourhood Scale

The conversion of Cascina Corba into the operational hub of the Renewable Energy Community links technical infrastructure to social governance. The program allocates space for REC offices, conference and event rooms, a neighbourhood watchman function, and collective energy storage, alongside shared circulation, toilets, and technical storage. The reuse of this existing structure avoids new construction while anchoring the community's administrative and social life within the physical boundaries of the district. The use conversion is designed to take advantage of the existing internal layout and installations, minimizing structural intervention and reducing embodied carbon relative to a new-build alternative.

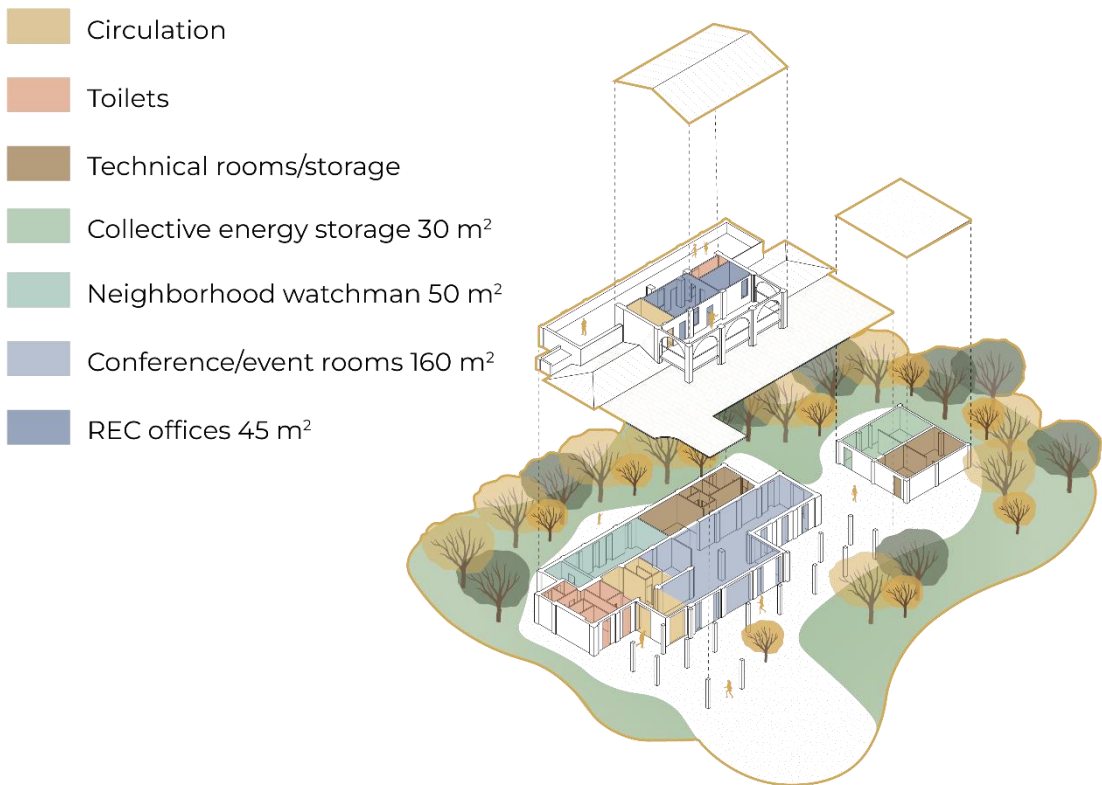
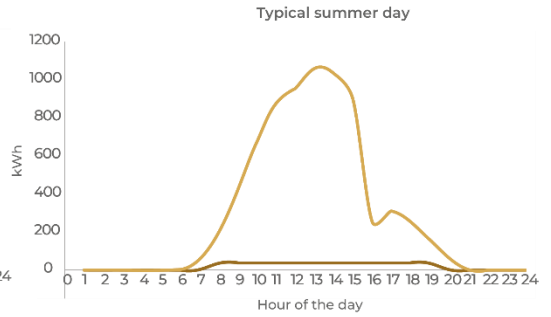
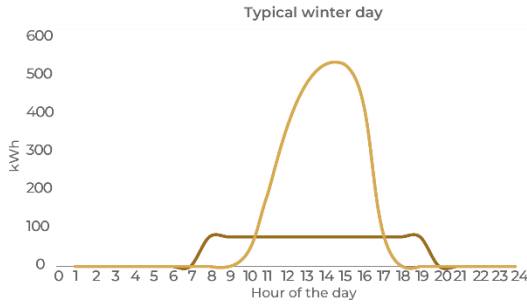


Figure 51 Cascina Corba functional conversion.

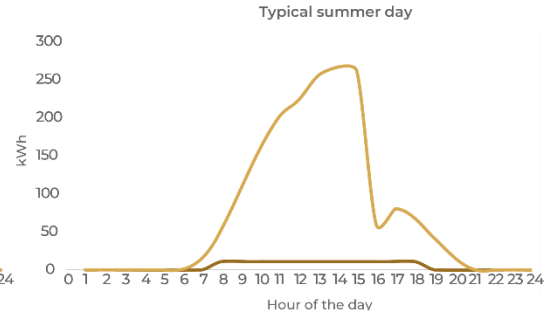
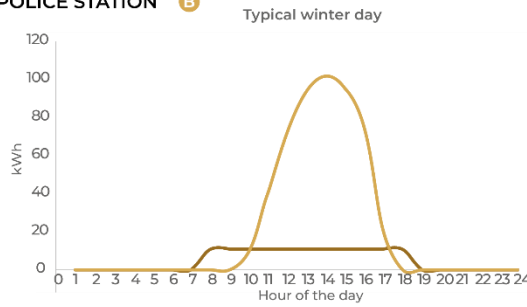
In the next page: Figure 50 yearly energy production and consumption of the district's public buildings.

— Medium energy production from PV panels  
 — Medium energy consumption

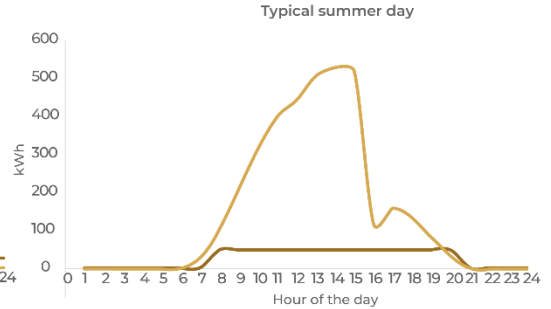
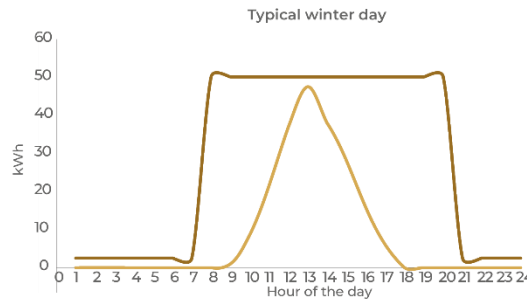
**COMPREHENSIVE SCHOOL NARCISI A**



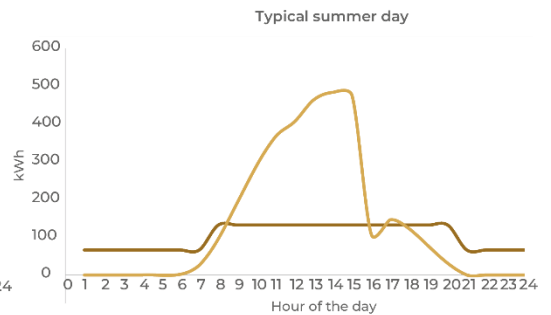
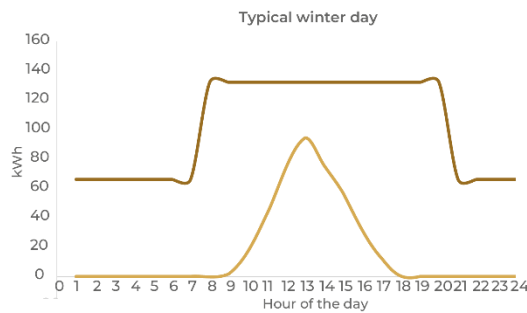
**POLICE STATION B**



**PUBLIC LIBRARY C**



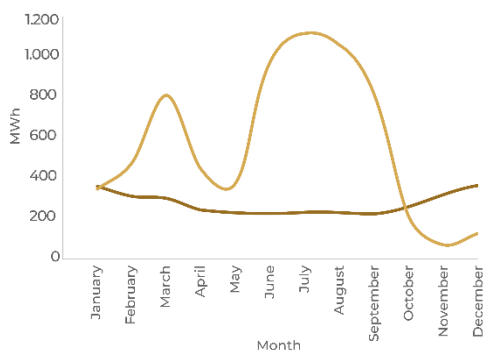
**MUNICIPAL MARKET D**



## District Scale

At the district scale, four public buildings are designated as “big prosumers”<sup>1</sup> within the REC: the Comprehensive Institute Narcisi, the municipal market, the police station, and the public library. Their selection reflects both the availability of unshaded roof area suitable for PV installation and their complementary demand profiles, which collectively stabilize the community's annual energy balance.

Each facility exhibits a characteristic daily demand curve that varies between a typical winter day and a typical summer day. The school displays a pronounced daytime peak aligned with occupancy schedules, making it a well-matched host for solar generation. The police station and public library show more distributed demand profiles with lower absolute values. The municipal market presents the highest aggregate consumption among the four, driven by the energy-intensive requirements of food storage and refrigeration, but its available roof area for PV is comparatively constrained by shading, resulting in a less favorable production-to-consumption ratio.



*Figure 52 Summary of yearly production (yellow) and consumption (brown) estimate of the neighbourhood's public buildings.*

When the energy balances of all big prosumers are aggregated at the neighbourhood level, the combined monthly data reveal that production clearly exceeds consumption during most months in the solar year. This structural surplus during spring, summer, and early autumn months enables two

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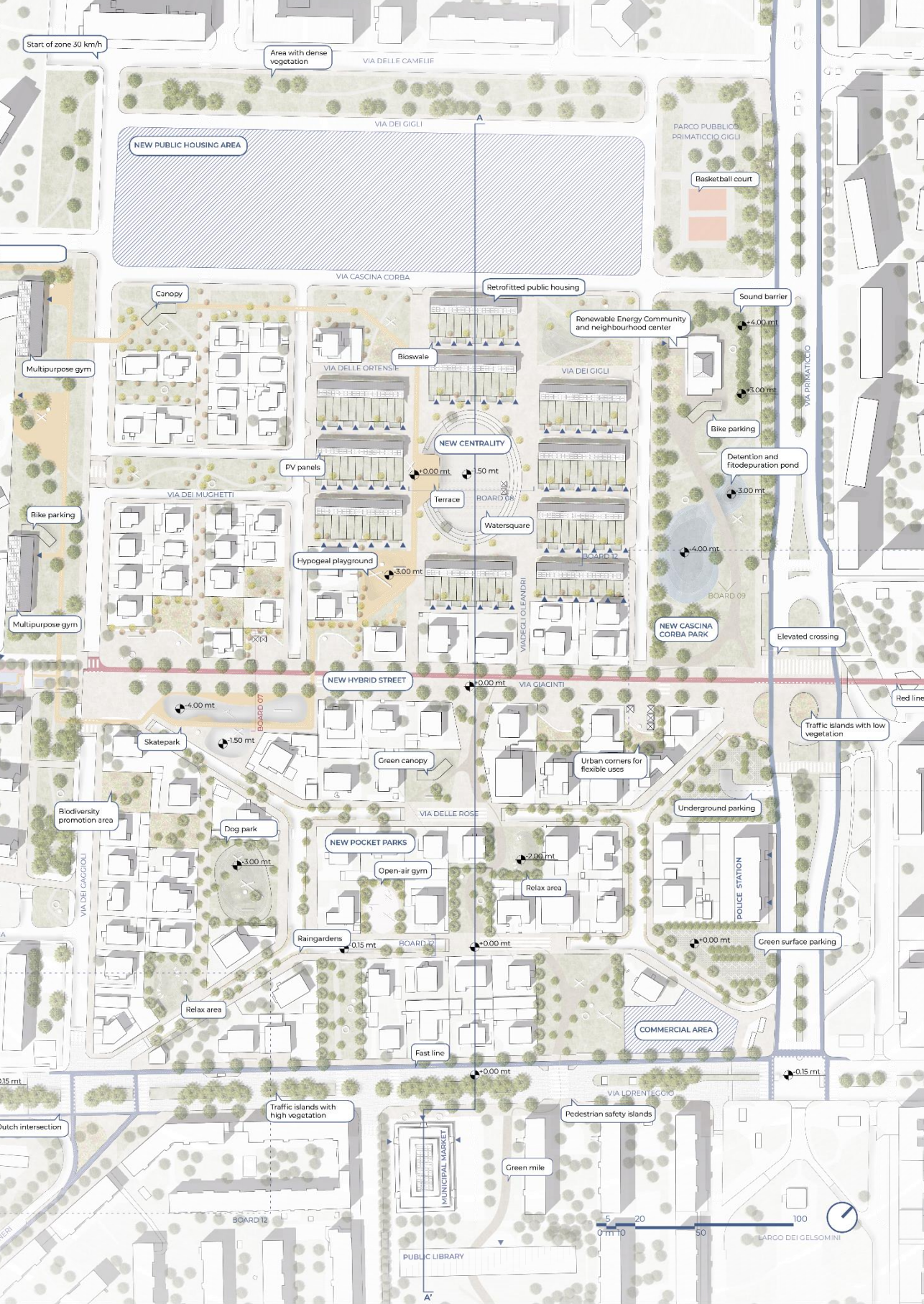
<sup>1</sup> A prosumer is an individual or entity that both produces and consumes a particular good, service, or energy, bridging the gap between producer and consumer.

complementary mechanisms: collective self-consumption within the REC, which directly reduces grid energy purchases by member buildings, and surplus resale to other users located under the same primary substation. The latter opens the pathway for expanding the energy community progressively to include private citizens and businesses beyond the current perimeter of public assets. In winter, particularly from November through February, the production-consumption balance inverts. During these months, the community will need to supplement self-produced energy with grid supply, underscoring the importance of designing a diversified energy procurement strategy and integrating battery storage at the district level and demand-side management protocols as the REC matures.

Within the overall project framework, the REC is not conceived as a parallel sustainability intervention but as a complementary governance mechanism to the proposed Nature-Based Solutions. The two systems operate at different but reinforcing registers: blue-green infrastructure reduces heat stress and pluvial flood risk in the public realm, thereby lowering cooling and drainage costs; energy sharing through the REC reduces electricity expenditure and carbon emissions, while simultaneously strengthening social equity by addressing energy poverty in public housing. Together, they constitute a green social infrastructure in the fullest sense, one in which ecological performance and community governance are co-produced rather than layered independently onto an existing urban fabric.

*In the next page: Figure 54 Project masterplan.*

*In the second next page: Figure 53 thematic diagrams of used strategies.*



Start of zone 30 km/h

Area with dense vegetation

VIA DELLE CAMELIE

VIA DEI GIGLI

NEW PUBLIC HOUSING AREA

PARCO PUBBLICO PRIMATICCIO GIGLI

Basketball court

VIA CASCINA CORBA

Retrofitted public housing

Renewable Energy Community and neighbourhood center

Canopy

Multipurpose gym

Bioswale

Sound barrier

4.00 mt

3.00 mt

Bike parking

Detention and fitodepuration pond

3.00 mt

NEW CENTRALITY

0.00 mt

50 mt

Terrace

Watersquare

NEW CASCINA CORBA PARK

4.00 mt

Elevated crossing

VIA DEI MUGHETTI

Hypogeal playground

3.00 mt

Bike parking

Multipurpose gym

NEW HYBRID STREET

0.00 mt

VIA GIACINTI

Skatepark

4.00 mt

1.50 mt

Green canopy

Urban corners for flexible uses

Traffic islands with low vegetation

Biodiversity promotion area

Dog park

3.00 mt

NEW POCKET PARKS

Open-air gym

2.00 mt

Relax area

Underground parking

POLICE STATION

Raingardens

0.15 mt

0.00 mt

Green surface parking

Relax area

Fast lane

0.00 mt

COMMERCIAL AREA

VIA LORENTECCIO

0.15 mt

Dutch intersection

Traffic islands with high vegetation

Pedestrian safety islands

Green mile

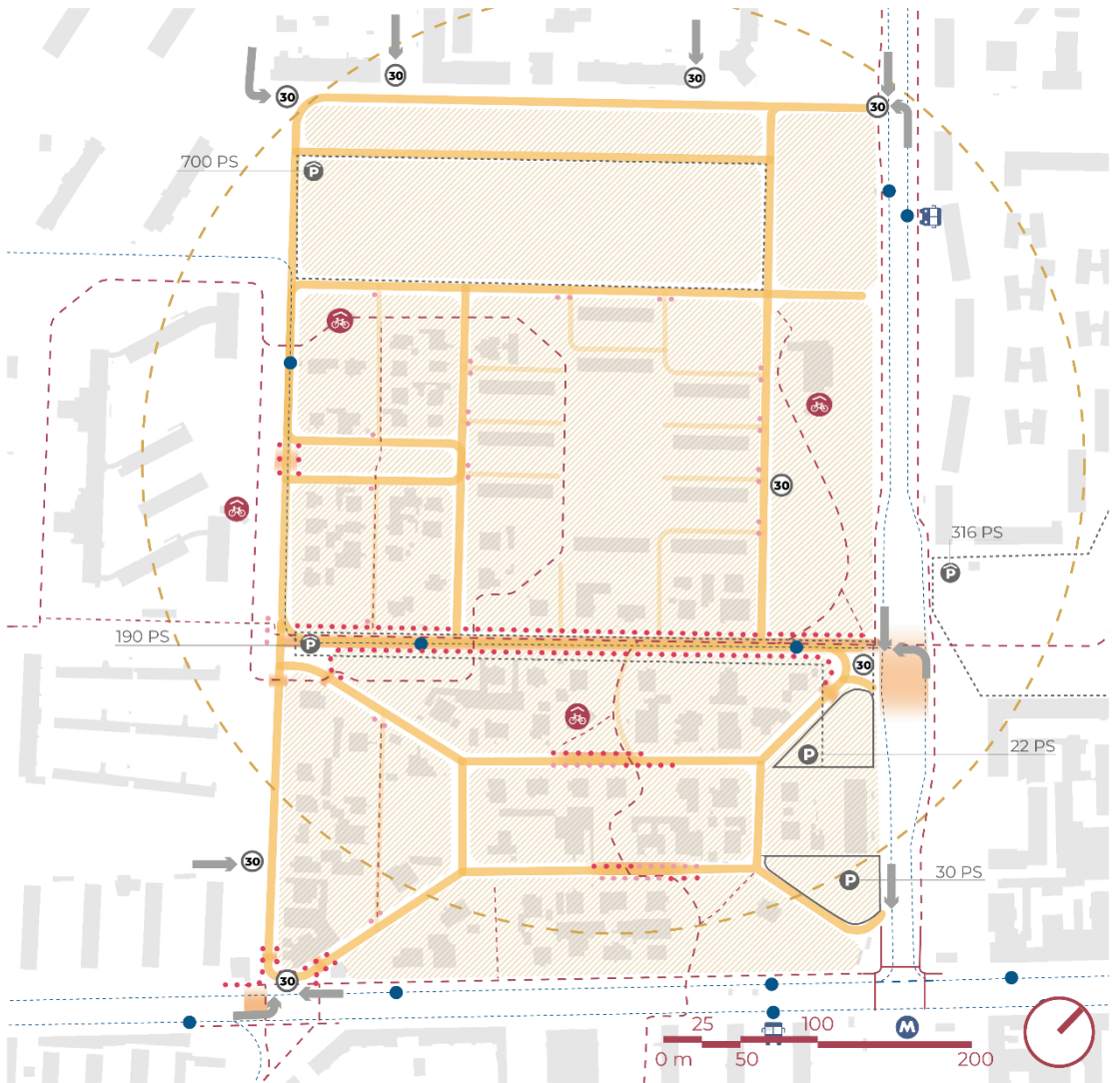
MUNICIPAL MARKET

PUBLIC LIBRARY

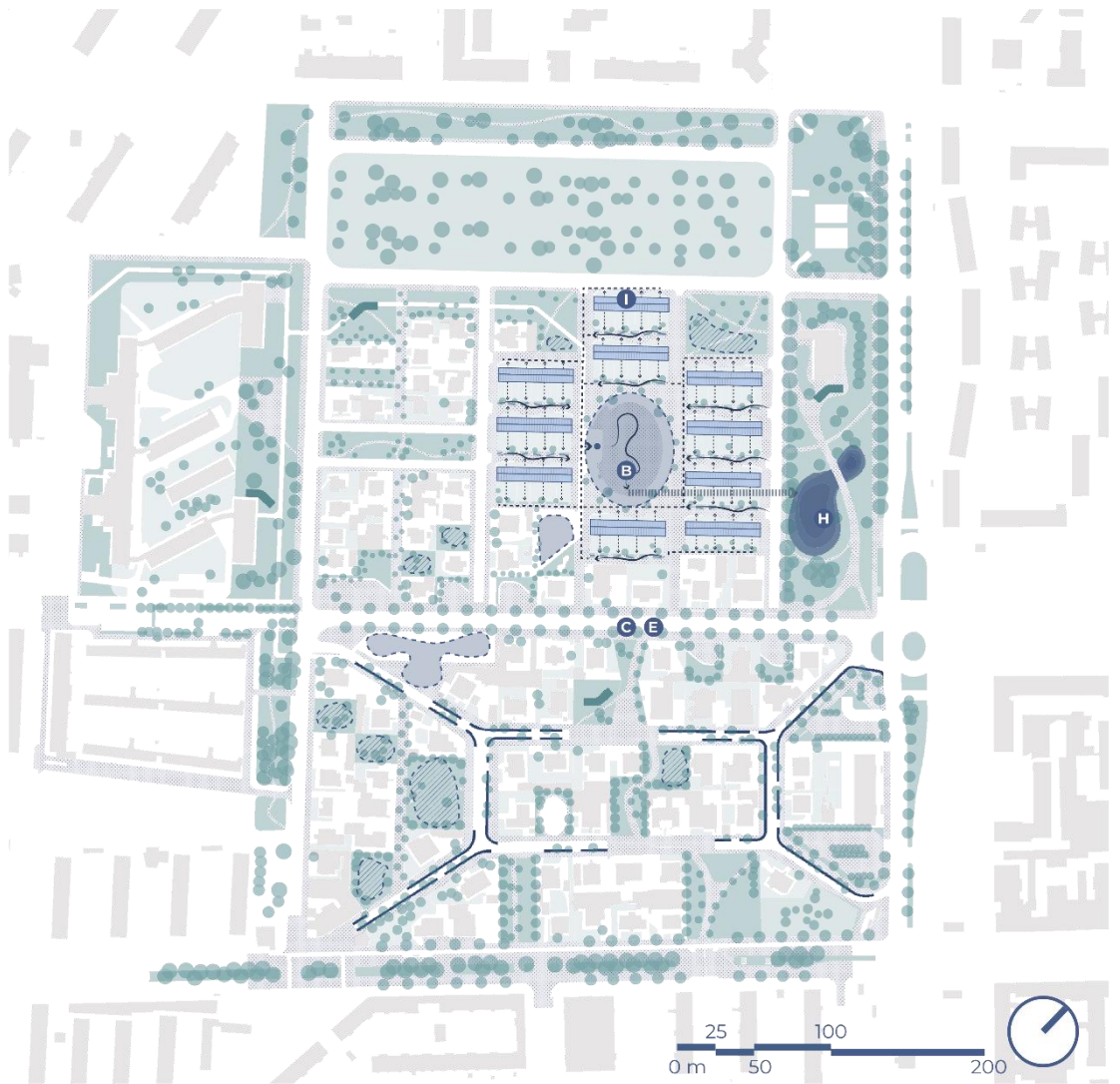
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LARGO DEI GELSOMINI






-  Metro stops
 Existing cycle routes
-  Public transport routes
 Cyclists as guests
-  Access for motorized traffic
 Pedonal islands
-  Pedestrian oriented street design
 New cycle routes
-  Elevated crossings
 Removable bollards
-  Road bollards



 Permeable paving **(A)**

 Green surfaces

 Private green surfaces

 Terrain depressions **(D)**

 Emergency water basins **(F)**

 Raingardens **(G)**

 Surface water

 Pitched roof

 Bioswales **(J)**

 Rainwater tank

 Gutters

 Secondary flow

 Primary flow



 Trees





### LANDSCAPE 1

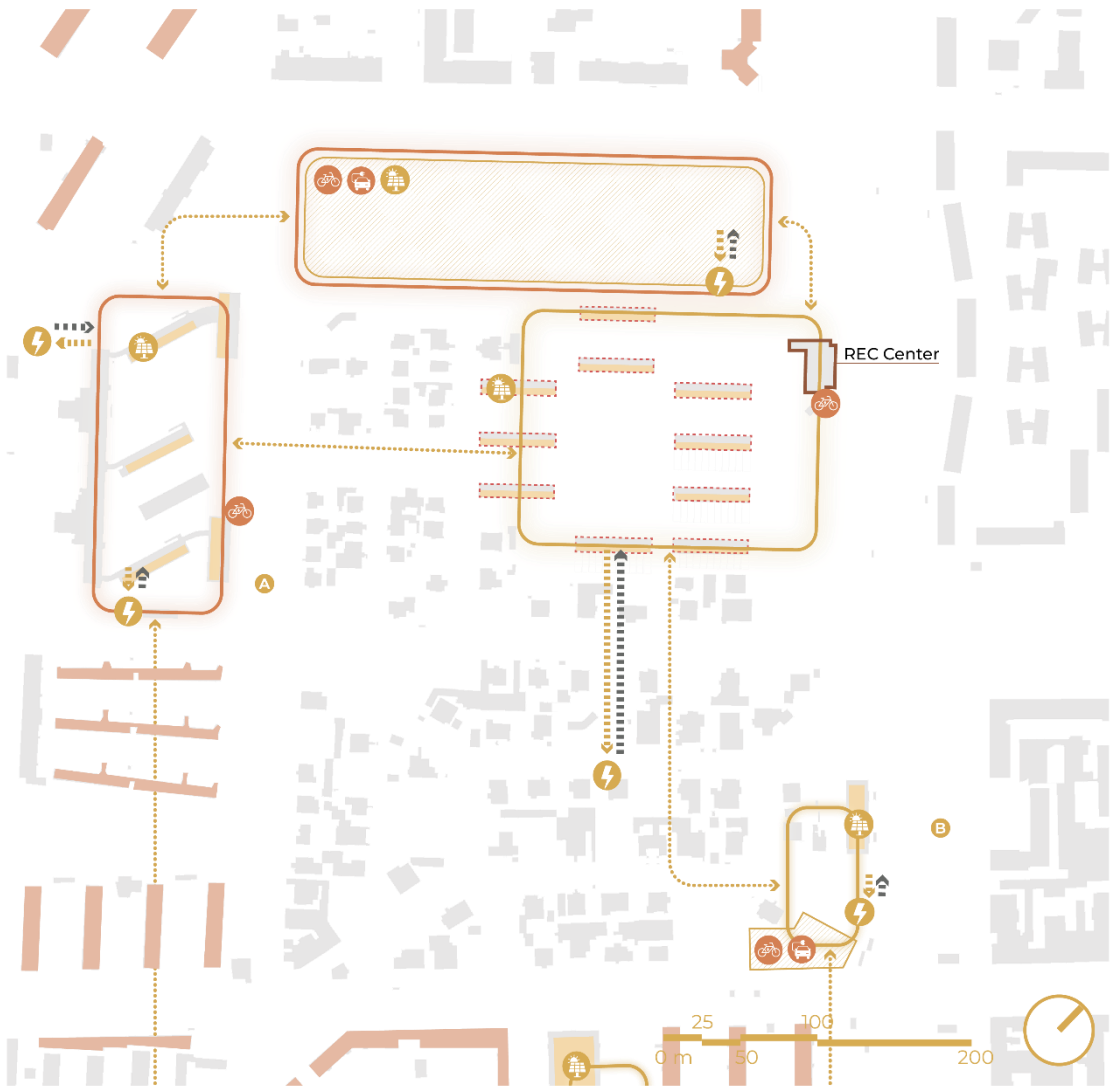
-  Evergreens **F**
-  Lawn
-  Aquatic plants **B**

### LANDSCAPE 2

-  Flowering trees **D**
-  Grass with blooms **A**

### LANDSCAPE 3


-  Deciduous trees **E**
-  Raingardens **C**





 Areas destined to PV installation

 Future constructions with PV

 Self-consumption

 Collective self-consumption

 Public housing residences that qualify for membership in REC.


 Major prosumers

 Energy surplus

 Grid supply

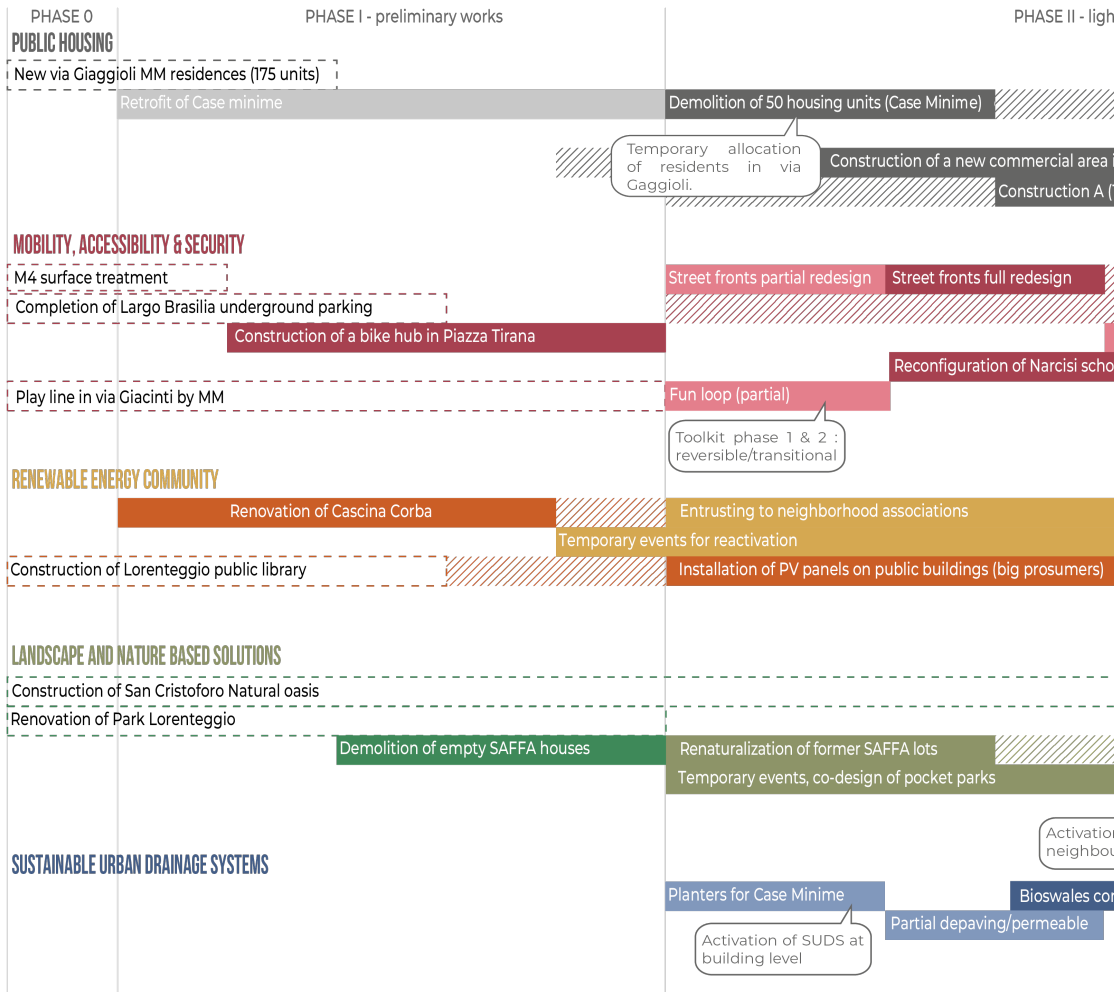
 Energy exchange

 Secondary cabin

 Bike charging

 Car charging

### 3.3.5. Project implementation and feasibility



All the aspects and strategies illustrated in previous chapters show regeneration as a phased and learning-oriented process rather than a single final-state image. For this reason a 10-year schedule (2025-2035) is structured. The timetable takes in consideration the coexistence of major metropolitan works previously illustrated in chapter 3.1.2. and local neighbourhood actions, acknowledging that implementation capacity, funding cycles, and resident tolerance impose real constraints.

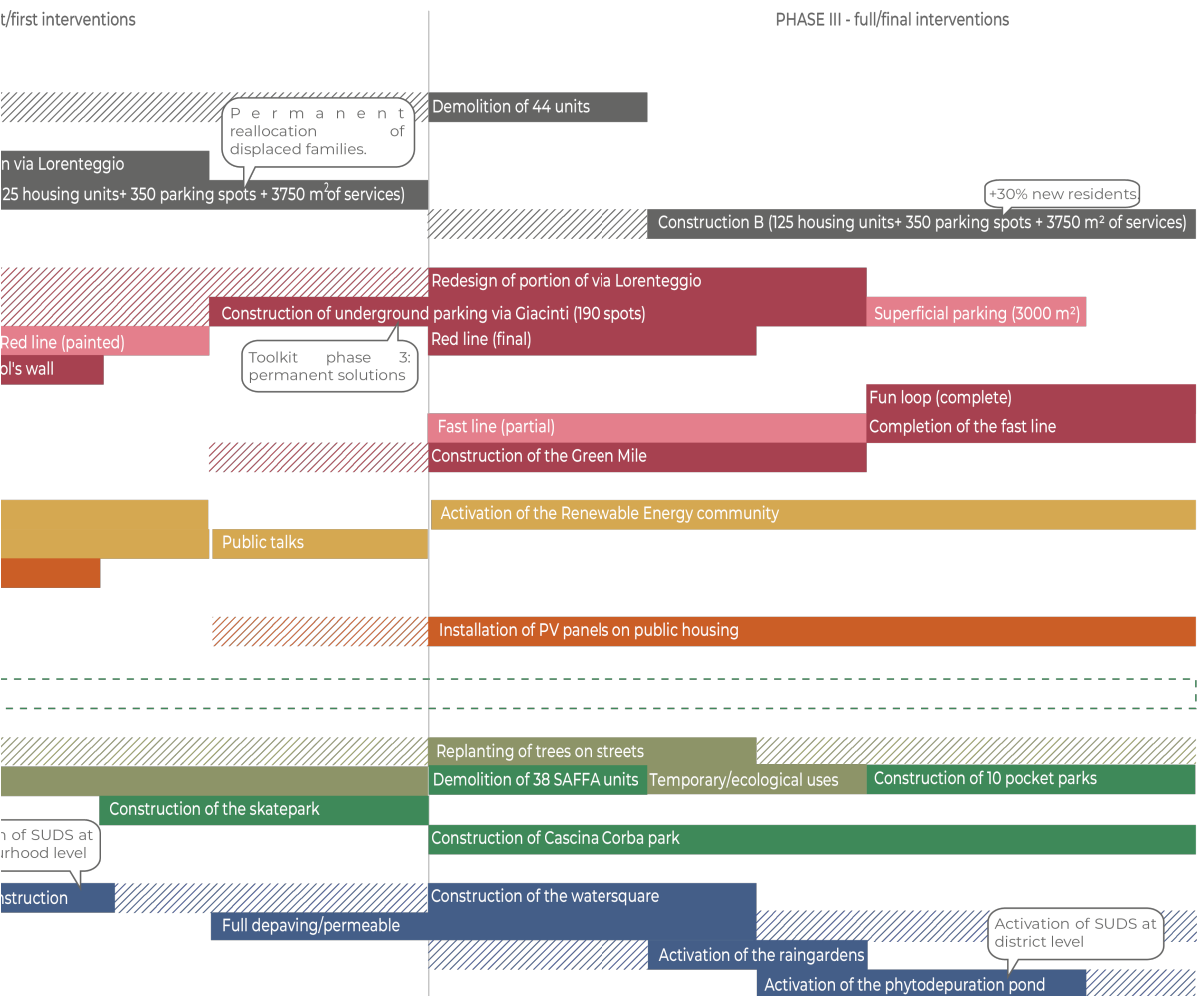


Figure 55 Project schedule.

Controlled transformation is particularly important when it comes to providing new housing. A detailed study has shown that it is possible to provide the area with 30% more housing without having to move any residents from the area. The presence of new ERP residences in Via Gaggioli, which are still being allocated, is fundamental to the success of this operation, with the relocation of families living in the blocks to be demolished. The energy retrofit of the other blocks, on the other

hand, allows tenants to remain in their homes, as the planned interventions on the building envelope do not involve work inside the apartments.

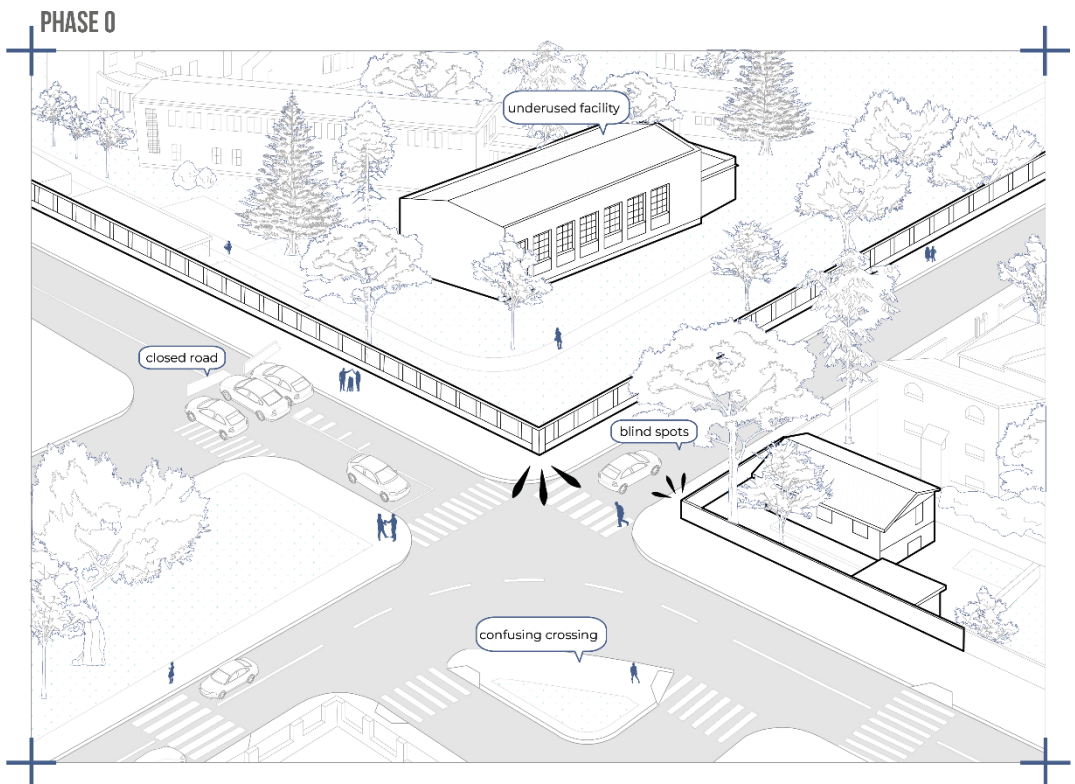
Another key methodological move is the differentiation between light/temporary interventions and full permanent ones in the public realm. By proposing reversible street measures and tactical public-space upgrades first, the project creates early improvements while testing layouts before higher-impact construction.

An example of this approach is demonstrated thru the requalification of Narcisi school: a degraded edge defined by aged asphalt and a rigid wall is reconfigured through incremental steps, from painted and pigmented surfaces to planters, fencing, and wall setback, culminating in a safer and more legible frontage.

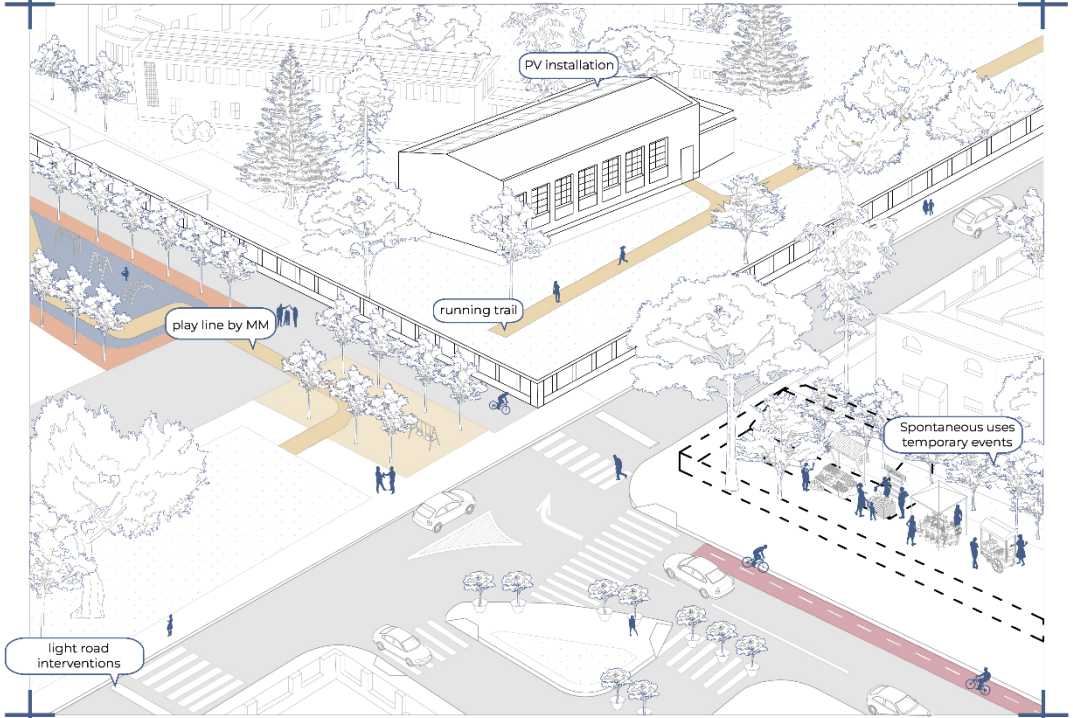
Another example can be found in the method regarding the construction of pocket parks. S.A.F.F.A. housing is demolished and paired with renaturalization to avoid long vacancy. This approach allows plants to grow in situ, which can then be transplanted to the roadside. Renaturalization can be followed by the use of the areas for temporary events and activities such as markets, food trucks, installations, and cultural events. This strategy stimulates interest from the community and, at the same time, tests its response without the need for major interventions. A series of scheduled meetings with the community will then decide the final use of the pocket parks, which may be recreational, sporting, cultural, or natural. This phased transformation system allows for controlled development and ensures that citizens always receive benefits at every stage, whether ecological or in relation to services.

In synthesis, the schedule embeds 'soft' actions like temporary events, co-design moments, and entrusting spaces to local associations within the same framework as construction. This reflects the project's claim that long-term NBS performance depends on stewardship as much as on design: maintenance, programming, and social ownership reduce the risk of re-degradation and make ecological devices part of everyday life. The schedule provides a feasible pathway from research principles to delivery, aligning technical systems with governance milestones and adaptive feedback. Phasing becomes a research instrument: reversible steps are monitored, and results guide later investments and maintenance plans.

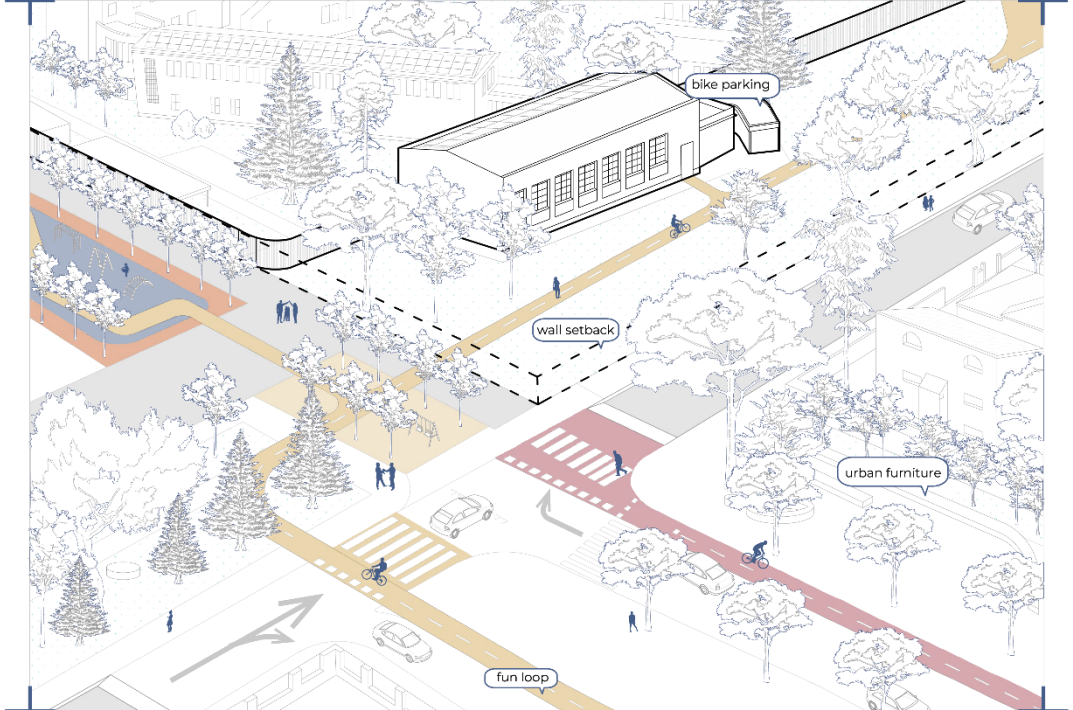
Figure 56 phased transformation of Narcisi's school surroundings.



## PHASE 1



## PHASE 2



## 3.4. PROJECT IMPACT AND PERFORMANCE ASSESSMENT

The regeneration proposal developed in this thesis is grounded in the hypothesis that Nature-Based Solutions, mobility reallocation, and collective energy infrastructures can simultaneously enhance environmental resilience and social cohesion; but such claims require traceability. So, to verify the internal coherence of the design, assess measurable improvements and support replicability, a structured **performance assessment toolkit** is introduced.

The toolkit does not aim to simulate long-term monitoring with real-time data; rather, it translates design decisions into measurable proxies, allowing ex-ante comparison between “before” and “after” conditions.

The KPI are organized across three spatial scales:

- **District scale (D)**, where systemic performance is measured across the neighborhood.
- **Node scale (N)**, regarding performance at intersections and key public spaces.
- **Street scale (S)**, showcasing micro-climatic and hydraulic behavior of street sections.

This scalar differentiation reflects the thesis’ methodological claim: regeneration effects must be observable from territorial systems down to material devices. The indicators are also grouped into four thematic domains, consistent with the toolkit developed in Chapter 3.3.

Table 3 Designed key performance indicators for project assessment.

	<b>Water resilience</b>	<b>Heat mitigation</b>	<b>Mobility &amp; safety</b>	<b>Public perception</b>
<b>District scale</b>	Retention capacity	Tree covered meters traveled	Cycling Infrastructure Quality	Public space quality
<b>Node scale</b>	-	-	Conflict points reduction	Estimated public space occupancy
<b>Street scale</b>	Infiltration capacity	Surface temperature reduction	-	-

Water resilience indicators assess the performance of the intervention in terms of resilience to weather events, comparing the urban area's capacity to absorb, transport, and contain rainwater in situations before and after the intervention, to demonstrate its effectiveness.

Heat mitigation indicators demonstrate the effectiveness of the project in combating the urban heat island phenomenon using different strategies from canopy cover increase to substitution of paving materials.

Mobility and safety indicators assess the intrinsic quality of the street redesign transforming security and connectivity of quantifiable entities.

Finally, public perception aims to provide a forecast of how the public will respond to the intervention. The two KPIs proposed aim to anticipate an assessment that is usually carried out after construction, based on observation of behavior and questionnaires/meetings.

Energy performance indicators have not been included in this section as the results of applied strategies are already presented in chapter 3.3.4. Renewable Energy Community.

### 3.4.1. Water resilience indicators

#### Retention Capacity (D)

The Retention Capacity Index (RCI) quantifies the stormwater retention capacity provided by Sustainable Drainage Systems (SuDS) installed within the project area. Rather than measuring impervious ratio alone, RCI translates the physical dimensions of each device into a unified volume per unit area metric, directly comparable before and after the intervention.

The formula used is:

$$RCI = \sum V_i / A_{imp\_drained} \text{ [litres per m}^2\text{]}$$

Where:

- $\sum V_i$  = sum of retention volumes (see table below) of all SuDS devices within the project area
- $A_{imp\_drained}$  = total impervious surface area draining to the SuDS devices (m<sup>2</sup>), from planimetry

Each device type has a specific formula for estimating its retention volume. The table below provides standardized formulas, and typical parameter ranges applicable to the Milan context:

*Table 4 Device volume calculation sheet.*

SuDS Device	Storage capacity formula	Typical values
<b>Bioswale</b>	$L \times W \times d \times V_r$ (length × width × depth × void ratio)	d = 0.3–0.6 m $V_r = 0.35$
<b>Rain garden</b>	$A \times d$ (area × depression depth)	d = 0.2–0.4 m
<b>Pocket park with depression</b>	$A \times d \times \text{fill\_factor}$ (area × depth × 0.85)	d = 0.1–0.3 m fill_factor = 0.85
<b>Watersquare / emergency basin</b>	V (total basin volume)	V = 5–200 m <sup>3</sup> depending on scale
<b>Permeable pavement (contribution)</b>	$A \times d_{sub} \times V_r$ (area × sub-base depth × 0.10)	$d_{sub} = 0.15\text{--}0.30$ m
<b>Green roof</b>	$A \times d_{sub} \times 0.50$ (retention substrate, 50% voids)	$d_{sub} = 0.08\text{--}0.15$ m

Table 5 RCI evaluation scale.

<b>RCI Value</b>	<b>Rating</b>	<b>Interpretation</b>
<b>&lt; 5 L/m<sup>2</sup></b>	Critical	Negligible retention capacity: area will produce full runoff during typical events
<b>5–15 L/m<sup>2</sup></b>	Low	Limited SuDS provision: minor attenuation of light rainfall only
<b>15–30 L/m<sup>2</sup></b>	Moderate	Adequate for frequent events (return period < 2 years): target minimum
<b>30–50 L/m<sup>2</sup></b>	Good	Well-designed SuDS: handles 5-year storm events typical of Milan
<b>&gt; 50 L/m<sup>2</sup></b>	Excellent	High resilience: approaches natural pre-development retention capacity

Comune di Milano (PGT 2030) requires stormwater retention for new developments  $\geq 500 \text{ m}^2$  at a minimum of 25 mm of rainfall depth: equivalent to approximately 25 L/m<sup>2</sup>. A well-designed project should reach the 'Good' range (30–50 L/m<sup>2</sup>).

## Infiltration Capacity (S)

The Infiltration Capacity Index (ICI) measures the area-weighted capacity of a street cross-section to infiltrate rainwater into the sub-base, expressed as a dimensionless score between 0 (fully impermeable) and 1 (maximum infiltration). It is calculable directly from project planimetry without specialist software, and provides a comparable before/after metric for the improvement of surface permeability at street scale<sup>2</sup>.

$$ICI_{street} = \Sigma (A_i \times ICI_i) / A_{tot}$$

Where:

- $A_i$  = area of surface type  $i$  within the street cross-section or segment ( $m^2$ )
- $ICI_i$  = Infiltration Capacity Index of surface type  $i$  (dimensionless, 0.00–1.00)
- $A_{tot}$  = total surface area of the street cross-section or segment ( $m^2$ )

The following simplified ICI values are used directly in the formula, avoiding the need to work with absolute mm/h rates. They represent the relative infiltration contribution of each surface type within a street cross-section:

---

<sup>2</sup> ICI measures the infiltration potential of the street surface itself; the Retention Capacity Index (RCI) measures the storage volume provided by SuDS devices in the wider neighbourhood. The two are complementary: ICI addresses the first stage of stormwater management (surface infiltration), while RCI addresses the second stage (temporary storage of surplus water).

Table 6 ICI values for calculation.

Surface type	ICI (Infiltration Capacity Index)	Rationale
<b>Permeable asphalt / concrete (new)</b>	1.00	Full infiltration capacity: maximum contribution
<b>Permeable asphalt / concrete (&gt;5 yrs, maintained)</b>	0.75	Partial clogging expected represents maintained condition
<b>PICP / interlocking permeable paving</b>	0.85	High but slightly lower than monolithic permeable surfaces
<b>Gravel / crushed stone</b>	0.95	Near-maximum; minor fines migration over time
<b>Rain garden / bioswale substrate</b>	0.80	Engineered mix; effective infiltration with some surface ponding
<b>Grass / established vegetation</b>	0.35	Lower than often assumed, compaction in urban parks reduces rate
<b>Standard asphalt / concrete</b>	0.00	Impermeable, no contribution to infiltration
<b>Compacted bare soil</b>	0.05	Minimal, residual crack infiltration only

Table 7 ICI evaluation scale.

ICI	Rating	Interpretation
<b>0.00 – 0.05</b>	Critical	Fully impermeable street: all rainfall becomes immediate surface runoff
<b>0.05 – 0.20</b>	Low	Marginal improvement: minimal permeable surface or poor-condition materials
<b>0.20 – 0.40</b>	Developing	Partial permeable coverage: mixed surfaces, some infiltration capacity
<b>0.40 – 0.60</b>	Good	Significant permeable provision: most non-trafficked surfaces are permeable
<b>0.60 – 0.80</b>	Very good	High infiltration capacity: permeable paving dominant, green integration
<b>0.80 – 1.00</b>	Excellent	Near-maximum infiltration: approaches pre-development hydrological behavior

Comune di Milano PGT 2030 requires a minimum surface permeability coefficient of 0.30 for public spaces in new developments. The European Green Deal urban resilience targets recommend restoring at least 30% of urban surfaces to permeable condition by 2030, both targets correspond to ICI  $\geq$  0.3.

### 3.4.2. Heat mitigation indicators

#### **Tree Covered Meters Traveled (D)**

The TCMT (Tree Covered Meters Traveled) measures the proportion of meters walked in an area that occurs under tree cover. A high value indicates that residents mainly walk along tree-lined streets, with benefits for thermal comfort, health and perceived quality of public space. Adapted from the model developed by A. Alhassan (MIT, 2020) within the CityForm workshop.

The TCMT is calculated as the ratio between person-meters walked under tree cover and total person-meters walked in the study area. It is therefore a proportion indicator (0–100%), not an absolute quantity.

$$\text{TCMT (\%)} = [\sum (F_s \times L_s \times C_s)] / [\sum (F_s \times L_s)] \times 100$$

Where:

- $F_s$  = pedestrian flow of street segment
- $L_s$  = length of street segment
- $C_s$  = tree cover of street segment

Table 8 TCMT calculation steps.

Element	Formula / Logic
<b>Pedestrian flow of segment s (Fs)</b>	Fs = sum of person × distance through segment s Derived from UNA Toolbox simulation (MIT) or proportional estimate
<b>Tree cover of segment s (Cs)</b>	Cs = 1 if segment has trees on at least one side (coverage ≥ 50%) Cs = 0 otherwise (manual input or NDVI/LiDAR analysis)
<b>Tree-covered person-meters (TCMT numerator)</b>	= $\sum s (Fs \times Ls \times Cs)$ where Ls = length of segment s in meters
<b>Total person-meters travelled (TCMT denominator)</b>	= $\sum s (Fs \times Ls)$ sum over all pedestrian segments in the study area
<b>TCMT (%)</b>	= $[\sum s (Fs \times Ls \times Cs)] / [\sum s (Fs \times Ls)] \times 100$ Range: 0% (no trees) to 100% (fully tree-covered)

Table 9 Project interventions and impact on TCMT.

Intervention	Impact on Ped. Flow (Fs)	Impact on Cover (Cs)	Effect on TCMT
<b>Tree row planting on existing axis</b>	None direct	Cs from 0 to 1 on planted segments	Direct and immediate: increases numerator
<b>Street pedestrianization</b>	Increases Fs (higher comfort)	None direct (if already treed)	Amplifies effect of existing trees
<b>New square with trees in project</b>	Attracts flows, local Fs increase	High Cs in project area	High: creates new node with double effect
<b>Residential densification near treed axis</b>	Increases Fs on already-covered routes	None	High: more people walk under trees
<b>New pedestrian shortcuts without trees</b>	Diverts Fs away from treed axes	None direct (if not planted)	Negative: reduces TCMT by diverting flow
<b>Tree budget optimization (plant where flow is highest)</b>	None direct	Maximizes Cs × Fs on key segments	Maximum impact with limited resources

Table 10 TCMT results judgement.

TCMT (%)	Judgement	Significance / Reference contexts
< 8%	Critical	Almost no tree cover on pedestrian routes
8–14%	Low	Limited cover: many trees in private courtyards, few on street
14–20%	Medium	Moderate cover: some tree rows on main axes
20–28%	Good	Good cover concentrated on high-flow axes
> 28%	Excellent	Outstanding cover: combination of high pedestrian density and continuous tree rows

## Surface Temperature Reduction (S)

The Surface Temperature Reduction Index (STRI) measures the expected reduction in summer peak surface temperature achieved by replacing standard asphalt with higher-albedo or vegetated surfaces, and by adding tree canopy shade. It quantifies the Urban Heat Island (UHI) mitigation potential of the project at street and section scale<sup>3</sup>.

$$STRI = \Sigma (A_i \times \Delta T_i) / A_{tot} + \Sigma (A_s \times \Delta T_{shade} \times C_s) [^{\circ}C]$$

Where:

- $A_i$  = area of surface type  $i$  ( $m^2$ )
- $\Delta T_i$  = surface temperature reduction of type  $i$  vs. reference asphalt ( $^{\circ}C$ )
- $A_{tot}$  = total project area ( $m^2$ )
- $A_s$  = area exposed to tree shade ( $m^2$ )
- $\Delta T_{shade}$  = additional cooling from tree shade =  $-40^{\circ}C$
- $C_s$  = shade correction factor = 0.5 (trees do not provide 100% shade; accounts for partial coverage, sun angle, season)

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<sup>3</sup> Surface temperature vs. air temperature: this KPI measures Land Surface Temperature (LST), not air temperature. Surface temperature drives radiant heat gain for pedestrians and affects the microclimate at street level. The relationship between surface temperature reduction and air temperature reduction is approximately 1:0.3 (a  $10^{\circ}C$  surface reduction yields roughly a  $3^{\circ}C$  reduction in ambient air temperature at pedestrian level).

Table 11 Reference Values for surface types.

Surface type	Solar albedo ( $\alpha$ )	Typical summer max. temp ( $^{\circ}\text{C}$ )	$\Delta\text{T}$ vs reference asphalt ( $^{\circ}\text{C}$ )	Notes
<b>Standard asphalt (reference)</b>	0.05	65–70 $^{\circ}\text{C}$	0 (reference)	Baseline: worst case
<b>Concrete (standard grey)</b>	0.30	45–55 $^{\circ}\text{C}$	-15 $^{\circ}\text{C}$	Significant improvement
<b>Light-coloured concrete / white</b>	0.50	35–45 $^{\circ}\text{C}$	-25 $^{\circ}\text{C}$	High albedo paving
<b>Cool pavement (coating)</b>	0.50–0.65	30–40 $^{\circ}\text{C}$	-28 $^{\circ}\text{C}$	Specialist cool-coating products
<b>Brick / cobblestone</b>	0.20–0.30	50–58 $^{\circ}\text{C}$	-12 $^{\circ}\text{C}$	Traditional Milanese
<b>Permeable / gravel paving</b>	0.20–0.25	42–50 $^{\circ}\text{C}$	-18 $^{\circ}\text{C}$	Also contributes to infiltration
<b>Grass / low vegetation</b>	0.20–0.25	25–35 $^{\circ}\text{C}$	-35 $^{\circ}\text{C}$	Evapotranspiration dominant

Table 12 STRI evaluation scale.

STRI ( $^{\circ}\text{C}$ reduction)	Rating	Interpretation
<b>&lt; 3<math>^{\circ}\text{C}</math></b>	Negligible	Minimal change in surface temperature: no significant UHI mitigation
<b>3–8<math>^{\circ}\text{C}</math></b>	Low	Minor improvement: some substitution of asphalt with better materials
<b>8–15<math>^{\circ}\text{C}</math></b>	Moderate	Meaningful reduction: combination of light pavements and some green
<b>15–22<math>^{\circ}\text{C}</math></b>	Good	Strong mitigation: significant use of green surfaces and high-albedo paving
<b>&gt; 22<math>^{\circ}\text{C}</math></b>	Excellent	Major UHI reduction: approaching natural surface thermal behavior

Urban surfaces in dense built-up areas typically reach 65–70 $^{\circ}\text{C}$  on summer afternoons. A well-designed street regeneration project replacing asphalt with light paving and adding a row of trees can realistically achieve STRI of 15–25 $^{\circ}\text{C}$ , significantly reducing pedestrian thermal stress and lowering air conditioning demand in adjacent buildings.

### 3.4.3. Mobility and safety indicators

#### Cycling Infrastructure Quality (D)

The Cycling Infrastructure Quality Index (CIQI) measures the quality and extent of safe cycling infrastructure within the project area. It weights each street segment by the quality of its cycling provision using the Level of Traffic Stress (LTS) framework, rewarding separated infrastructure and penalizing gaps and discontinuities in the network. Adapted from the model developed by R. Morgan (MIT, 2020).

The central formula is:

$$CIQI = [ \sum (L_i \times W_i) / \sum L_i ] + C_{adj}$$

Where:

- $L_i$  = length of street segment  $i$  (m)
- $W_i$  = quality weight of segment  $i$  based on its LTS classification
- $\sum L_i$  = total length of all street segments in the project area that are relevant for cycling
- $C_{adj}$  = connectivity adjustment, sum of gap penalties and route continuity bonuses (see connectivity table)

The Level of Traffic Stress (LTS) metric (Furth, 2012) classifies each road segment from 1 to 4 based on cycling comfort. Each LTS level corresponds to a multiplier on the actual distance: an LTS 4 segment is perceived as eight times longer than an LTS 1 one, strongly discouraging its use.

Table 13 Level of traffic stress classification.

LTS	Infrastructure type	Typical users	Score contribution
<b>LTS 1 (highest quality)</b>	Physically separated cycle path, full barrier	Everyone (children, elderly, beginners)	Weight = 1.0 (full contribution)
<b>LTS 2 (good quality)</b>	Protected lane, flexible posts or buffer, OR low-traffic residential street	Regular cyclists	Weight = 0.70
<b>LTS 3 (low quality)</b>	Painted cycle lane only, no physical protection	Experienced cyclists	Weight = 0.30
<b>LTS 4 (unsafe)</b>	No cycling infrastructure, shared with traffic at > 30 km/h	“Fearless” cyclists only	Weight = 0.0 (no contribution to safe network)

The connectivity adjustment captures the network effects that the basic length-weighted score misses: a 1 km protected lane that dead-ends at a busy junction is far less valuable than one that connects two destinations.  $C_{adj}$  is calculated by identifying specific network features:

Table 14 Connectivity adjustment table.

Connectivity indicator	Definition	Penalty/bonus applied to CIQI
<b>Network gap</b>	A section of LTS 3 or 4 that interrupts an otherwise continuous LTS 1–2 route	-0.05 per gap (max -0.20 total)
<b>Missing crossing</b>	A cycle route that ends at a junction without a marked or protected crossing	-0.03 per missing crossing (max -0.12)
<b>Route continuity bonus</b>	An uninterrupted LTS 1–2 route connecting two key destinations (station, school, commerce) $\geq 300$ m	+ 0.05 per complete route (max +0.15)
<b>District permeability</b>	Any street in the network allows cycling (including contraflow or shared at $\leq 20$ km/h)	+ 0.02 per additional permeable street beyond baseline

The existing cycling network in central Milan scores approximately CIQI 0.25–0.35 on most district-scale areas (many painted lanes, few protected sections). A good regeneration project should aim to reach 0.55–0.70 within the project

boundary, contributing to the city's target of 750 km of protected cycle lanes by 2035 (Piano Biciclette Milano 2035).

Table 15 CIQUI evaluation scale.

CIQI	Rating	Interpretation for Milan
<b>0.0–0.20</b>	Critical	Virtually no safe cycling infrastructure — cycling is unsafe or impossible for most users
<b>0.20–0.40</b>	Poor	Minimal provision — isolated painted lanes with many gaps; LTS 3 dominant
<b>0.40–0.60</b>	Developing	Partial network — some protected sections but major continuity gaps remain
<b>0.60–0.75</b>	Good	Coherent network emerging — majority of key routes covered by LTS 1–2
<b>0.75–0.90</b>	Very good	High-quality network — continuous LTS 1–2 on all main routes, few gaps
<b>&gt; 0.90</b>	Excellent	Comprehensive safe cycling network — comparable to best European cycling cities

## Conflict Points Reduction (N)

The Conflict Points Reduction Index (CPRI) measures the before-and-after reduction in the total weighted number of geometric conflict points at a transport node. It accounts not only for the count of conflicts but also for their severity, the type of users involved, and the presence of protective infrastructure<sup>4</sup>.

$$CPRI (\%) = (WCS_{before} - WCS_{after}) / WCS_{before} \times 100$$

Where:

$$WCS = \sum [Nk \times Wk \times Mk]$$

- WCS = weighted conflict score
- Nk = number of conflict points of type k identified on the node diagram
- Wk = base severity weight of conflict type k

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<sup>4</sup> A geometric conflict point is any location where the trajectory of two different user groups intersect, merge, or diverge. This method, based on the Conflict Point Technique (Perkins & Bowman, 1986; FHWA 2004), is standard in traffic safety engineering and does not require accident data, making it applicable to new projects before construction.

- $M_k$  = composite design modifier for type  $k$

Table 16 Conflict type classification.

Conflict type	Users involved	Base severity weight	Description
<b>Type A Crossing conflict</b>	Vehicle × Pedestrian	3.0 (high)	Vehicle trajectory crosses pedestrian crossing path: the most dangerous typology
<b>Type B Merging/weaving</b>	Vehicle × Cyclist	2.5 (high)	Vehicle lane merges with cyclist trajectory: no physical separation
<b>Type C Turning conflict</b>	Vehicle × Cyclist (at junction)	2.0 (medium)	Right or left-turning vehicle conflicts with straight-going cyclist
<b>Type D Cyclist × Pedestrian</b>	Cyclist × Pedestrian	1.0 (low)	Shared surface or ambiguous priority: lower severity but frequency-dependent
<b>Type E Vehicle × Vehicle</b>	Vehicle × Vehicle	1.0 (low)	Merging or crossing of motor vehicles: relevant for intersection design

Table 17 Design feature modifiers.

Design feature	Conflict type affected	Modifier (applied to weight)	Rationale
<b>Protected / separated cycle lane (physical barrier <math>\geq 0.5</math> m)</b>	Type B, Type C	× 0.20 (80% weight reduction)	Separation eliminates most vehicle–cyclist conflicts; residual at entry/exit points only
<b>Raised pedestrian crossing</b>	Type A	× 0.35 (65% reduction)	Forces vehicle speed reduction; increases driver awareness of crossing
<b>Standard zebra crossing</b>	Type A	× 0.70 (30% reduction)	Defined crossing point but no speed enforcement
<b>Crossing distance <math>\leq 4</math> m</b>	Type A	× 0.60 additional (multiplicative)	Shorter crossing exposure time
<b>Signalized intersection</b>	Type B, C, D	× 0.50	Temporal separation of conflicting movements
<b>Shared surface at <math>&lt; 20</math> km/h</b>	All types	× 0.40	Low speed equalizes user vulnerability

Table 18 CPRI evaluation scale.

<b>CPRI improvement (%)</b>	<b>Rating</b>	<b>Interpretation</b>
<b>&lt; 10%</b>	Negligible	Minor geometric changes, no meaningful safety improvement
<b>10–30%</b>	Low	Some crossing improvements, limited infrastructure changes
<b>30–50%</b>	Moderate	Significant safety investment, some protected infrastructure or raised crossings
<b>50–70%</b>	Good	Strong conflict reduction, protected cycle lanes and raised crossings combined
<b>&gt; 70%</b>	Excellent	Transformative, near-complete separation of conflicting movements

### 3.4.4. Public perception

#### Public Space Quality (D)

This KPI measures the perceived quality of public space by adapting the Public-Private Index (MIT, 2020). It is calculated before and after the intervention to quantify the improvement in terms of vibrancy and functional diversity of street-level space.

The KPI produces two complementary indices:

- VIBRANCY Index measures how active, busy and publicly accessible a space is (weighted mean of space-type scores along street segments).
- DIVERSITY Index measures the variety of land uses encountered while walking.

Each ground-floor building or space receives a base score from 1 to 10 based on its category (public, occupiable, semi-private, private) and accessibility level.

*Table 19 Space type scoring system.*

	<b>Free access</b>	<b>Constrained access</b>	<b>No access</b>
<b>Public</b>	Open plaza (10) Public Park (9) Bus stop (9)	Pocket park (7) Library (8) Church (8)	—
<b>Occupiable</b>	Shop / Retail (9) Bar / Restaurant (9) Public services (8)	School courtyard (5) School entrance (5)	—
<b>Semi-private</b>	Arcaded passage (4) Accessible lobby (3)	Communal garden (3)	—
<b>Private</b>	—	—	Private house / Office (1) Public housing (1) SoHo / Apartment (2)

Corrective coefficients are applied to the base score to capture the physical quality of the street frontage, elements directly modifiable through the urban regeneration intervention

Table 20 Corrective coefficients for PSQI calculation.

Coefficient	Description	Value	Type
<b>Wall permeability</b>	Visually permeable / open frontage	× 1.25	Multiplier
<b>Wall permeability</b>	Partially visually permeable	× 1.00	Multiplier
<b>Wall permeability</b>	Closed / blank	× 0.75	Multiplier
<b>Entrances</b>	Each additional entrance on street	+ 0.3 per entrance	Addend
<b>Frontage quality</b>	Outdoor seating, greenery, canopy	+ 0.5	Addend
<b>Facade length</b>	% of street segment length	Proportional weight	Weight
<b>Pedestrian flow</b>	From survey or estimate (low/med/high)	× 0.8 / 1.0 / 1.2	Final multiplier

The calculation is structured at three levels: first building, then street segment, finally project area.

Table 21 Calculation steps of PSQI.

<b>Building Score (Bi)</b>	= Type_Score × Permeability_Coeff + Entrance_Bonus + Quality_Bonus
<b>Street Segment Score (Si)</b>	= $\Sigma(Bi \times Li) / \Sigma(Li)$ — weighted average by facade length Li
<b>Weighted Score (Si*)</b>	= Si × Pedestrian_Flow_Coefficient
<b>VIBRANCY Index (area)</b>	= Mean of all Si* scores (non-residential segments only)
<b>DIVERSITY Index (area)</b>	= Standard deviation of Si* scores (variety of land uses)
<b>Overall KPI</b>	= $\alpha \times \text{VIBRANCY} + \beta \times \text{DIVERSITY}$ (default: $\alpha = \beta = 0.5$ )

Typical project target: raise the Overall KPI from a range of 2–4 (Low) to 6–8 (Good), with particular attention to increasing the Diversity Index in mixed-use zones.

Table 22 Evaluation scale for PSQI.

Score	Judgement	Vibrancy	Diversity
<b>0.0–2.0</b>	<b>Critical</b>	Mono-functional, inactive space	No variety of uses
<b>2.1–4.0</b>	<b>Low</b>	Little pedestrian activity	Very similar land uses
<b>4.1–6.0</b>	<b>Medium</b>	Moderate activity	Limited functional mix
<b>6.1–8.0</b>	<b>Good</b>	Active, well-used space	Good functional variety
<b>8.1–10.0</b>	<b>Excellent</b>	High public use intensity	Rich and diversified mix

## Estimated Public Space Occupancy (N)

Estimated space occupancy is a KPI that measures the number of users that a road can accommodate. Using coefficients derived from literature, which indicate the number of people per hour that each type of mobility (vehicles, buses, cycle paths, etc.) can accommodate per lane or per square meter in the case of cycle paths, sidewalks, and green areas, it is possible to estimate the maximum user potential.

$$EPSO\left(\frac{P}{h}\right) = \sum \frac{\text{people}}{h} \times n^{\circ} \text{ of lanes or width (m)}$$

*Table 23 Capacity coefficients per street space type.*

<b>STREET SPACE TYPE</b>	<b>UNIT CAPACITY</b>	<b>SOURCE</b>
Sidewalk	2,000 people/h per meter	(Pushkarev et al., 1975)
Bike lane	1,500 people/h per meter	(Zhou et al., 2015)
Dedicated bus lane	6,000 people/h per lane	(City of Boston, 2023)
Traffic lane	1,800 people/h per lane	(Koonce et al., 2008)
Parking/greenery/social space	0 people/h	Method choice

### 3.4.4. KPI results

The KPI toolkit is applied to the regeneration of Villaggio dei Fiori to demonstrate the quantifiable impact of the proposed nature-based strategies across the three spatial scales of intervention.

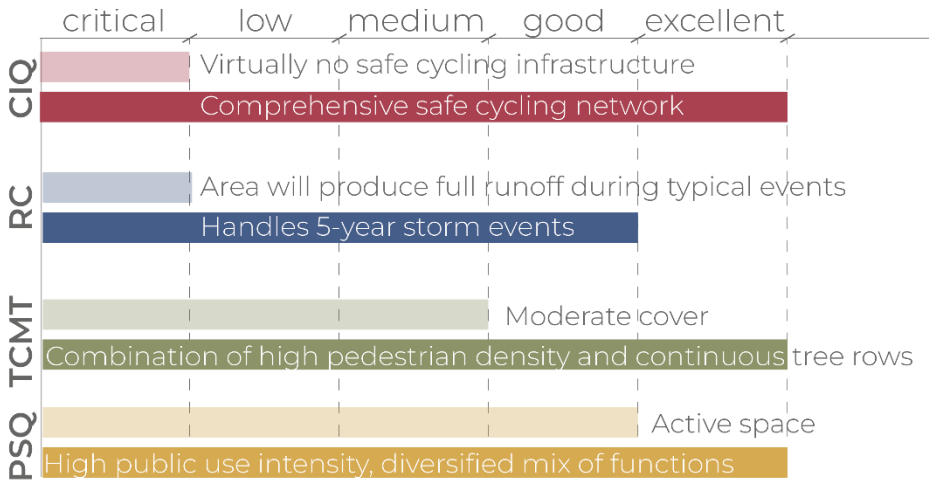


Figure 57 District KPIs performance before and after intervention.

At the district scale, the results show consistent improvements across all four indicators. The cycling infrastructure quality index rises from 0.10 to 1.10 (from critical to excellent) as the project replaces a network dominated by LTS 3–4 infrastructure with a fully safe cycling environment in which 100% of segments reach LTS 1–2. The retention capacity increases from 0 to 32.8 L/m<sup>2</sup>, reducing the total drained impervious surface from 91,250 to 71,750 m<sup>2</sup> and providing 2,350 m<sup>3</sup> of stormwater retention through a distributed system of bioswales, rain gardens, pocket parks, a water square and permeable paving. The tree covered meters traveled index improves from 43% to 97%, reflecting both the significant increase in tree-covered segments (from 17% to 67% of the network<sup>9</sup> and the growth in average pedestrian flow, from Fs = 1.39 to 1.61, driven by the improved walkability of the streets. Public space quality moves from good (7.96) to excellent

(9.54), with Vibrancy reaching 9.42 following the transformation of ground-floor interfaces and the introduction of new public program.

At the node scale, the redesign of the via Primaticcio intersection demonstrates a 41.7% reduction in weighted conflict score, from 49.5 to 28.9. The total number of geometric conflict points decreases from 49 to 38, primarily through the introduction of a roundabout, raised crossing surfaces, reduced crossing distances and a dedicated bus stop island. The public space occupancy potential of via Lorenteggio increases by 56.2% (from 19,200 to 30,000 people per hour) as the modal composition of the street section is restructured to include six modalities compared to four, replacing private parking and general carriageway space with bus lanes, protected cycle paths and generous pedestrian footways.

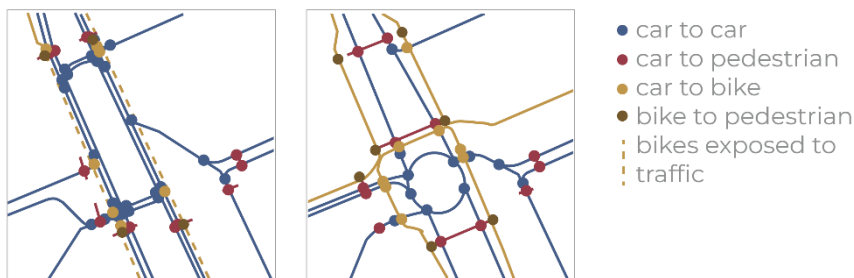


Figure 59 Geometric conflict points in via Primaticcio before and after.

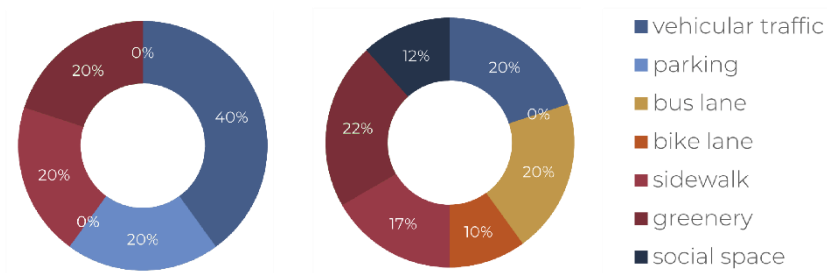


Figure 58 Modalities before and after in via Lorenteggio.

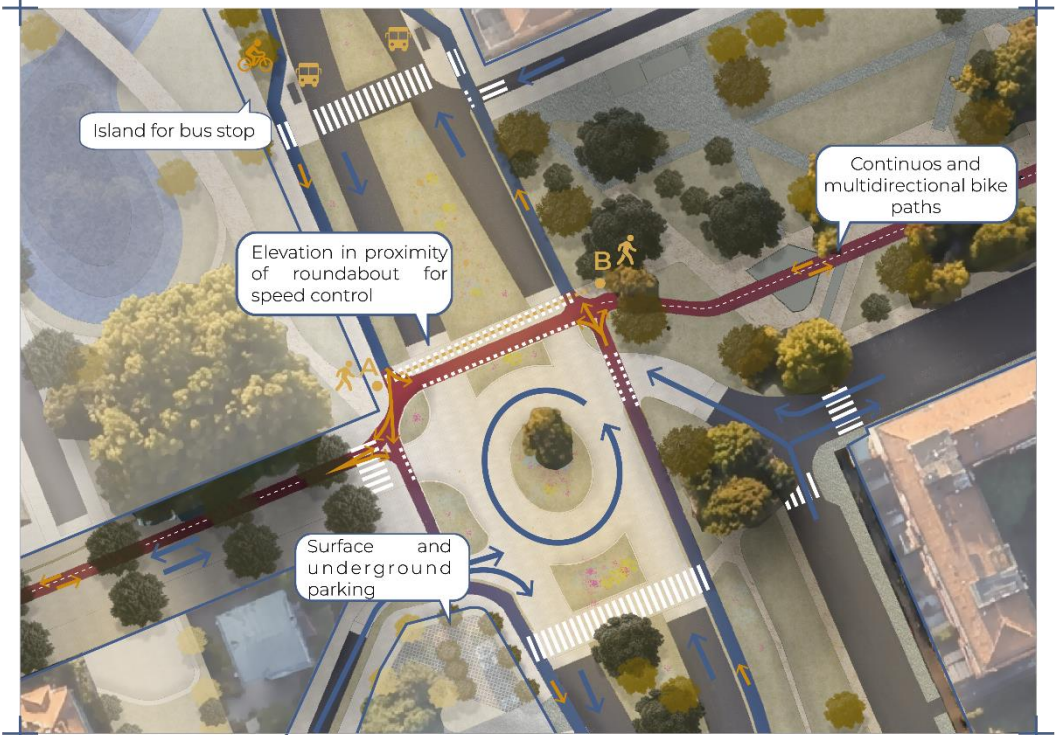
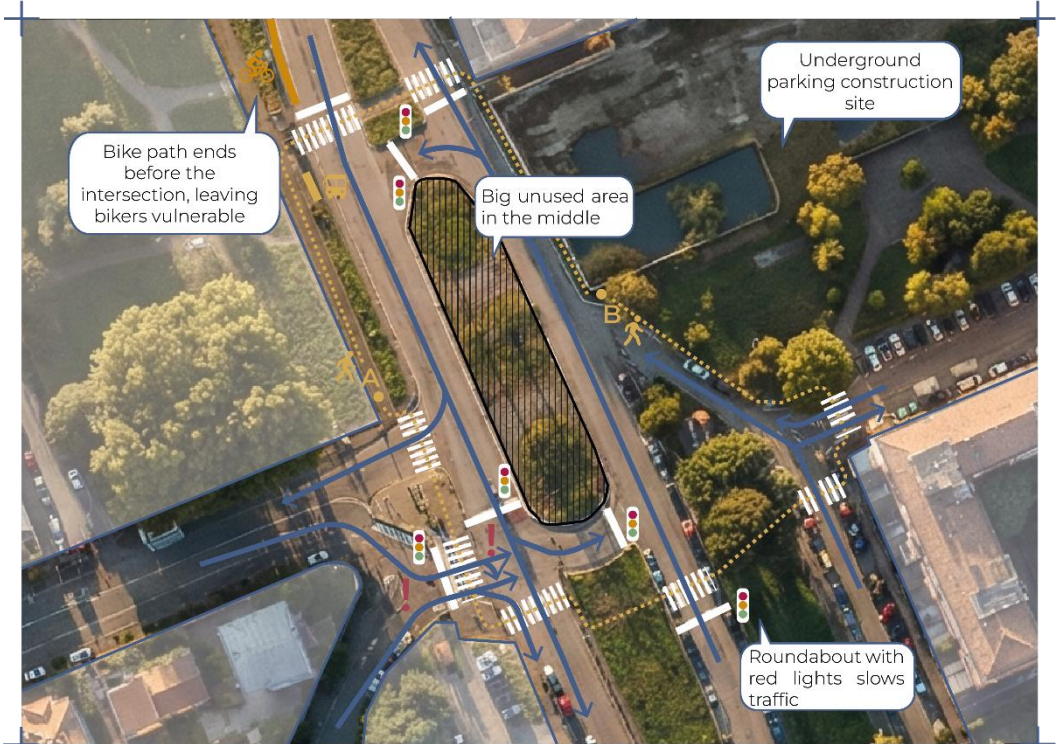


Figure 60 via Primaticcio before and after the intervention.

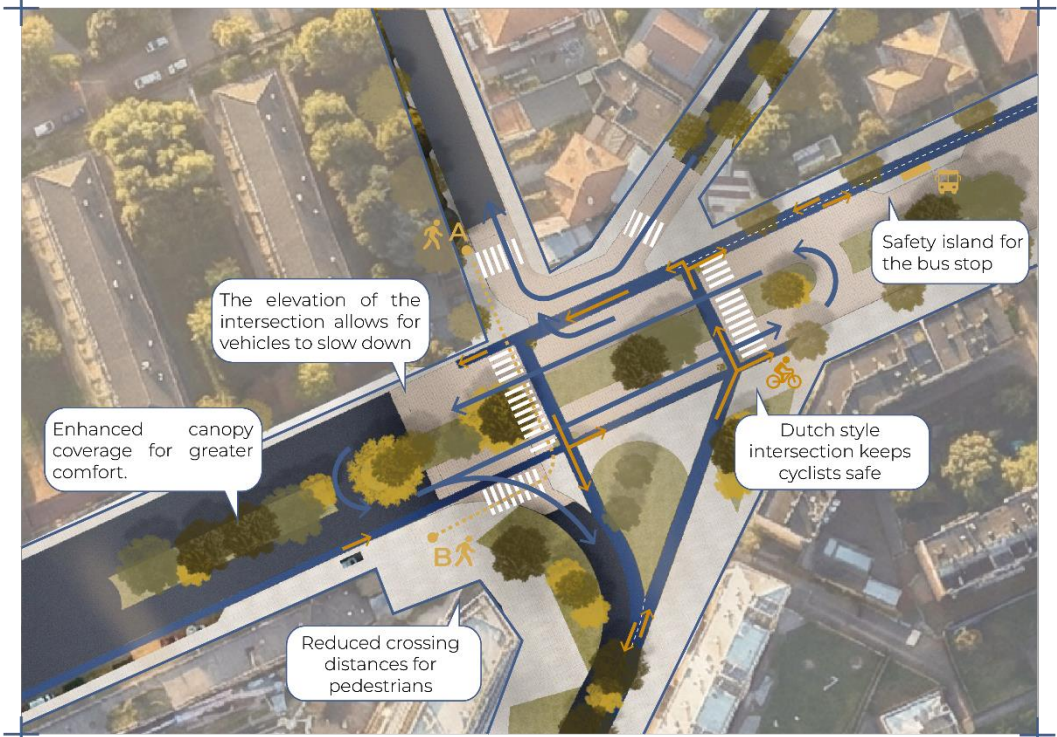
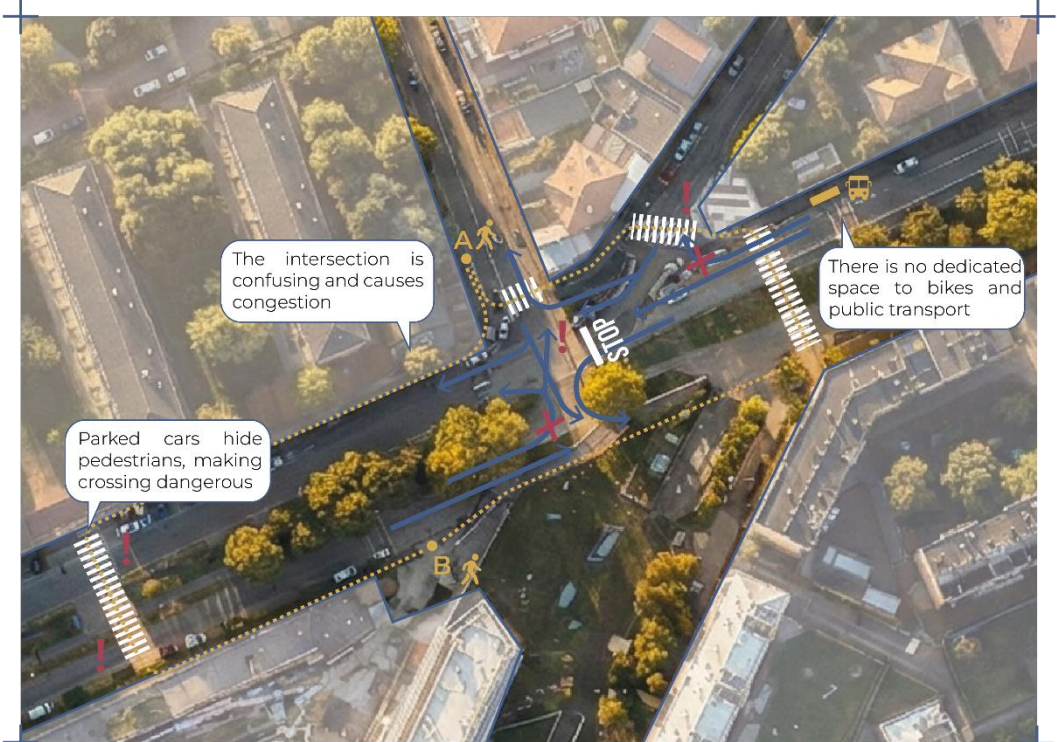


Figure 61 via Lorenteggio before and after the intervention.

At the section scale, two street typologies illustrate the microclimatic performance of the intervention. Via dei Gigli undergoes full carriageway removal and replacement with permeable paving, with the addition of a bioswale system fed not only by surface runoff but also by roof drainage rerouted from building downpipes through planters before reaching the swale; a strategy that disconnects the public housing rooftops from the combined sewer network. The result is an infiltration capacity index of 0.82, with impervious surface dropping from 100% to 0% of the section. Via delle Rose demonstrates the thermal dimension of the intervention: partial pavement removal, rain garden insertion and the replacement of standard paving with light-colored permeable surfaces produce a mean albedo increase from 0.05 to 0.18 and, combined with new tree planting, maximum summer surface temperature reduction of  $-26.8^{\circ}\text{C}$ , rated excellent against the baseline of standard asphalt.

Taken together, the results confirm that the proposed strategies are not only spatially coherent but measurably effective. The toolkit provides a replicable framework for evaluating nature-based urban regeneration, linking design decisions directly to quantifiable environmental and social outcomes.

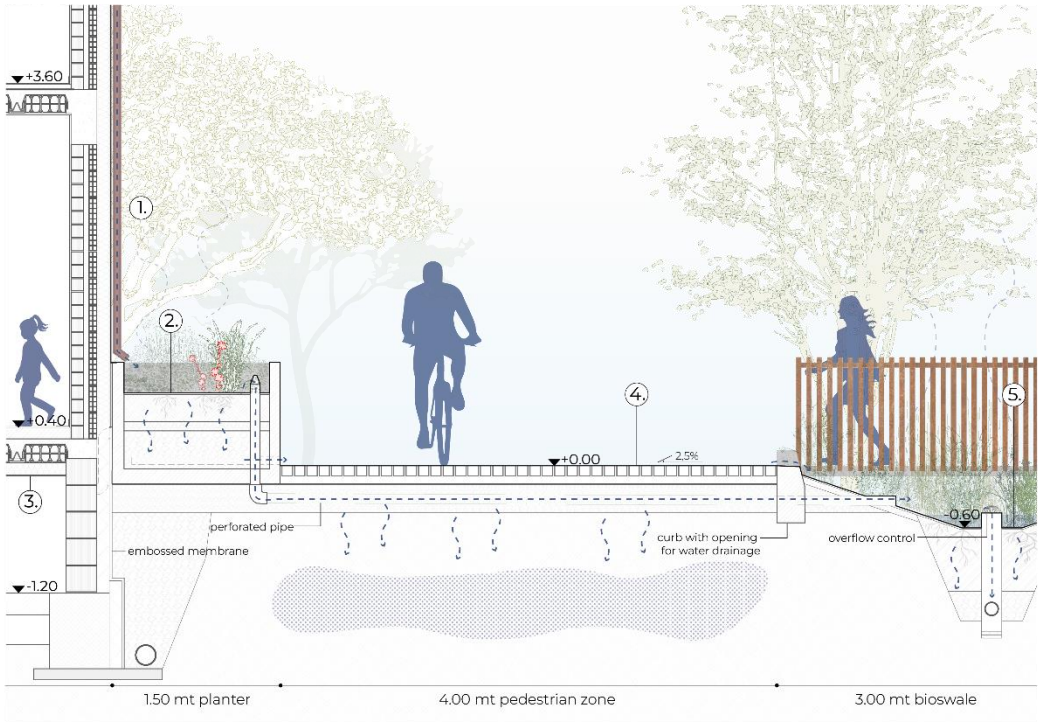


Figure 62 Sections 1:50 showcasing the micro-climate performance.

# CONCLUSIONS

This thesis sets out to test a central proposition: that Nature-Based Solutions can operate as credible, desirable, and implementable tools within urban regeneration, particularly in public housing contexts.

The work developed through a design-led research structure. A theoretical framework reconstructed the contemporary convergence of risks affecting cities, showing how these processes reinforce one another and why single-issue solutions remain insufficient. Within this frame, the thesis clarified the operational meaning of NBS: a toolkit that requires spatial allocation, technical coherence, and governance capacity. The evidence base then provided an additional layer of credibility, presenting replicable principles and strategies through effectively constructed designs.

The project application on Villaggio dei Fiori translated this knowledge into a site-specific proposition. The project treated regeneration as a re-structuring of the “green-social infrastructure” of the district: improving accessibility and slow mobility, reactivating micro attractors and commons, and constructing a continuous blue/green network capable of addressing climatic vulnerabilities while supporting everyday sociality.

The research outcomes support the thesis hypothesis in three key ways. First, the project demonstrates that NBS become feasible in regeneration contexts when they are embedded in a

clear enabling hierarchy: mobility measures and parking management create the spatial capacity for greening; public space redesign converts environmental devices into everyday welfare; SUDS elements operate as a connected district system; and energy strategies are anchored to public assets and governance structures.

Second, the work shows that NBS are desirable precisely because they provide co-benefits: the same interventions that reduce runoff and surface temperatures also improve comfort, mobility, and the usability of common spaces, thus strengthening social cohesion and perceived safety.

Third, the project highlights that NBS are implementable when conceived through phasing and maintenance logic: legible devices, robust typologies, and incremental delivery reduce institutional risk and align with the real constraints of public realm management.

At a broader level, the thesis positions Villaggio dei Fiori as an underutilized urban resource whose regeneration can contribute to Milan's wider transition goals. The project's approach is aligned with current municipal agendas that prioritize climate resilient public space, active mobility, and increased public housing. Yet it also acknowledges that implementation remains contingent upon governance capacity, funding continuity, and the coordination of actors across public administrations, service companies, and local communities. For this reason, the project framework insists on traceability: design moves are linked to causal chains and performance intentions, so that future evaluation can assess whether presumed benefits have been achieved and where adjustments are required.

In conclusion, this thesis argues that NBS are not only compatible with urban regeneration in public housing contexts but can become one of its most effective and socially meaningful drivers.

Lastly, the thesis contributes a method and a project hypothesis: an integrated model of contemporary regeneration where sustainability, technology, and social consistency are not parallel ambitions, but a single design logic.

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