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Urban Heat Resilience Planning: A European Comparative Analysis

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Abstract

Cities around the world face significant issues due to the Urban Heat Island phenomenon, which is caused by urbanization and global warming, in particular in densely populated areas. This phenomenon exacerbates socioeconomic inequality, affect public health, puts stress on resources and intensifies the consequences of heatwave events. This thesis analyses climate action plans in seven European cities—Vienna, Paris, Lisbon, Madrid, Berlin, Athens, and Milan— and their projects at ground level in order to evaluate the efficiency of the projects in addressing the consequences of urban heat island and how implemented initiatives effectively mitigate with this issue.

The study utilizes a comparative methodology to examine several strategies, including urban greening, blue-green infrastructure, reflecting materials, and cutting-edge urban design. It emphasizes essential strategies, such as Vienna's integration of green spaces, Paris' OASIS schoolyard transformations, Madrid's Río Park and Calle 30 initiatives, Milan's Vertical Forest and Library of Trees Park, and Lisbon's biodiversity-oriented interventions. Outstanding practices, such the adaptive design of green infrastructure in Paris, multifunctional urban spaces in Milan, and the incorporation of ecological corridors in Vienna, are recognized as replicated frameworks for improving urban heat resilience.

The most important findings of the thesis point out that efficient UHI mitigation requires a comprehensive strategy which included nature-based solutions, community involvement , and innovative urban design which customized to specific local circumstances. Cities like Vienna and Paris, for instance, have effectively integrated green infrastructure, while Berlin's limited ground level interventions show the gaps in implementation and documentation. In order to cope with global climate change and more specifically urban heat island issues in European cities, the thesis highlights the importance of collaborative knowledge sharing and the scalability of solutions.

This research thesis provides practical information and scalable recommendations for urban heat island adaptation and mitigation planning for more resilient cities which if followed, will lead to enhancing the development of equal, sustainable and heat resilient cities. Additionally, it puts emphasis on the necessity of including environmental, social, and cultural factors in urban planning, offering a framework for tackling urban heat island mitigation deficiencies and promoting resilient urban ecosystems in different circumstances.

Table of content

Table of content

02

Table of content

02

Table of content

02

Table of content

02

Table of content

02

Table of content

List of Figures

List of Figures

List of Figures

List of Maps

List of Maps

PART I

THEORETICAL FRAMEWORK

CHAPTER 1

INTRODUCTION

- Background and statement of problem
- Significance of study
- Research objectives
- Research questions
- Methodology of research
- Limitation

Background and statement of problem

The twentieth century has experienced dramatic increases in both global temperatures and urbanization, resulting in the urban heat island impact gaining substantial attention in scholarly research. Heat island impacts generally are created by a combination of physical factors, such as large impermeable surfaces and little vegetation in metropolitan areas, which raise temperatures in cities relative to nearby rural areas. In addition, over half of the world's population currently inhabits in cities, and estimations indicate that proportion will increase to 68% by 2050 (United Nations, 2018); that is, more vulnerable individuals will be exposed to the detrimental impacts of urban heat islands. It is also important to take into consideration that the impacts of urbanization on local climates, particularly the rise in air temperatures which is becoming increasingly evident.

The other one is anthropogenic activities, such as economic and industrial processes that worsen urban vulnerability by lowering air circulation as well as restricting nocturnal cooling. In addition the phenomenon of urban heat is further intensified by absorbent material such as asphalt and concrete, a situation that is aggravated by the urban heat island effect. This entails both direct and indirect effects on individuals health, ecosystems and air quality (World Bank, 2020; Yadav et al., 2023).

According to Copernicus 2024, heat waves have become a significant environmental stressor, especially in European Union countries, where they pose health risks, pressure economic resources, and exacerbate societal differences. The upward trend of global temperatures and the increasing frequency of extreme heat events are also contributing to intensified mortality and morbidity rates, specifically in urban environment where the urban heat island impacts exacerbates these consequences.

Messelot et al, (2025) also provides strong evidence based on a comprehensive assessment of 854 European cities that temperature-related mortality is expected to increase across Europe because of climate change with a potential 50% increase and over 2,000,000 cumulative death by the end of the century if adaptation actions are not implemented in cities. Hence, urban areas must adapt to these challenges by coming up with effective planning processes and implementing efficient heat mitigation and management strategies in order to preserve public health and urban infrastructure. That is why addressing the urban heat island phenomenon and its impacts on urban environment becomes crucial for mitigating heat-related risks as well as creating resilient, sustainable cities.

Significance of the study

This research thesis seeks to objectively evaluate the climate action plans of seven European cities; namely, Athens, Milan, Berlin, Madrid, Paris, Lisbon, and Vienna with concentrating on the measures they have undertaken to mitigate the urban heat island impacts. This study analyzes the wide-ranging climate action plans of these cities, offering an in-depth summary of their UHI-related initiatives and investigating the variety methods employed to reduce heat and strengthen urban resilience. This comparative analysis mainly seeks to identify the most effective approaches, evaluate their consequences, and enhance the understanding of how cities may adapt to and mitigate the challenges posed by. Ultimately, this study aims to provide significant insights and a framework for the ongoing development of climate action plans in urban settings, emphasizing the replication of effective solutions in other cities confronting analogous climatic difficulties.

Research objectives

1. To investigate and make comparison the climate action plans of Athens, Milan, Berlin, Madrid, Paris, Lisbon, and Vienna, specifically emphasizing the plans and implementation designed to mitigate the UHI impact.
2. To assess the efficacy of urban heat island reduction strategies in European cities, focusing on their impact on air quality, public health, urban temperatures, and heatwave resilience.
3. To identify and document outstanding implementation, integrated within the climate action frameworks of the selected cities to mitigate the UHI effect.
4. To analyze best practices and lessons learned from climate action plans and UHI mitigation projects in selected cities, providing recommendations for enhancing urban heat resilience.
5. Hand in proposals aimed at addressing the Urban Heat Island mitigation gaps through case studies.

Research questions

1. What are the essential elements of the climate action plans initiated by Athens, Milan, Berlin, Madrid, Paris, Lisbon, and Vienna in order to mitigate the urban heat island effect,and in what ways do these tactics vary among the cities?

2. How effective are the urban heat island mitigation action plans in each case study in urban temperature reduction as well as improving resilience to extreme heat events?
3. What challenges and obstacles do these cities have in implementing urban heat island mitigation initiatives, and what lessons may be learned from their experiences for other urban areas confronting analogous climate-related issues?

Methodology of the research

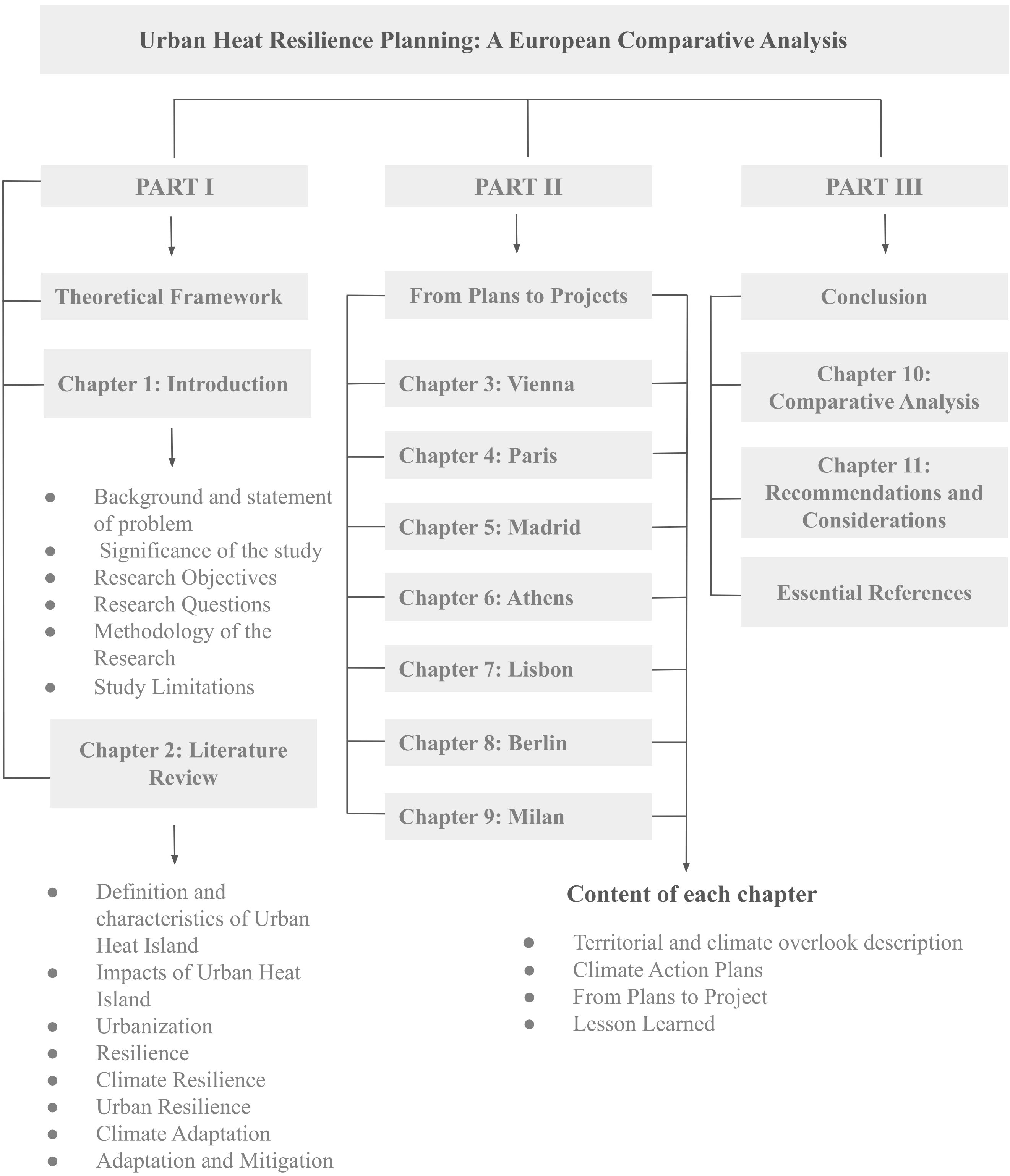
This thesis analyzes climate action frameworks and projects in seven European cities: Athens, Milan, Berlin, Madrid, Paris, Lisbon, and Vienna. It employs original sources, secondary data, and a comparative methodology to evaluate the effectiveness of different actions. Critical elements such as urban planning strategies, green buildings, and technological advancements are examined. The methodology facilitates the identification of best practices and challenges that provides lessons for other urban areas confronting analogous climatic issues and recognizing transferable strategies related to the urban heat island phenomenon.

Study Limitation

The only limitation of the present study is the lack of access to ongoing projects at ground level in Berlin and insufficient documented project in some case studies which gives rise to the impossibility of conducting a detailed analysis.

Research outline

Figure 1: Research Outline. Source: Personal elaboration.



CHAPTER 2

LITERATURE REVIEW

- ❖ Definition and characteristics of Urban Heat Island
- ❖ Impacts of Urban Heat Island
- ❖ Urbanization
- ❖ Resilience
- ❖ Climate Resilient
- ❖ Urban Resilience
- ❖ Climate Adaptation
- ❖ Adaptation and mitigation

Definition and characteristics of Urban Heat Island

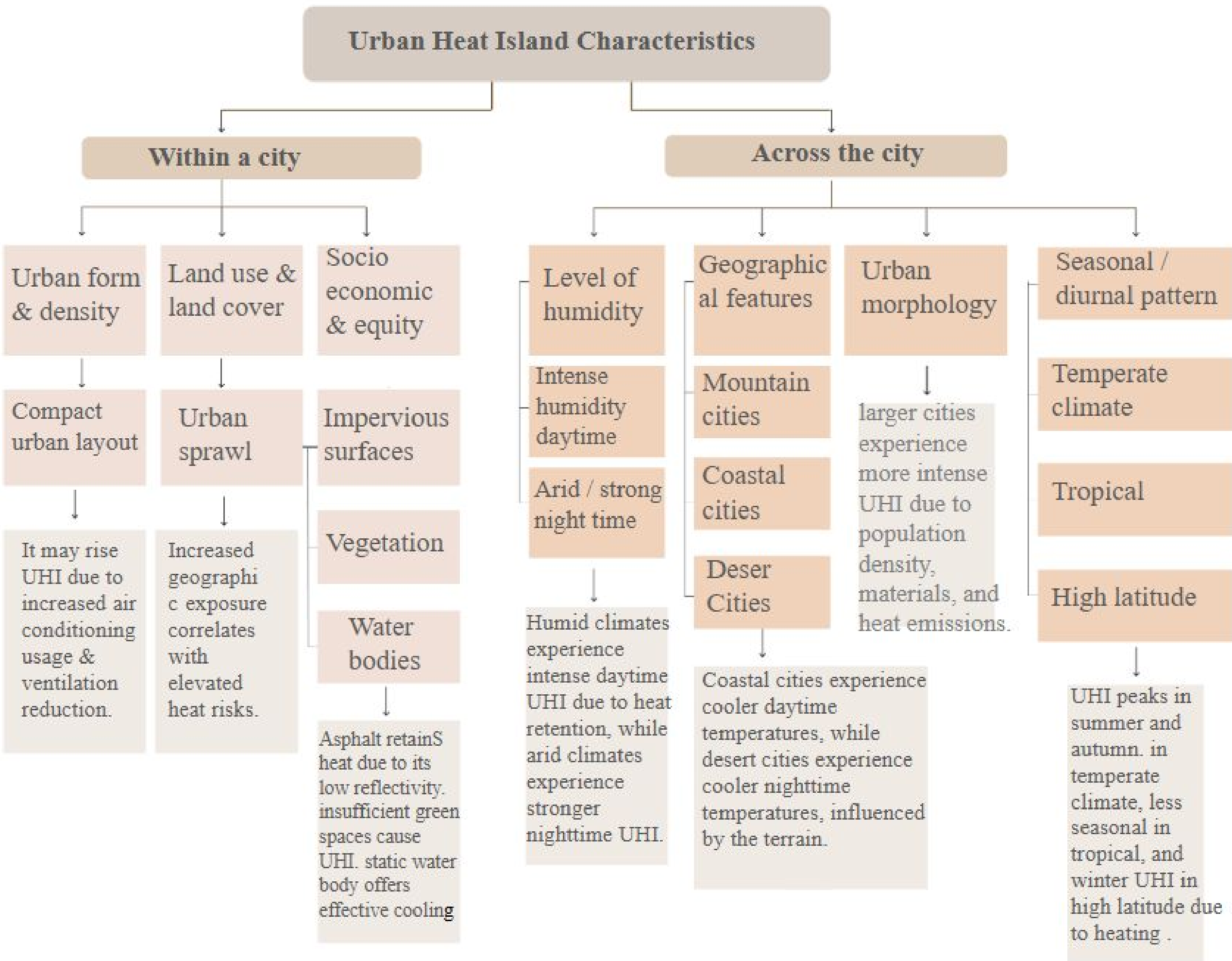
Urban heat islands are localized occurrences through which temperatures in urban areas are greater than in rural ones mainly caused by urban canopy structure and cover development, which causes heat storage improvement. This phenomena can also be divided into three categories: urban heat island boundaries, canopy, and surface, which differ between urban and rural areas. There are several reasons for this, including the density of buildings, the surface's decreased albedo, the thermal retaining materials, the heat produced by human activity, the loss of vegetation, the geometry of the canyon, the expansion of impermeable surfaces, and the coverage of impervious surfaces. (Clemins et al., 2019; Crilly et al., 2020; Gago et al., 2013; Klok et al.,2012; Hu, Hou, Jia, Zhao, Zhen, & Xu, 2019; Peng & Huang, 2022; Spyrou, Ioannou, Souliotis, Savvides, & Fokaides, 2023).

Each of these factors contributes to the aggravation of the urban heat island phenomenon in a unique way. “Anthropogenic heat is another significant contributor to the formation of urban Heat Islands as it directly affects the surrounding temperature in urban areas which the restricted airflow resulting from densely clustered buildings restricts the effective diffusion and elimination of human-generated heat”. The heat retention in the building's structure and the urban ground give rise to the air temperature to rise. Therefore, static airflow around densely packed and tall buildings cause weak anthropogenic heat removal and dilution in the street canyon (Yuan, Adelia, Mei, He, Li, & Norford, 2020).

Another contributing factors in terms of increasing urban heat island effects is green space reduction and expansion of grey spaces. A common method to mitigate rising temperatures is to implement measures involving the blocking or absorption of solar radiation, typically achieved by establishing green spaces. For instance, the shading of trees, wind corridors, and the transpiration of water from plants all contribute to a reduction in net thermal radiation and an increase in latent heat, which at some point brings about a decrease in sensible heat (Park, Shin, Kim, Lee, & An, 2022; Semenzato & Bortolini, 2023).

The next significant component is the geometry of the canyons, which makes it clear that street canyons—the fundamental geometrical units of an urban area—are crucial to the development of microclimates. “Urban canyons determine the solar access, shading, and wind conditions, which then affect the air and surface temperatures. The canyon is considered uniform if it has an aspect ratio approximately equal to 1, shallow if the canyon has an aspect ratio less than 0.5, and deep if the aspect ratio is 2 or greater" (Peng & Huang, 2022, p. 2). Besides, Sara Meerow and Ladd Keith (2022) point out that urban heat presents a substantial and inequitable threat, worsened by climate change, highlighting the importance of comprehensive urban planning to tackle these difficulties. Jabbar, Hamoodi, and Al-Hameedawi (2023) also indicates that "Urban Heat Island is a form of air pollution that exacerbates global warming". The following scheme is the summary of different scholarly document which indicates the characteristics of UHI (Zhang et al., 2009; Diem et al., 2024; Ibrahim et al., 2018; Joshi et al., 2024; Kang et al., 2022; Hansen et al., 2013; Lemonsu et al., 2015; Schwarz & Manceur, 2015; Voelkel et al., 2018; Bhargava, Lakmini, & Bhargava, 2017).

Figure 2: Urban Heat Island characteristics. Source: Personal elaboration.



The following figures depicts the UHI phenomenon.

Figure 3: Urban Heat Island scheme. Source: EPA, 2012, pp. 4.

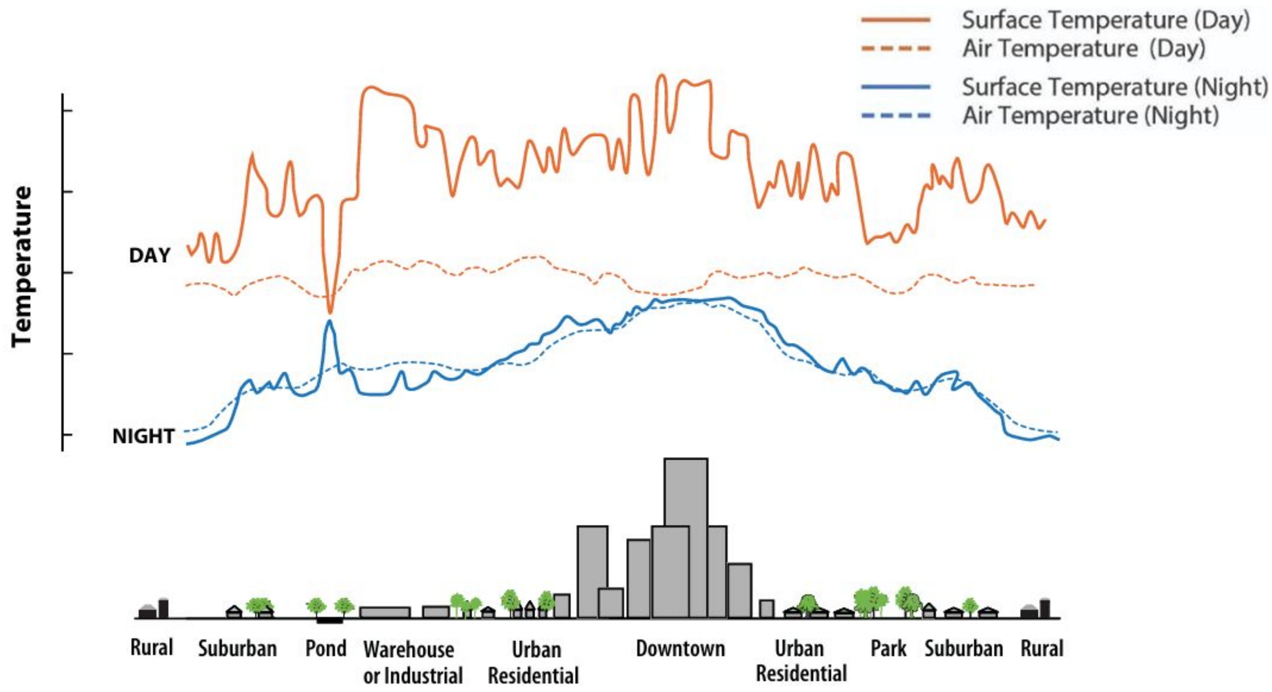


Figure 4: Illustration of UHI differences between rural areas, leafy neighbourhoods and downtown areas. Source: (SIRADEL, n.d.).

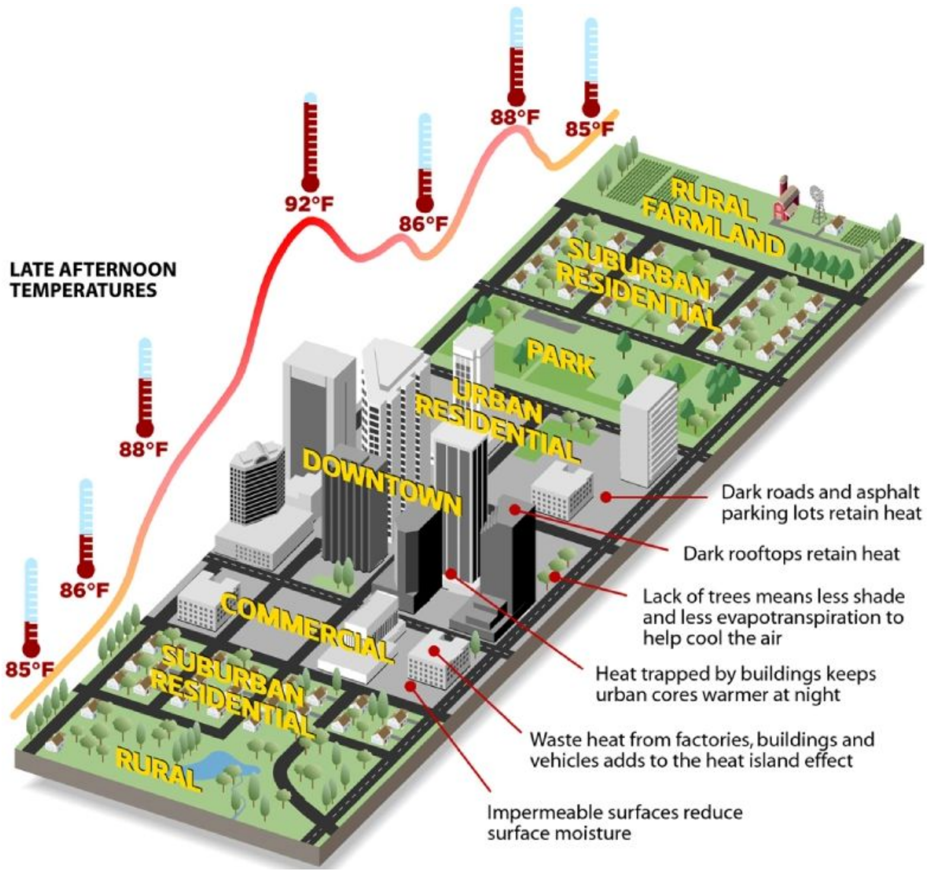


Figure 5: Types of Urban Heat Islands and the core components of the urban atmosphere. Source: Jabbar, Hamoodi, & Al-Hameedawi, 2023, pp. 4.

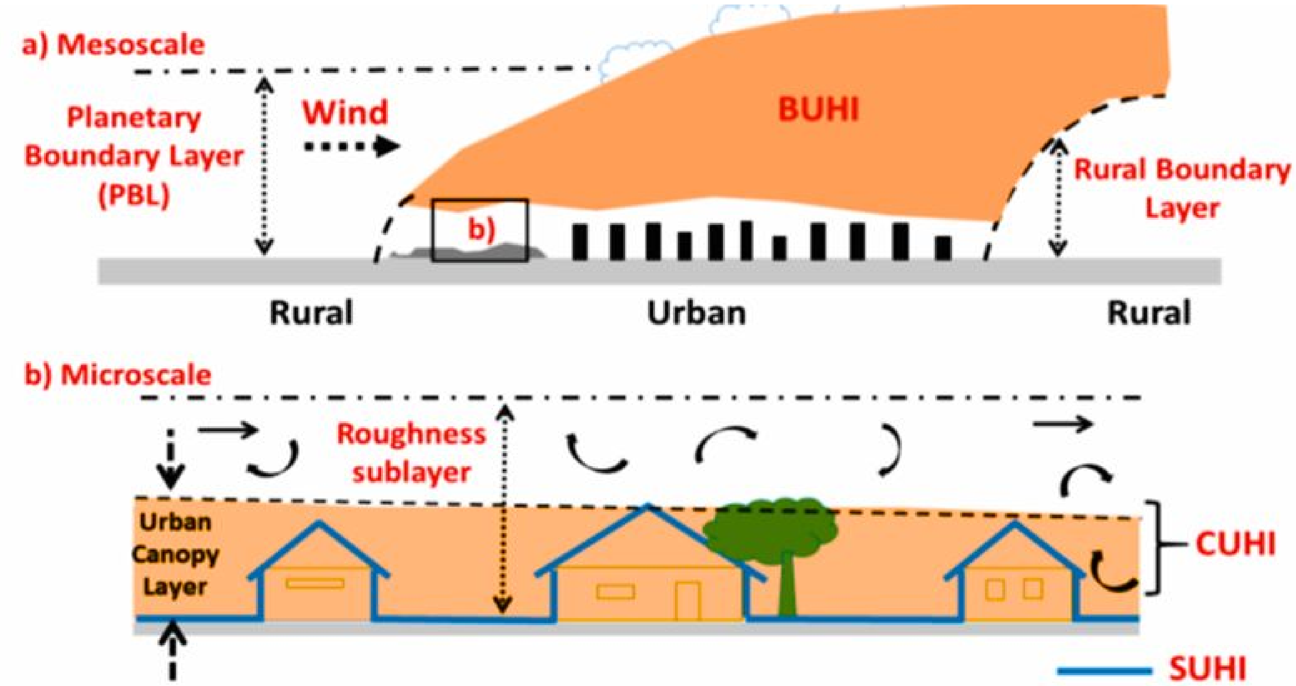
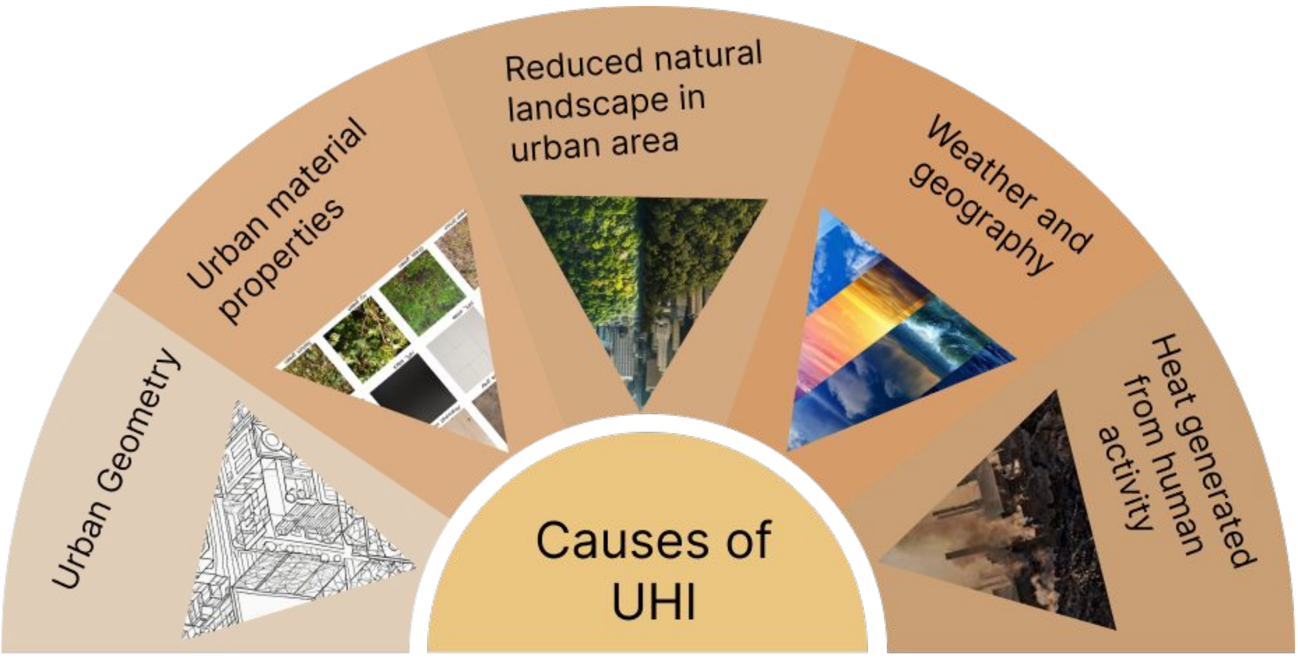


Figure 6: Main causes of Urban Heat Island. Source: Personal elaboration



Impacts of Urban Heat Island

Increased mortality rates and the spread of diseases are just two possible negative consequences of the urban heat island phenomenon on human health. As urban temperatures rise, so does the demand for cooling systems, which rises in parallel with rising energy use. As a result, the rise in air pollution is closely correlated with the rise in energy generation. Ground-level ozone generation rises in along with rising air temperatures. If everything else stays the same, this effect is more noticeable in sunny, hotter weather. As a result, air pollution increases (Jabbar, Hamoodi, & Al-Hameedawi, 2023, pp. 8-10).

Urbanization

A comprehensive definition of urbanization can be achieved by combining the viewpoints of the World Bank (2020) and the United Nations (2018) as follows:

Urbanisation is the proportion of people who reside in urban areas in comparison to rural area. the rate of urbanization has been driven by contributing factors such as better economic growth, more job opportunities and more favourable living conditions which in the long run causes migration of people from rural area to urban areas. Hence, cities and town start experiencing growth and expansion and at same time the become more populated as well as experiencing a greater variety of economic activities, and going through significant changes in their land use, social structures, and infrastructure. Urbanization is closely related to industrialisation and increasing demand for improves accessibility to social, heath and urban services.

Resilience

The notion of "resilience" primarily used to describe bounce-back or recover and return to the original state (Klein, Nicholls, & Thomalla, 2003). Resilience theory, a concept developed by Holling, emphasizes the capacity of an ecological system to persist despite changes, unlike engineering resilience which focuses on a single equilibrium state. This theory has evolved from a system characteristic to a normative vision, influencing urban resilience literature and being applied across various fields such as natural disasters, risk management, hazards, climate change adaptation, international development, engineering, and energy system planning (Meerow, Newell, & Stults, 2016). Also, Folke (2016) explains that resilience as concept that refers to a system's ability to manage continuous disturbances and shocks while maintaining its fundamental characteristics, structure, and interactions, thereby defining its identity as being resilient.

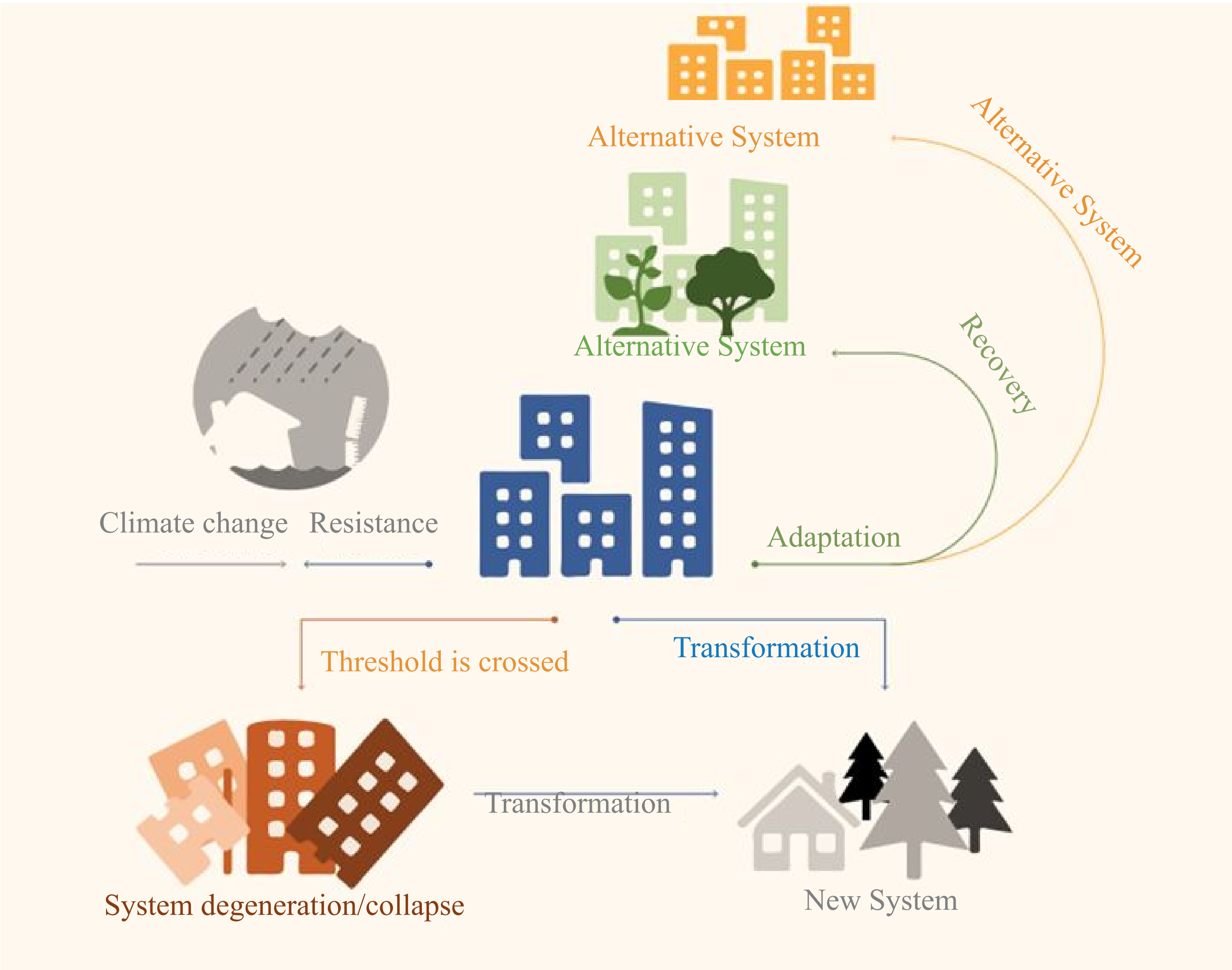
This concept is similar to the concepts of sustainable development and governance. Urban resilience pertains to the capacity of intricate urban systems to effectively respond and adapt to both natural and human-made hazards. The topic is examined in urban planning studies through the lens of systems theory, with particular concentration on the urban ecosystem. Resilience refers to a combination of adaptive abilities that enable a system to remain compatible and functional following a disaster. The concept of resilience may be categorised into two types: inherent resilience and adaptive resilience. Inherent resilience pertains to the system's performance during normal, non-crisis periods, while adaptive resilience refers to the system's capacity to effectively respond and adapt to critical events by demonstrating flexibility, resourcefulness, and problem-solving abilities.

Resilience is not only connected to the abilities of a system, but also to the way individuals interact with the environment. This connection can contribute to the long-term sustainability and resilience of urban regions for many generations. It is not only a distinct issue but also a component of vulnerability and urban sustainability research. The idea of resilience possesses a favourable semantic connotation, rendering it more appealing than other comparable concepts. Urban resilience, as defined by the Rockefeller Foundation, refers to the ability of individuals, communities, organisations, businesses, and systems within a city to withstand, adjust to, and grow in the face of ongoing challenges and pressures. The common thread across these resilience concepts is the urban environment capacity to rebound after a catastrophe and restore its original state. To gain a deeper understanding of urban resilience, it is necessary to use a systematic approach that examines the urban system's abilities to absorb, adapt, reconstruct, and learn in order to survive change and return to previous normal conditions (Irani & Rahnamayiezekavat, 2021, pp. 307-308).

Climate Resilient

City climate resilience refers to the ability of a system, such as a city, to respond or adjust to climate change. The city has the ability to either adapt and recover in its current state or adapt to other systems, for instance by implementing greening measures or improving its building design and infrastructure. even though the city undergoes transformations, its fundamental functions and structures remain intact. The result of lacking resilience would arise if climate change gives rise to in such severe damages that it necessitates the destruction of infrastructure and the destruction of broad areas, so requiring the city to undergo a total transformation into a new system. Politicians and strategic planners strive for prevention of such calamities. By applying the notion of resilience, one can effectively establish the appropriate preventative measures (Tötzer, Loibl, Neubert, & Preiss, 2018, pp.10). In the following graph the concept of climate resilience is depicted.

Figure 7: Climate resilience scheme.



Urban Resilience

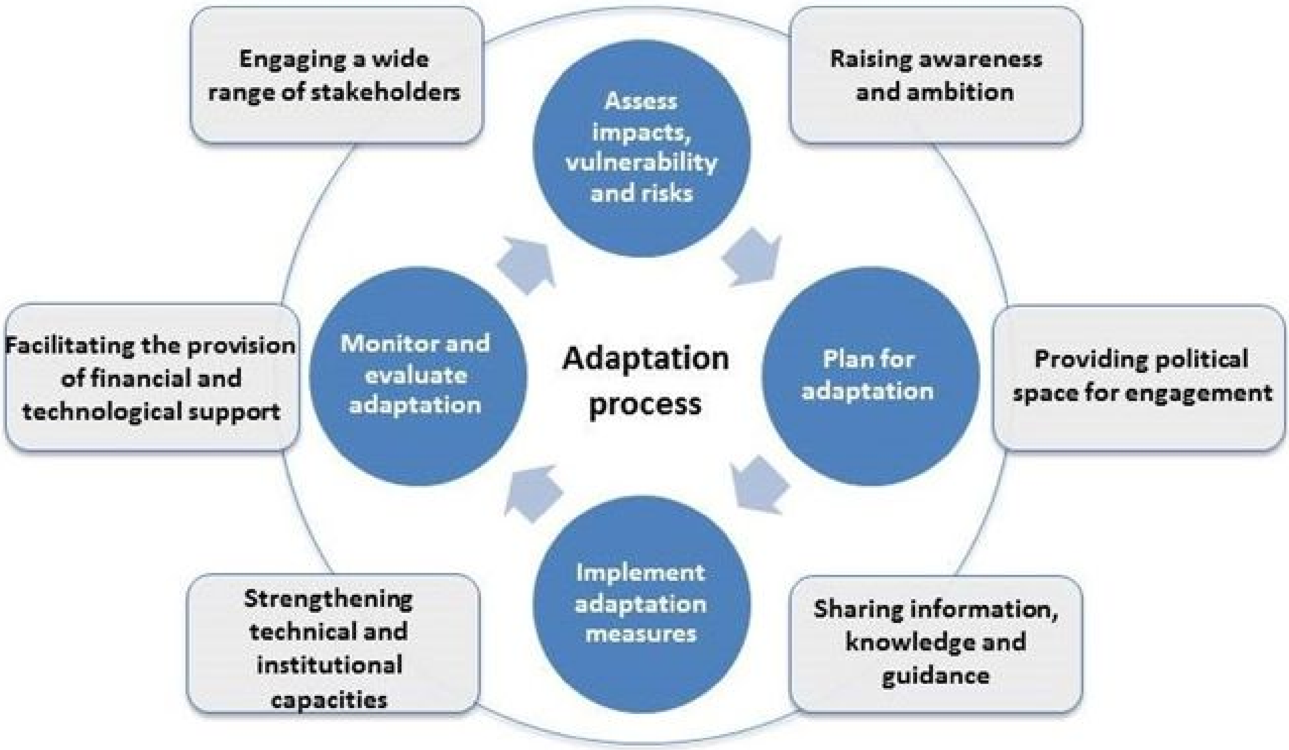
Kong, Mu, Hu, and Zhang (2022) focuses on the implementation of resilience theory within the context of urban development and they indicate that urban resilience conveys the capacity of a city to sustain and recover from natural disasters, as well as encompassing its capability to withstand in confronting risks and its fast recovery pace. In other words, Urban resilience refers to a system's ability of maintaining or rapidly returning to desired functions in confrontation of disturbance, adapt to change, and quickly transform systems (Meerow, Newell, & Stults, 2016; IPCC, 2007). This comprehensive performance approach aims to enhance urban areas' ability to hold up risks, decrease vulnerability, and minimize losses during disasters.

Furthermore, urban resilience is characterized by a strategic, global, and broad perspective, focusing on strong and sustainable networks of human communities and physical systems. Moreover, urban resilience is a broad notion that encompasses both "hard indicators" such as infrastructure and transportation, as well as "soft indicators" like economic and social factors. Research on urban resilience aims to enhance cities' ability to handle natural disasters and socioeconomic hazards due to climate change, globalization, and urbanization. This means the implementation of proactive plans before, during, and after catastrophic events to reduce negative consequences and limit detrimental impacts. It also takes into account cities' capacity to preserve or recover their original functions in response to disturbances across different temporal intervals and geographical regions.

Climate Adaptation

Climate adaptation, as defined by the United Nations, refers to the process of making adaptations in ecological, social, or economic systems in order to effectively respond to changes in climate conditions. Successful adaptation requires increasing awareness, fostering political involvement, bolstering technical and institutional capabilities, and delivering education through the sharing of knowledge and assistance (Motevalli, Talib, Al-Shaibani, Chan, Henshaw, & Roda, 2024). These aspects facilitate the efficient use of financial and technological assistance and involve a diverse group of stakeholders and organisations, as depicted in the subsequent diagram provided (Adger, Arnell, & Tompkins, 2005).

Figure 8: Adaptation Process. Source: Global Center on Adaptation, 2019.



Adaptation and Mitigation

According to European Environmental Agency (2024), "Adaptation and mitigation are two distinct approaches designed for alleviating the impacts of climate change. Adaptation is forecasting the detrimental impacts of climate change and implementing suitable measures to avert or mitigate damages. It entails extensive infrastructural modifications and behavioral adjustments, including minimizing exposure to extreme and high temperatures and monitoring at-risk family members and neighbors. Mitigation intends to cut back on the severity of climate change impacts by preventing or reducing greenhouse gas emissions. This can be accomplished by diminishing sources of greenhouse gases, such as renewable energy or better transportation systems, or by augmenting gas storage, such as expanding forest areas. Both methods are crucial for tackling climate change issues and securing a sustainable future".

PART II

FROM PLANS TO PROJECT

- Chapter 3: Vienna
- Chapter 4: Paris
- Chapter 5: Madrid
- Chapter 6: Athens
- Chapter 7: Lisbon
- Chapter 8: Berlin
- Chapter 9: Milan

CHAPTER 3

CASE STUDY: VIENNA

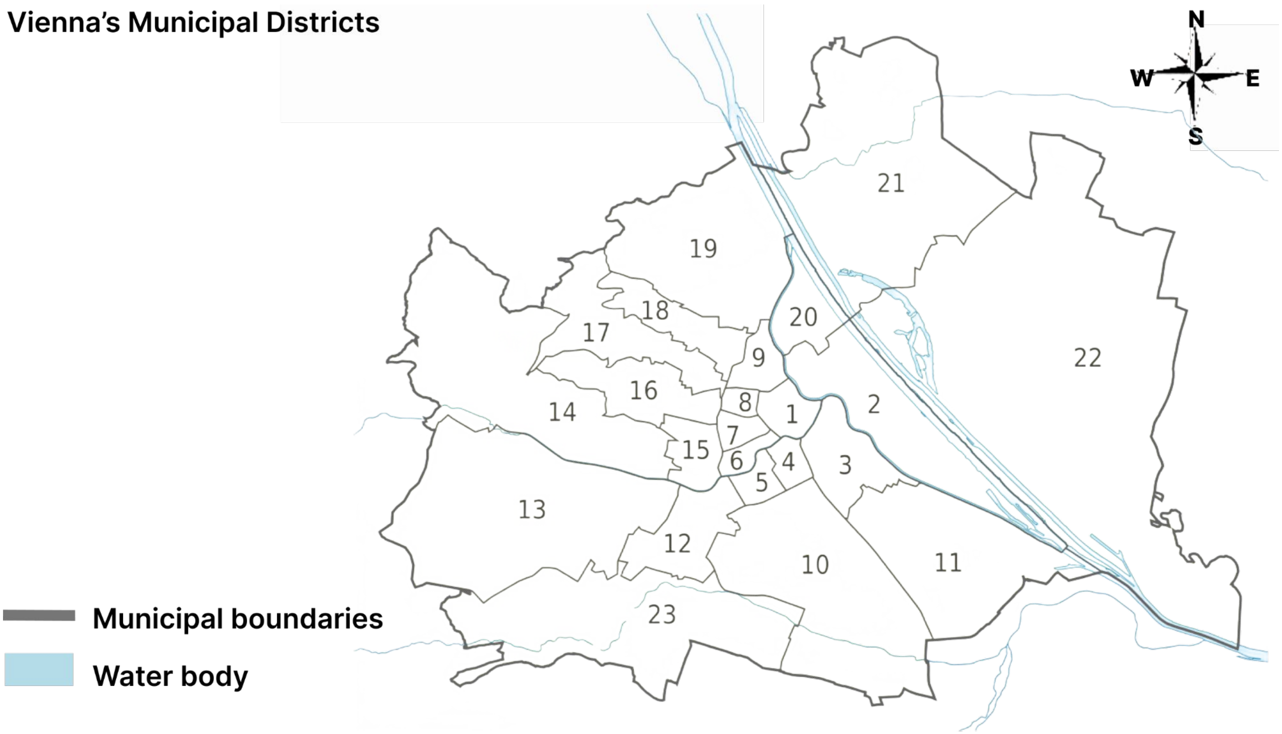
- Territorial and climate overlook description
- Climate action plan
- From lesson to project
- lesson learned

Territorial and climate overlook description

Territorial and climate overlook description

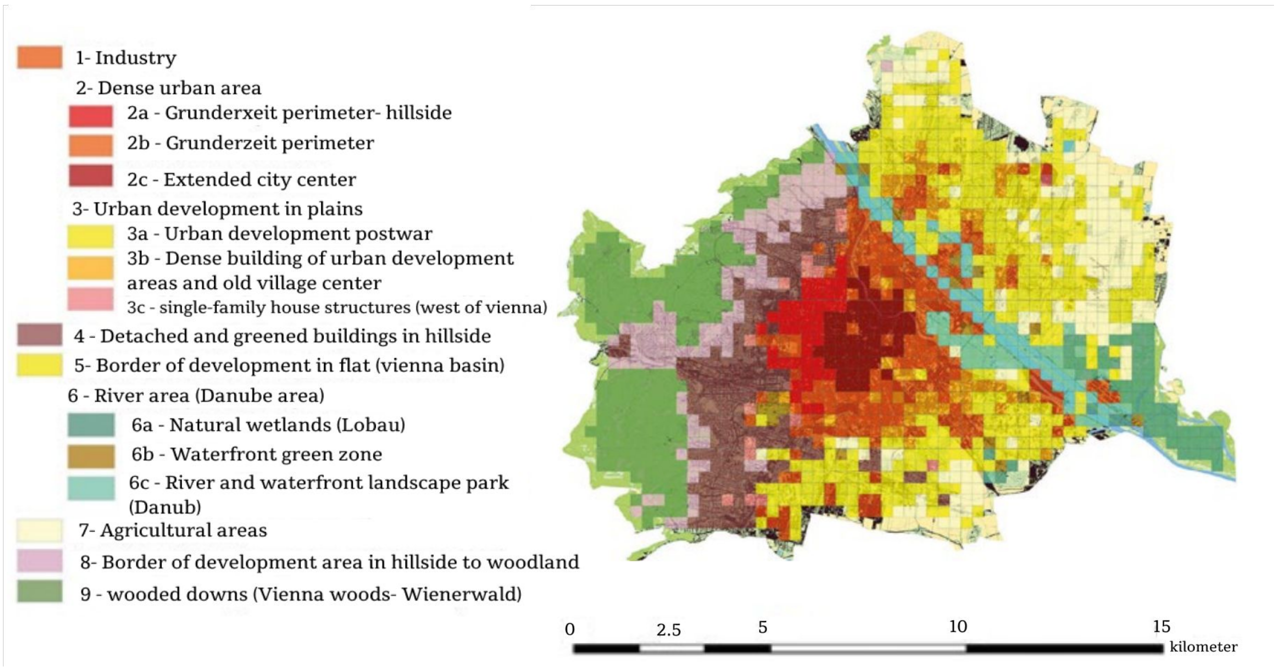
Vienna is geographically located in a temperate climatic region, where summer temperatures frequently reach highs of around 95°F (35°C). According to Vienna's official municipal website, Vienna is divided into 23 municipal districts (Bezirke), which serves for both administrative and functional purposes in urban governance. Each district manages local issues like green space management, school maintenance, and small infrastructure projects, whereas the central government manages larger development initiatives. This district system facilitates a equilibrium between localized decision-making and cohesive city-wide policies, which is crucial for effective urban planning that emphasizes sustainability, livability, and historical preservation. Each district also has an elected District Assembly (Bezirksvertretung) that administers local matters, although major decisions can be overridden by the central Municipal Council (Gemeinderat), in order to ensuring a structured approach to governance and development. In the following map the municipal districts of the city is illustrated.

Map 1: Vienna’s municipal districts. Source: personal elaboration



Nine distinct types of urban setting also have been identified using climate-related data and information from the Statistics Austria database. These classifications are based on factors such as typology, topography, climate, vegetation, and the extent of impermeable surfaces, as illustrated in Map 2, which visually represents these categories.

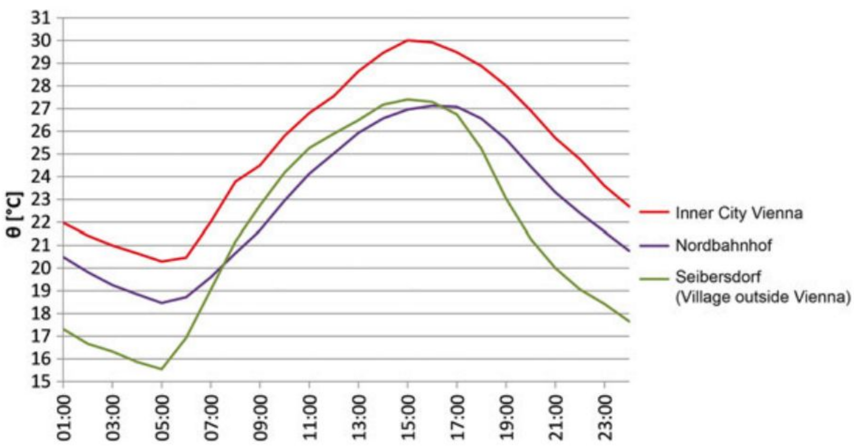
Map 2: Vienna’s urban space categorisation. Source: Urban Heat Island strategies city of Vienna, 2018.



In recent years, according to eurisy (2021), the urban heat island effect in Vienna has intensified due to population growth and increased urban construction, resulting in the reduction of permeable green spaces and elevated temperatures. In 2003, the city had 44 days of heat waves, resulting in 180 fatalities. Future projections indicate that from 2021 to 2050, Vienna would experience an average of 19 heat days year, while the population is anticipated to rise from 1.8 million to 2 million by 2029.

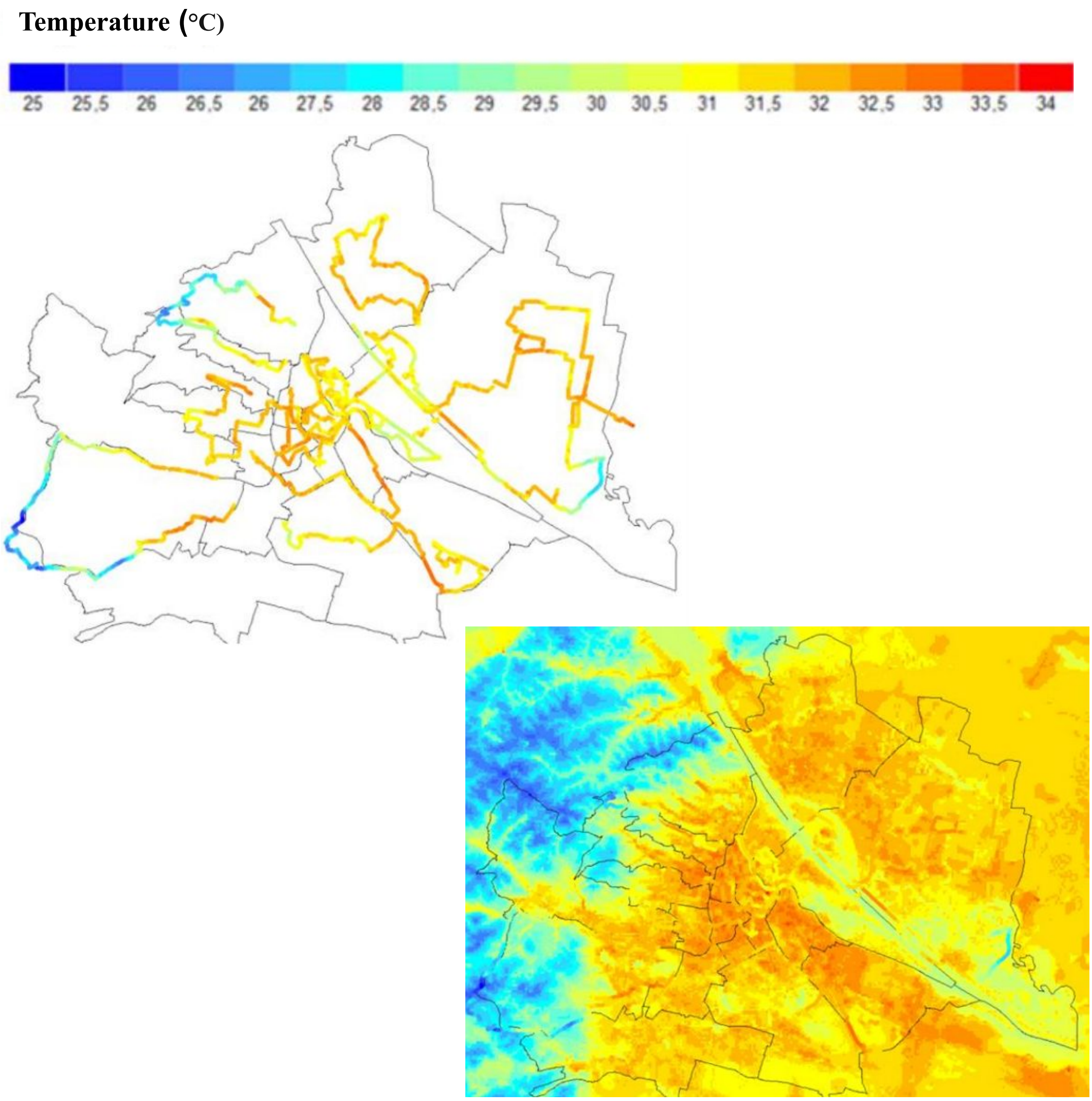
Figure 1 illustrates the average hourly temperature distribution for a certain day in the summer of 2012, comparing two selected regions in Vienna with a rural area in Seibersdorf. The results distinctly indicate significant variations in the microclimate of the examined sites, with notably elevated temperatures in the city center.

Figure 9: average hourly temperature dispersion for a specific day during the summer of 2012. Source: Damyanovic et al., 2016, pp. 307.



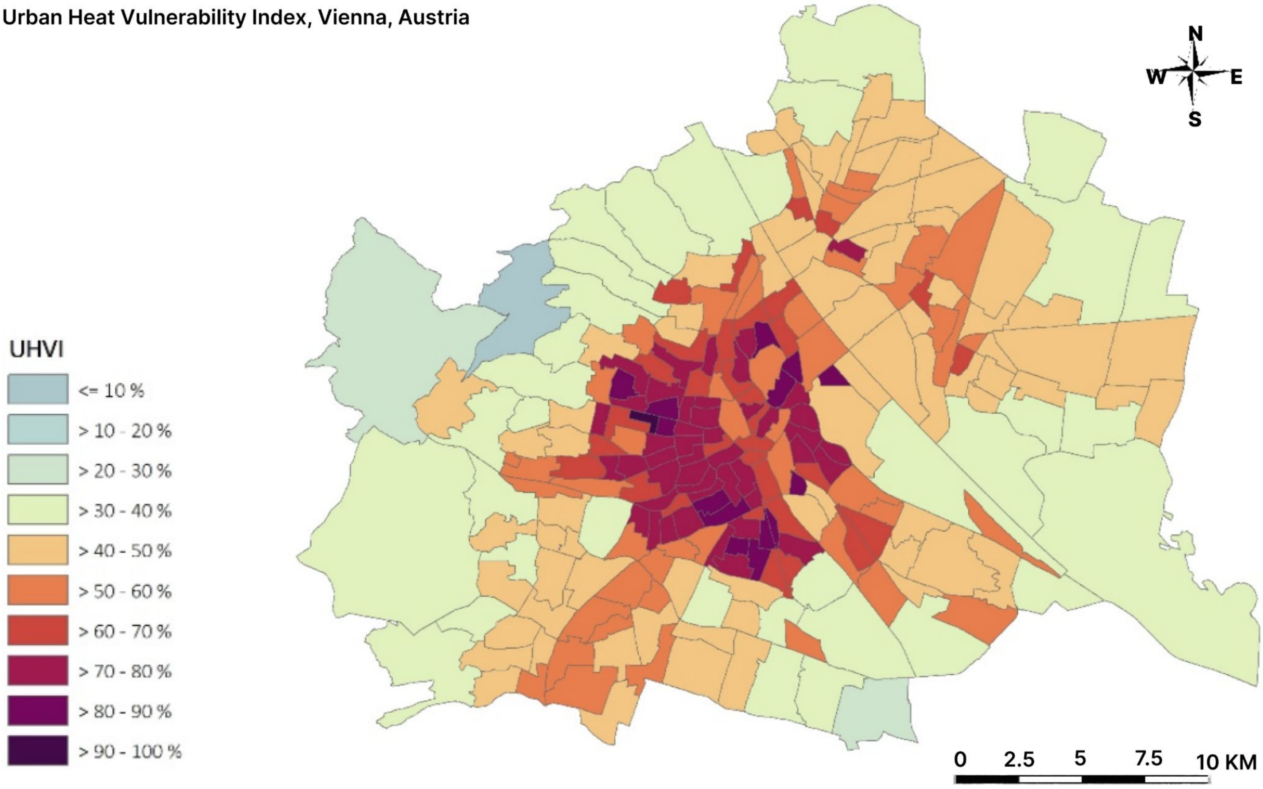
Zuvela-Aloise et al. (2013) conduct an detailed analysis of Vienna's temperature. This study measured the daily temperature cycle at fixed locations in 10-minute intervals across three monitoring stations: beside a water channel, in a park, and in a densely built-up area. The data indicated significant temperature differences between urban areas and open spaces, reaching up to 9°C at 15:00, with the highest temperatures recorded on streets and the lowest in the Wienerwald forest and Lobau nature reserve. Comparable geographic temperature gradients might be replicated using the MUKLIMO_3 model, provided that the initial conditions accurately reflect the climatic circumstances of a specific day. Figure below depicts these information.

Map 3: Temperature distribution in Vienna recorded during the bicycle trip on July 7, 2011 (left) and simulated using the urban climate model (right). Source: (Zuvela-Aloise et al., 2013. pp.6).

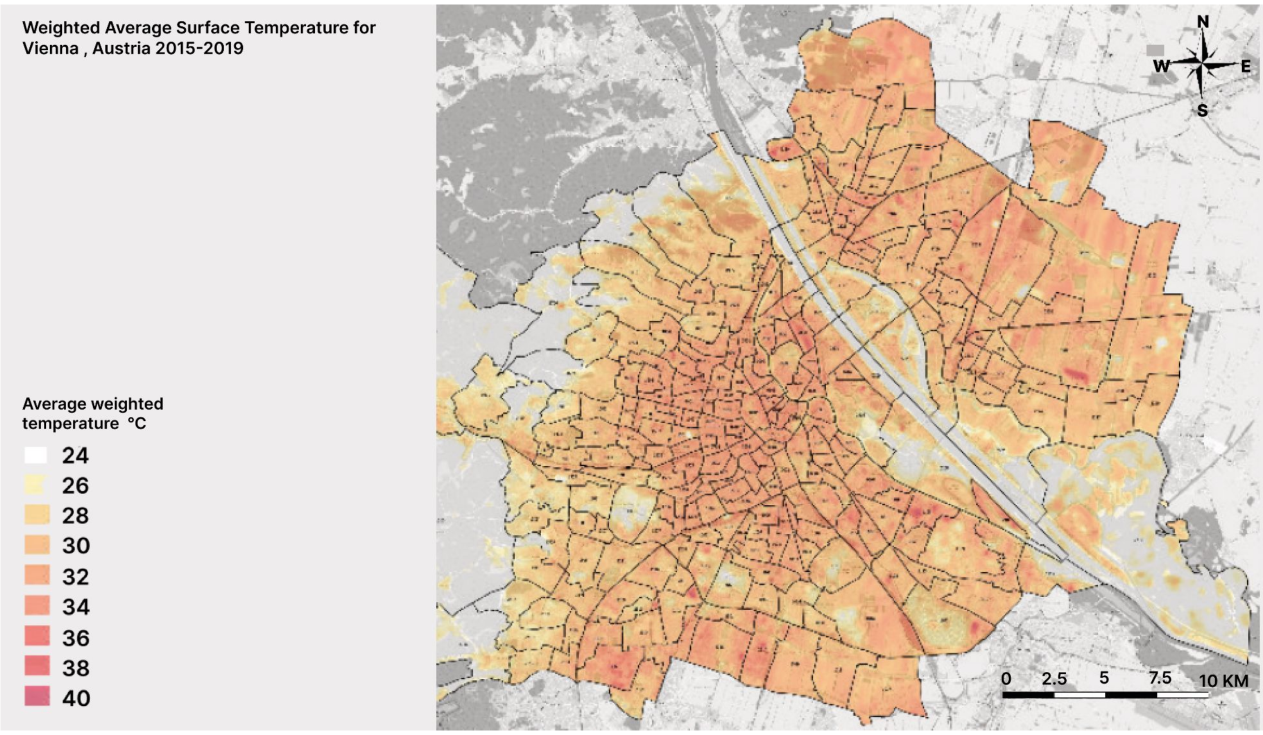


Map 4 indicates Urban Heat Vulnerability Index of city of Vienna in 2019 which consist of three important indicators; namely, exposure to the heat events, sensitivity of the population and adaptive capacity (green and blue infrastructure).

Map 4: Urban heat vulnerability index. Source: (Ecoten Smart Energy Solutions, 2019).

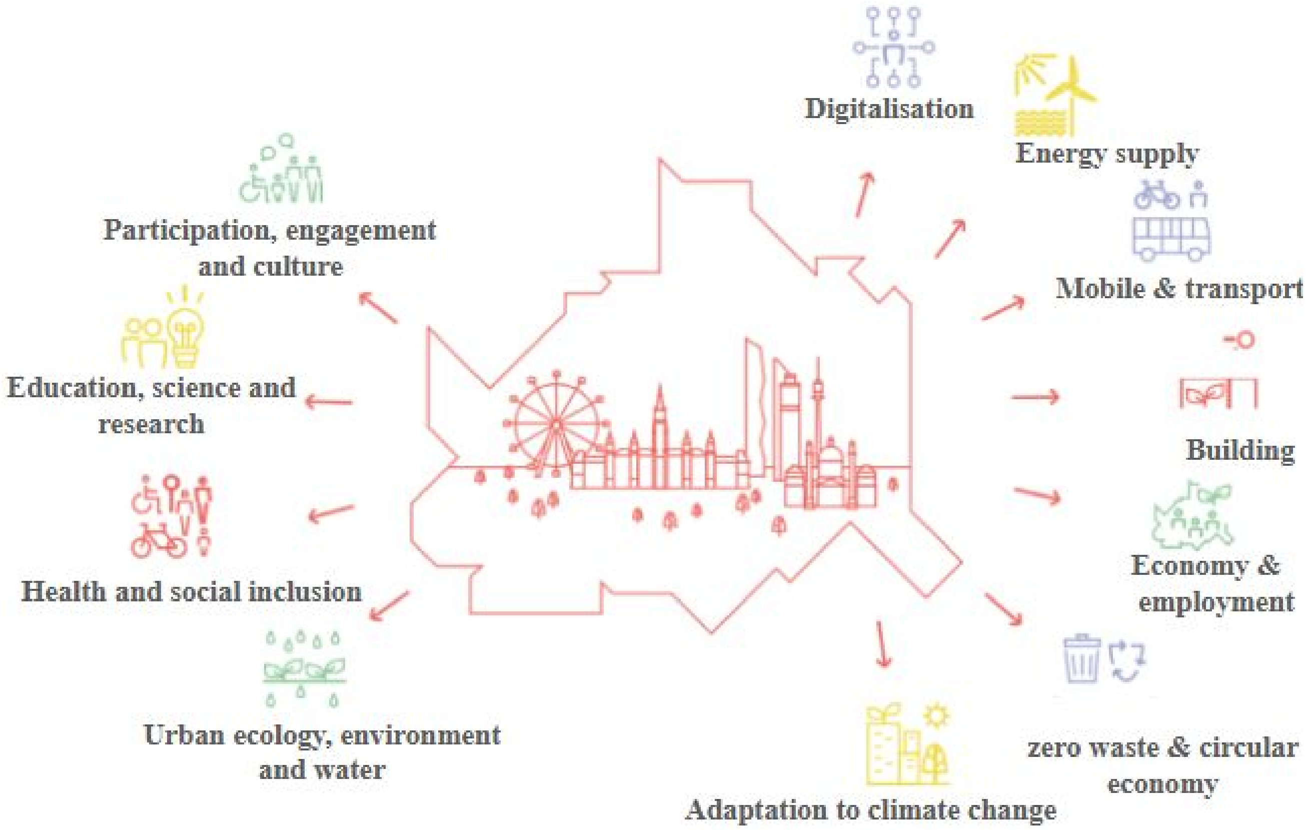


Map 5: weighted average surface temperature for vienna, Austria 2015-2019. Source: Gerasimov et al, 2019.



It is important to take into consideration that in last decade Vienna is well recognized as a prominent worldwide hub for urban sustainability, consistently attaining high rankings in terms of liveability because of its urban policies that maintain a mixed use, high density urban urban form, and effective public transportation systems, advantages for active mobility, affordably priced for eco friendly housing and high quality and high standards of public green spaces. Although the development plan initially included ecological and social considerations, there is now a significant movement towards prioritizing economic factors and using techno-managerial approaches to address climate change (Mocca et al., 2020, pp. 1). Figure 2 shows Vienna's Smart climate approach.

Figure 10: vienna's smart climate approach. Source: (The smart climate strategy, 2022. pp .24-25).

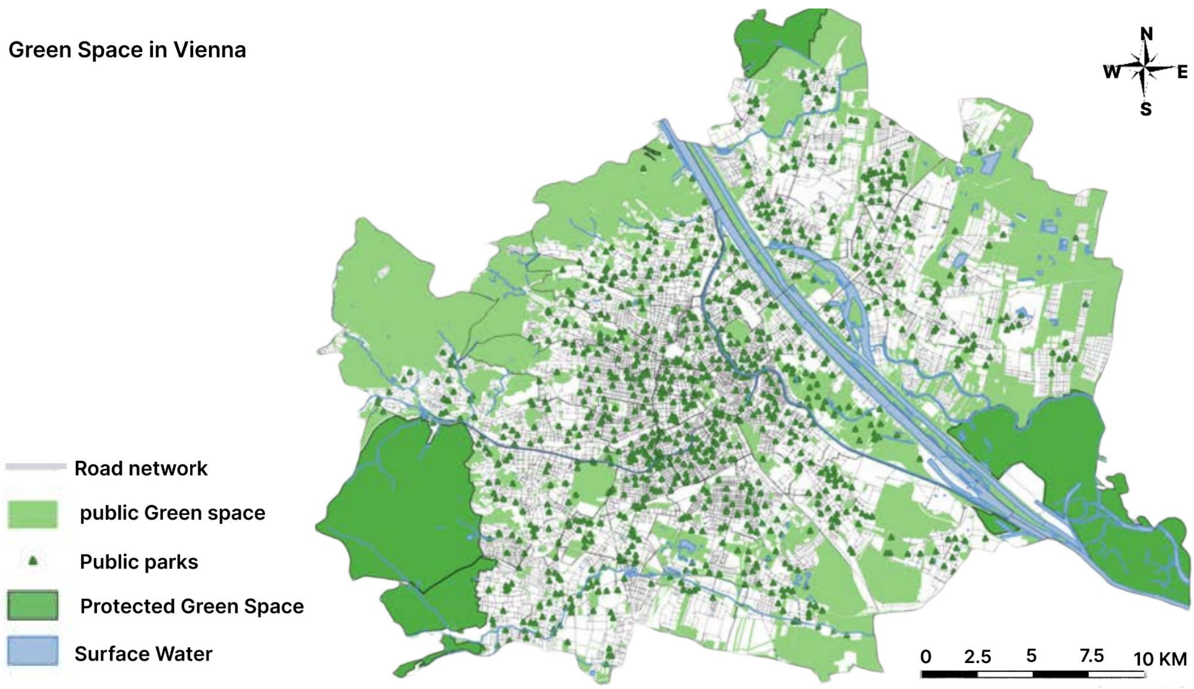


Moreover, the Environmental Protection Department of Vienna proactively addressed urban climate change by creating the "Urban Heat Island Strategy Plan" (UHI-STRAT), which was finalized in 2015. The plan aims to showcase strategies for mitigating and adapting to urban heat islands and promote awareness through partnerships across different sectors. The figure 3 shows the five planning levels in Vienna for mitigating of the Urban Heat Island impacts.

Figure 11: planning levels for mitigation of UHI effects. Source : (Tötzer, Loibl, Neubert, & Preiss, 2018).

In recent years, Vienna, recognized as the world's greenest city, which has practically fifty percent of its 200 km² designated as green spaces, with a substantial fraction accessible for public use at no cost. These green areas are associated with enhanced health and well-being of residents. Vienna has emphasized green spaces in its 2050 strategic plan, seeking to preserve more than 50% of the city's greenery. Green areas are regarded as instruments for social well-being, historically employed to tackle social issues. Nonetheless, their significance in addressing climate and biodiversity challenges has only recently become prominent. The city's emphasis on green spaces reflects its dedication to sustainable development (Kazepov et al., 2021, p. 47). Map 6 shows green spaces in Vienna.

Map 6: Green space in Vienna. source: (Open data osterreich, 2019 elaborated by Ambrosise Mahe).



Climate Action Plans

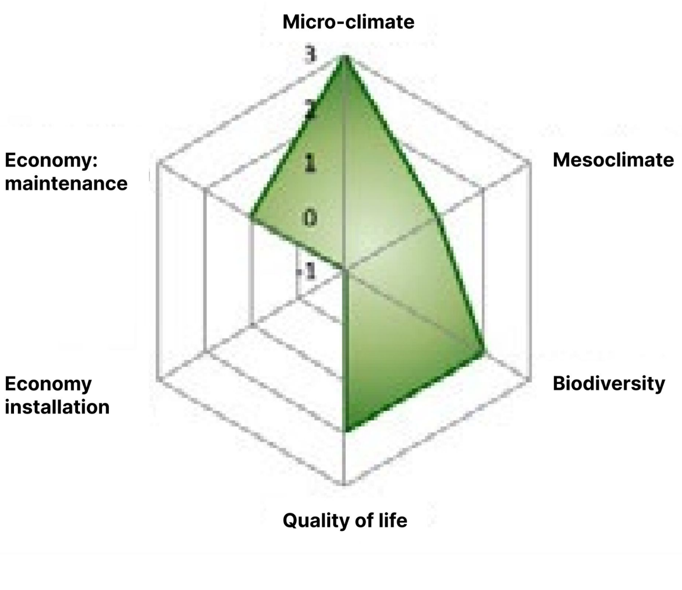
Vienna UHI Strategy levels of action are:

1. Masterplans and urban design competitions
2. Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA)
3. Zoning and development planning
4. Planning and design of public green and open spaces
5. Collaborative planning process, developer competitions, housing initiatives and public housing
6. Planning and design of public utility buildings
7. Promoting implementation

Strategic actions

Vienna's Urban Heat Strategy is and in-depth review of best practices and scientific literature in order to identify and explain mitigation measures to reduce UHI impacts in Vienna. The most significant factors are microclimate, mesoclimate, biodiversity, quality of life, constructions and cost's maintenance. Three different grades for benefits and drawbacks have been included in the classifies review key. The following diagram which is known for spiderweb diagram is designed aimed at making it easier to visualise and evaluate actions, ensuring comparability and explaining how each elements affect biodiversity, the microclimate, the meso climate, and human well-being.

Figure 12 : Spiderweb diagram. Source : Urban Heat Strategy for Vienna, 2018.

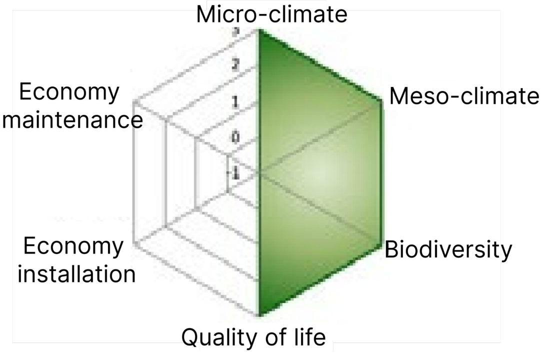


- ❏ 3- significant improvement
- ❏ 2- Improvement
- ❏ 1- slight improvement
- ❏ 0- Negligible impact
- ❏ -1 - Deterioration

* The higher the category rating is, the better.

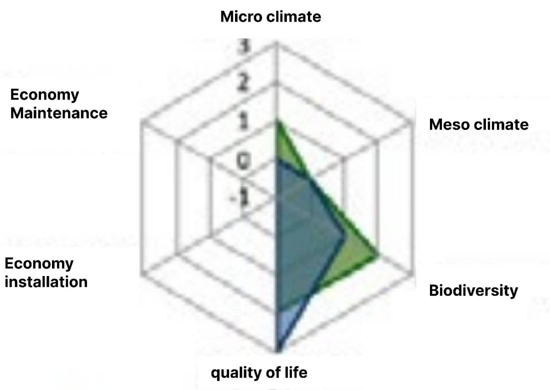
Strategic Action: Protecting urban air flow and open space network

Implementation 1: open space networks connected to areas producing cool air



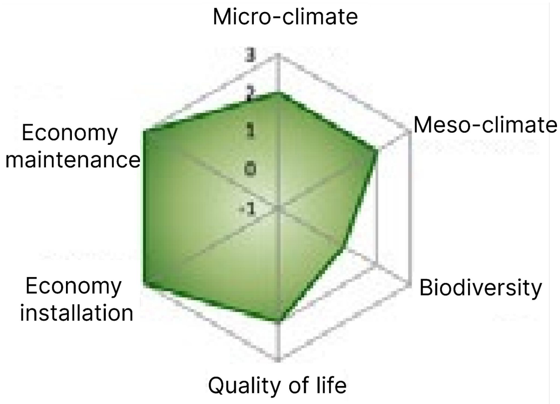
Urban airflow can be improved by enhancing connectivity of urban green and open spaces, focusing on prevailing winds and minor interventions like shade and evaporative cooling. This can protect agricultural and forestry practices, enhance biodiversity, and enhance recreational value. However, challenges include conflicting objectives of urban planning, competing demands in real estate utilization, and urban-rural cooperation. The Vienna Open Space Network, for example, can be implemented to connect inner-city open spaces with outer regions, while establishing new linkages for non-motorized transportation.

Implementation 2 : Green spaces with water bodies and their potential uses



water bodies function as an airways and have a large capacity to store heat, which decreases humidity and temperatures. Besides waterways, green and open spaces are able to improve urban biodiversity and recreational areas by cooling air flows. Along with establishing new recreational areas and benefits for biodiversity, nature-based river design in cities can enhance air flow and quality of life Challenges include maintenance, water quality, and creating sufficient green space along waterways more specifically in densely built-up area.

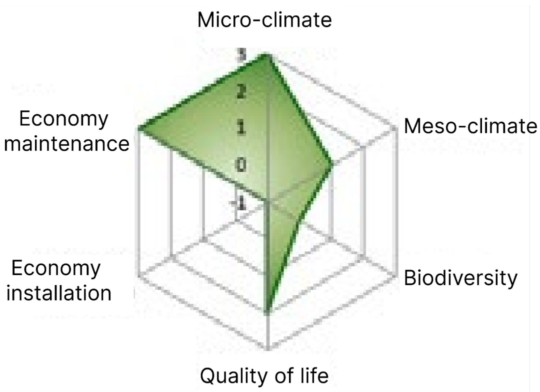
Implementation 3: Keeping slopes free of parallel terrace constructions



Topographical wind systems are crucial for delivering cool air to urban regions and eliminating pollutants. Vienna, particularly along the slopes of the Vienna Woods, possesses optimal circumstances for this. Development must incorporate extensive greenspace and significant spacing between structures to mitigate hill breezes. Preserving air flow corridors and letting low hillside construction can enhance the supply of fresh air. Advantages encompass the preservation and safeguarding of agricultural practices and biodiversity; nevertheless, obstacles arise from conflicting urban development goals on slopes and the identification of offset sites in desirable locations.

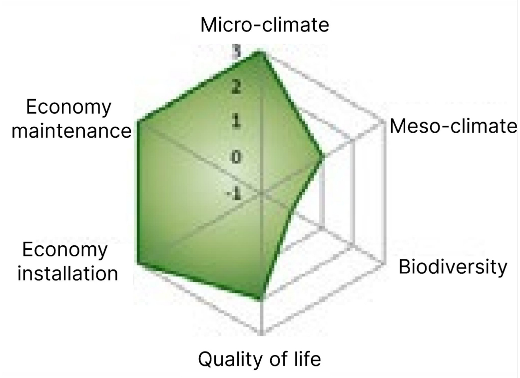
Strategic Action: Adaptation of the urban structure and development

Implementation 1: Evaluation of street routing and intersections



The microclimate of an urban area is affected by elements such as street orientation, intersections, vegetation, and structures. Broad avenues enhance air circulation and nocturnal cooling, while shade elements such as street trees offer amenity. For less heavily populated streets, it is advisable to implement a center avenue featuring two rows of trees. Vegetated facades can lower perceived temperature, facilitate passive cooling of buildings, enhance internal thermal comfort, and improve urban open space amenities. Nevertheless, the organization and design of streets has to combine practical considerations with UHI-related demands. Effective evaluation necessitates specialists employing empirical methodologies, and concentrating exclusively on climatic variables may result in issues with urban efficacy.

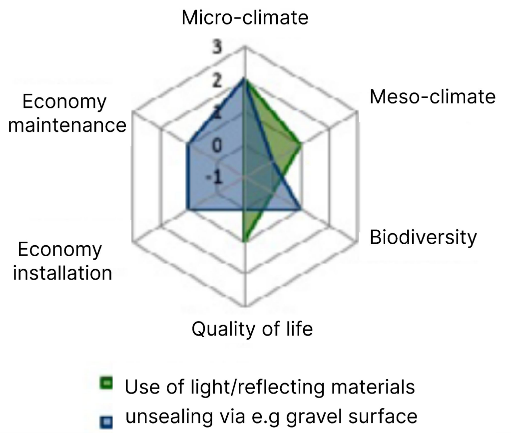
Implementation 2: Improvement of building structure and position



Night-time cooling in highly populated urban areas is markedly diminished due to the heat absorption capacity of buildings and their high impermeability. Elements such as surface materials, colours, and local vegetation influence building orientation and thermal comfort. Building orientation and urban structure should be evaluated individually, taking into account local elements such as wind direction, gradient, and topography. Green infrastructure is essential for enhancing climate impact, offering advantages such as increased thermal comfort in summer and decreased energy use for air conditioning. Facilitating passive solar gain during winter can save heating expenses and carbon dioxide emissions; nevertheless, it may also provide contradictions. It is advisable to compare total energy expenses and seasonally-adjusted technical solutions.

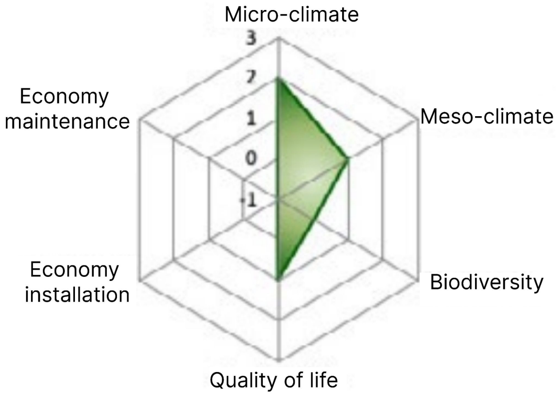
Strategic Action: Buildings and surface materials of lighter colors, along with increased permeability

Implementation 1: Lighter colour and increased permeability of surfaces in open space



Dark surfaces in public spaces and transportation zones can give rise to increase heat absorption and cooling, particularly in densely built areas. In order to reduce urban heat island impacts, some actions must be used like light-colored and reflective surfaces with low thermal mass. This can be implemented by replacing mastic asphalt with lightweight concrete, slabs, pavement, or crushed stone roofing decks. Permeable surfaces enhance amenities, improve quality of life and aesthetic appeal by facilitating evaporation and penetration. However, challenges include higher manufacturing costs, increased reflection, and accessibility concerns. Permeable surfaces are less suitable for traffic areas than asphalt.

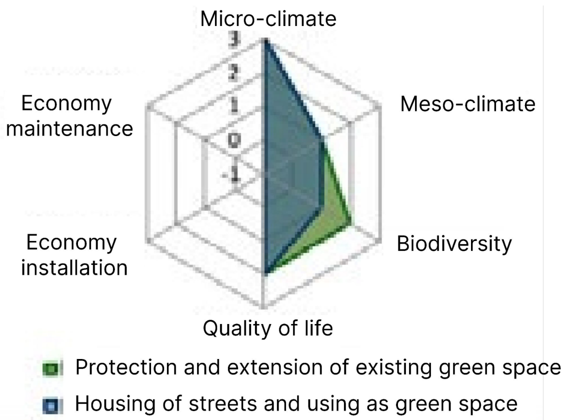
Implementation 2: lighter coloured building surfaces



Building surfaces on hot days can significantly affect their thermal characteristics, so it's recommended to use light-colored surface materials with low thermal mass for exterior components and cool roof materials for enhanced heat dissipation. Integrating thermal input with architectural strategies like shading devices or facade greening can reduce thermal input and improve indoor comfort. Vegetation initiatives offer numerous benefits, including reduced energy usage for air conditioning, improved indoor environment, and improved quality of life. Challenges include monument preservation, urban planning, architectural limitations, and winter solar heat gains.

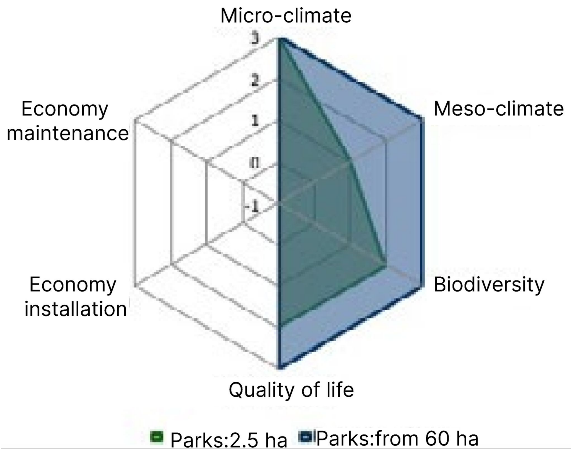
Strategic Action: Protection and expansion of green and open spaces

Implementation 1: Conservation and expansion of green places



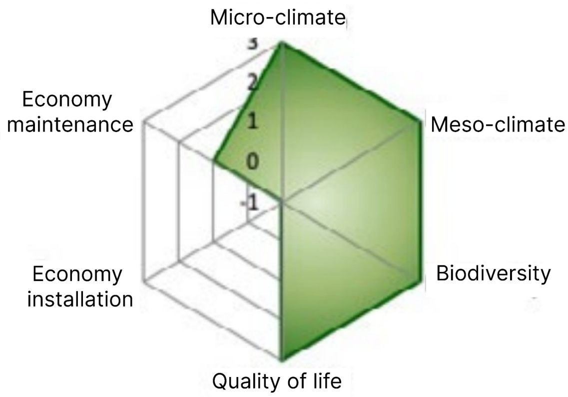
Vienna is enhancing its urban green and open space infrastructure to ameliorate local microclimates, especially in heavily populated regions. This entails the changing of agricultural zones into expansive parks and enhancing of impermeable surfaces via green space transformation, the integration of adjacent roadways, the selection of resilient tree species, the planting of shade trees, the improvement of irrigation systems, and the implementation of shading devices. Benefits encompass the preservation and enhancement of current green and open space assets for an expanding urban populace, the improvement of inner-city regions with subpar access to open space, augmented water absorption, delayed water runoff, enhanced amenities, fine particulate filtration, and elevated urban biodiversity. Challenges encompass limited space and economic perspectives on land use due to an increasing urban population.

Implementation 2: Creating paks



Parks play a crucial role in urban environments, mitigating heat and enhancing evaporation. Expansive green spaces over 50 hectares significantly impact the city-wide meso climate. However, the preference for these spaces remains ambiguous, with central parks favored for urban development and sustainable resource conservation. Comprehensive greening is essential for urban growth, and rehabilitated green areas can be used for recreational and leisure spaces, biodiversity enhancement, and drainage infrastructure alleviation. However, the need to use diminishing real estate assets for housing creates conflicting objectives. Medium-sized district parks in Vienna are beneficial for urban growth, but large parks face housing demands in expanding cities. Traffic flyovers are a viable alternative, but at a high cost.

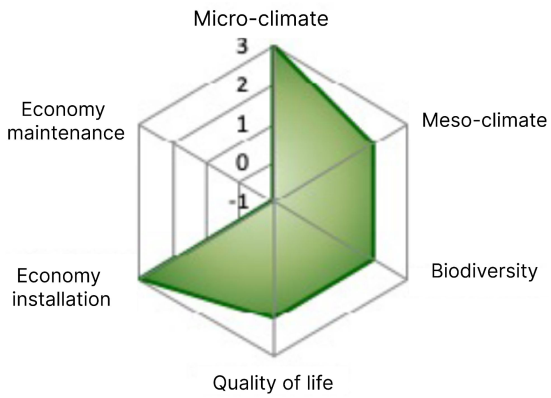
Implementation 3: Conservation and expansion of green places



Forests are essential for preserving moisture, cutting back on heat waves and cooling the atmosphere. Vienna, with 8,000 hectares of woodland, promotes sustainable forest management through species diversity, natural regeneration, and mixed growth. New forests are established on an annual basis, which is improving urban climate, providing recreational areas, and creating wildlife habitats. Forestry initiatives encourage people to engage in forestry, resulting in improved biodiversity and conservation zones. However, challenges include land competition from urban expansion and agriculture, potential conflicts among landowners, and preventing forest establishment in cool air corridors.

Strategic Action: Conservation and expansion of (street) tree stock

Implementation 1: protecting the tree stocks



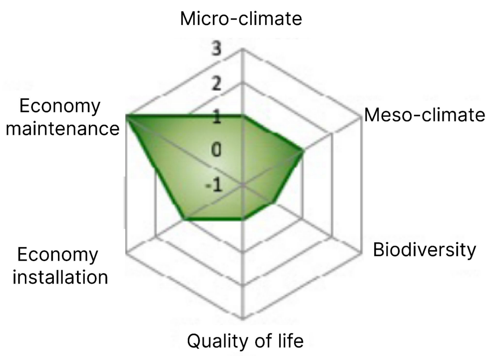
Vienna's tree population significantly impacts urban climates, but safeguarding it is moderately affecting micro and meso climates.

Urban trees face challenges like arid climates, elevated temperatures, and vehicular pollution. To protect Vienna's arboreal resources, maintenance, replacement strategies, and watering systems must be implemented.

The optimal tree age depends on size and health, but benefits include improved quality of life, improved climate, water retention, biodiversity, and landscape structure.

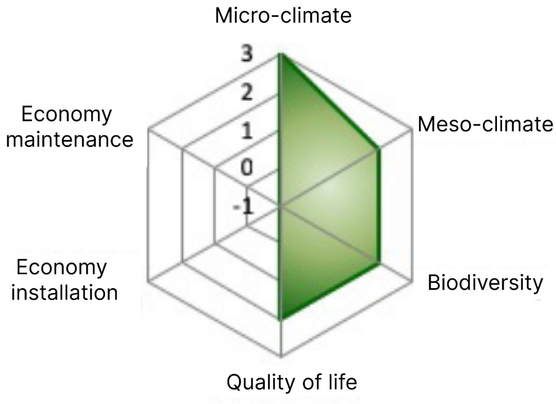
Challenges include urban densification and spatial competitiveness.

Implementation 2 : Choosing right tree species



Tree species selection and application are crucial for protecting and expanding tree stock, especially in areas like parks, housing estates, and outdoor areas. Urban Heat Island adaptation improves tree health and resilience, but many Vienna's street and park tree species only partially meet these requirements. Trees also improve air quality by absorbing pollution through their leaves' stomata, reducing ozone content and lowering air temperature. Benefits include improved quality of life, maintenance of urban climate, and protection of street and park tree stock. Challenges include ongoing species selection optimization and technical training on tree planting.

Implementation 3: Expanding the tree stock through replanting



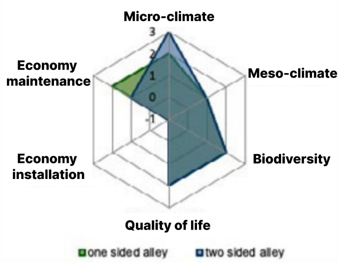
Urban tree stock expansion, especially in densely populated inner-city areas, is crucial for a cooler climate. This involves implementing tree lines along streets, new plantations in parks, green spaces, courtyards, squares, and playgrounds, and creating new forests. Trees increase evaporative cooling, reduce street temperatures, and filter air pollutants. However, narrow tree avenues on busy streets should not create a 'tunnel effect.

Benefits include protecting public spaces, improving urban climate, and increasing biodiversity.

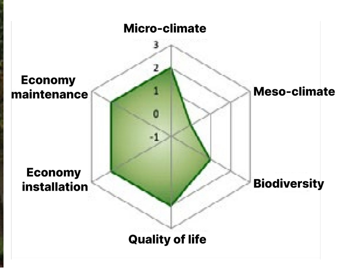
Challenges include competing with car parking, reducing light on buildings, increasing real estate prices, increasing maintenance and care, and existing street furniture.

Practical Actions 1: Increasing greening in streets and open spaces

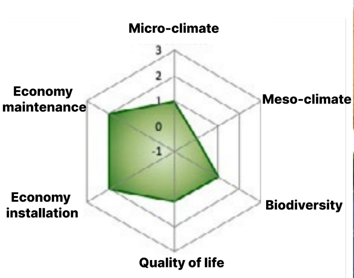
Street greening: single or double-sided avenue

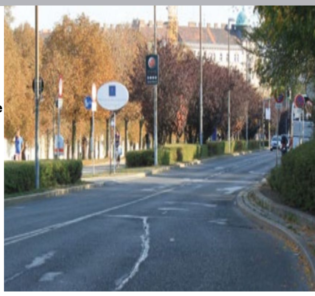


Street greening: Individual trees

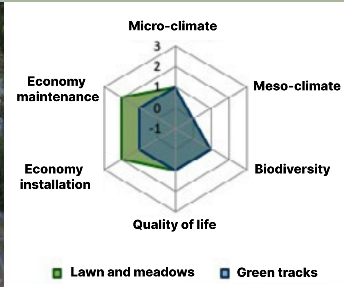


Street greening: Hedgerow

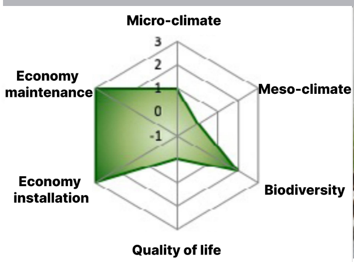




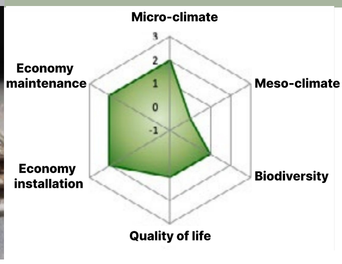
Street greening:Grass and meadows



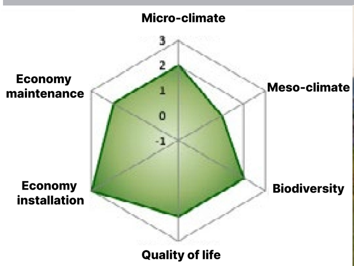
Street greening: Allowing unplanned greening



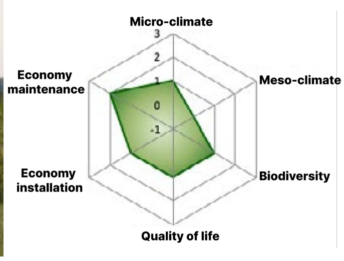
Street greening: Small-scale greening/courtyard



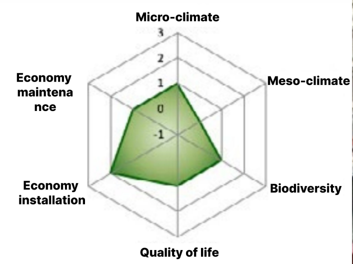
Street greening: use of urban brownfield sites



Street greening: Green walls

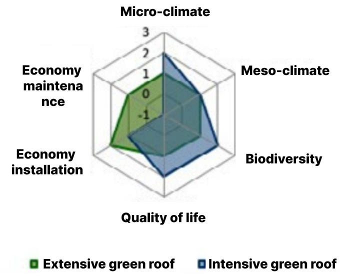


Street greening: Mobile Greening

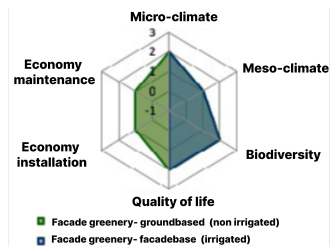


Practical Actions 2: Greening and cooling of buildings

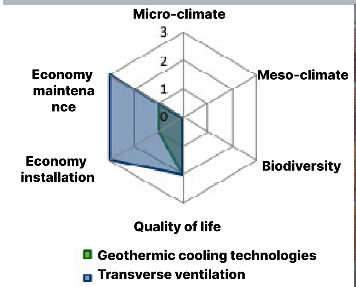
Green buildings : Green roofs

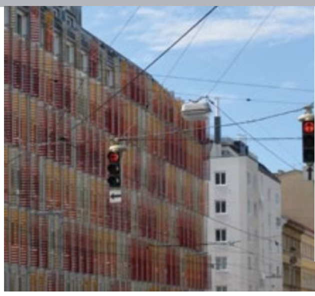


Green buildings: Green facades

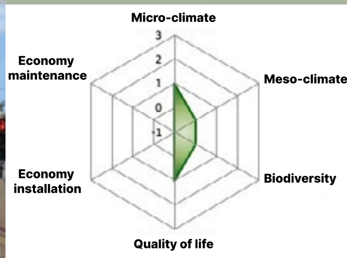


Green building: active/ passive building cooling



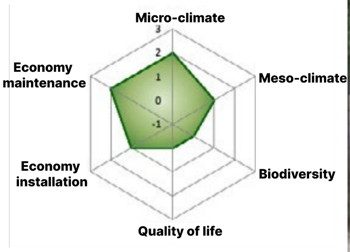


Green buildings: Water Based building cooling

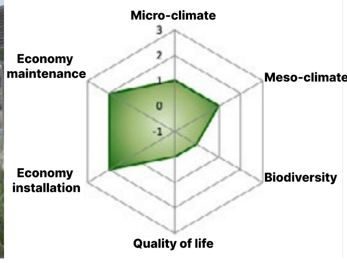


Practical Actions 3: increasing the amount of water in the city

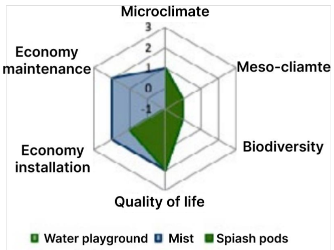
Water in the city:irrigation & rainwater management

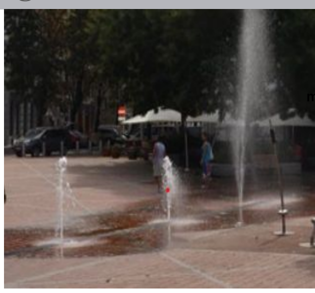


Water in the city: permeability & rainwater management

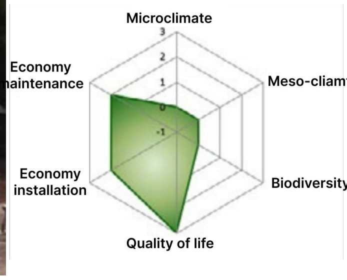


Water in the city: installing more water feature

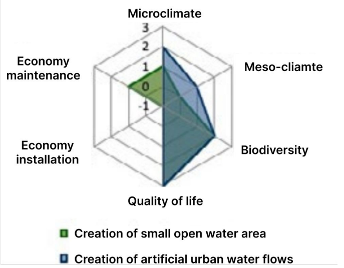




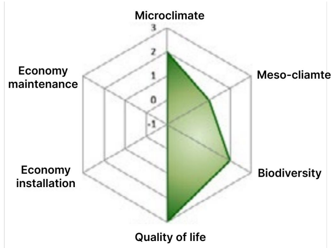
water in the city: provision of drinking water

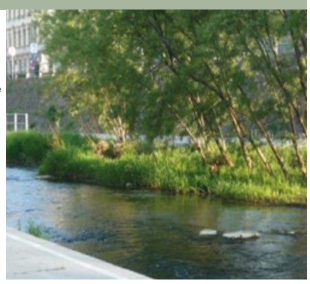


Water in the city: increasing water bodies' amount



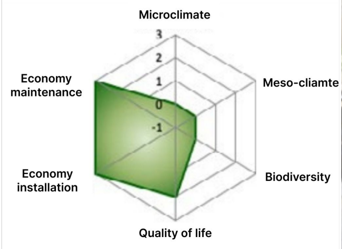
water in the city: up piped water channels/river restoration



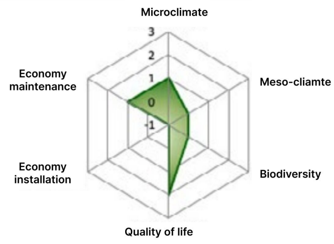


Practical Actions 4: Shading open spaces and footpaths

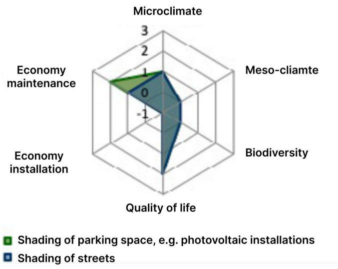
Provided shaded seating

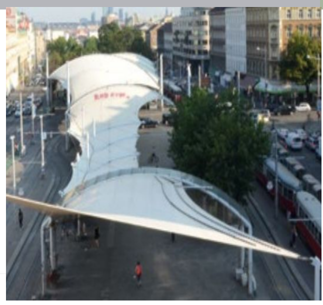


Shading open spaces around buildings



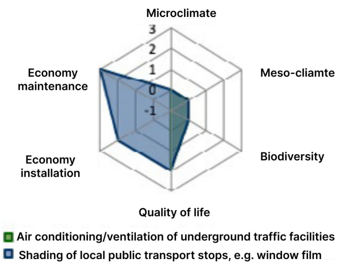
Shading open-air spaces



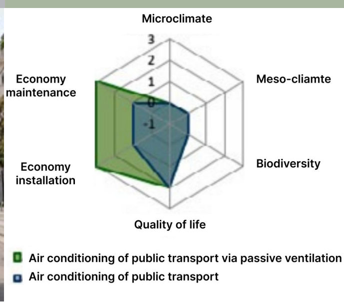


Practical Actions 5: Cooling public transportation

Cooling street-level and underground transport facilities



Cooling on public transport



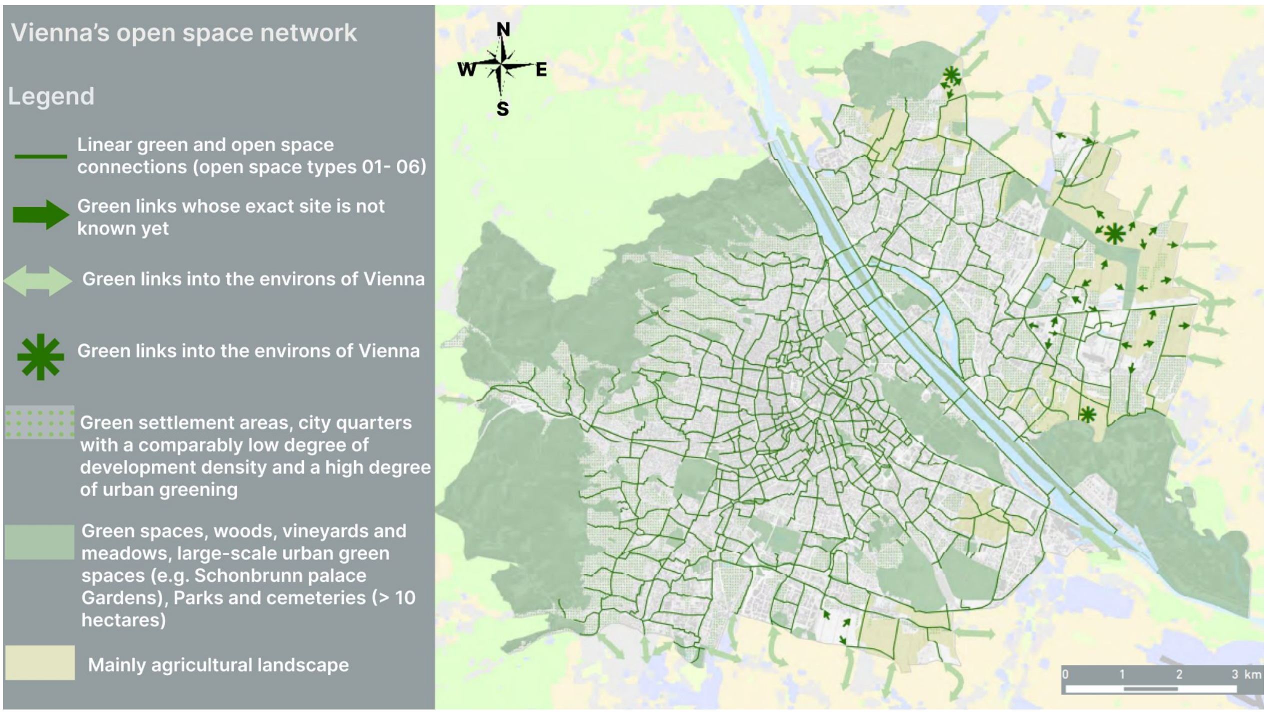
From Plans to Projects

Project 1: Green and open spaces

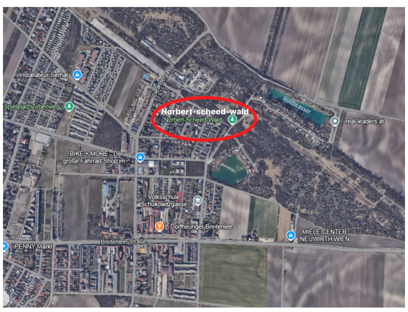
The City of Vienna is implementing a green space strategy to incorporate open spaces into urban infrastructure, ensuring equitable access for all residents, including those in low-income housing. The plan includes new recreational spaces like Norbert-Scheed-Wald, Rendezousberg and Lobau Foreland, which will link to existing green infrastructures.

These three recreational areas were designed as a network of green spaces, extending from Bisamberg to Rendezvousberg, to Norbert-Scheed-Wald, and culminating at the Donau-Auen National Park, similar to a string of pearls. Moreover, open and green spaces, along with water features, are crucial for enhancing urban climates by mitigating heat and providing natural cooling. The city is also implementing innovative greening techniques like rooftop and façade garden, etc to combat climate change. The following map shows all green spaces in Vienna.

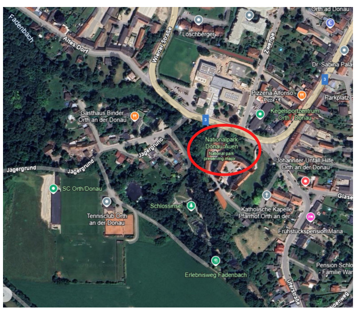
Map 7: Vienna's open spaces network. Source: (Urban heat strategy for vienna, 2018).



Norbert Scheed Wald, Am Russwasser, 1220 Vienna, Austria source: Google Earth



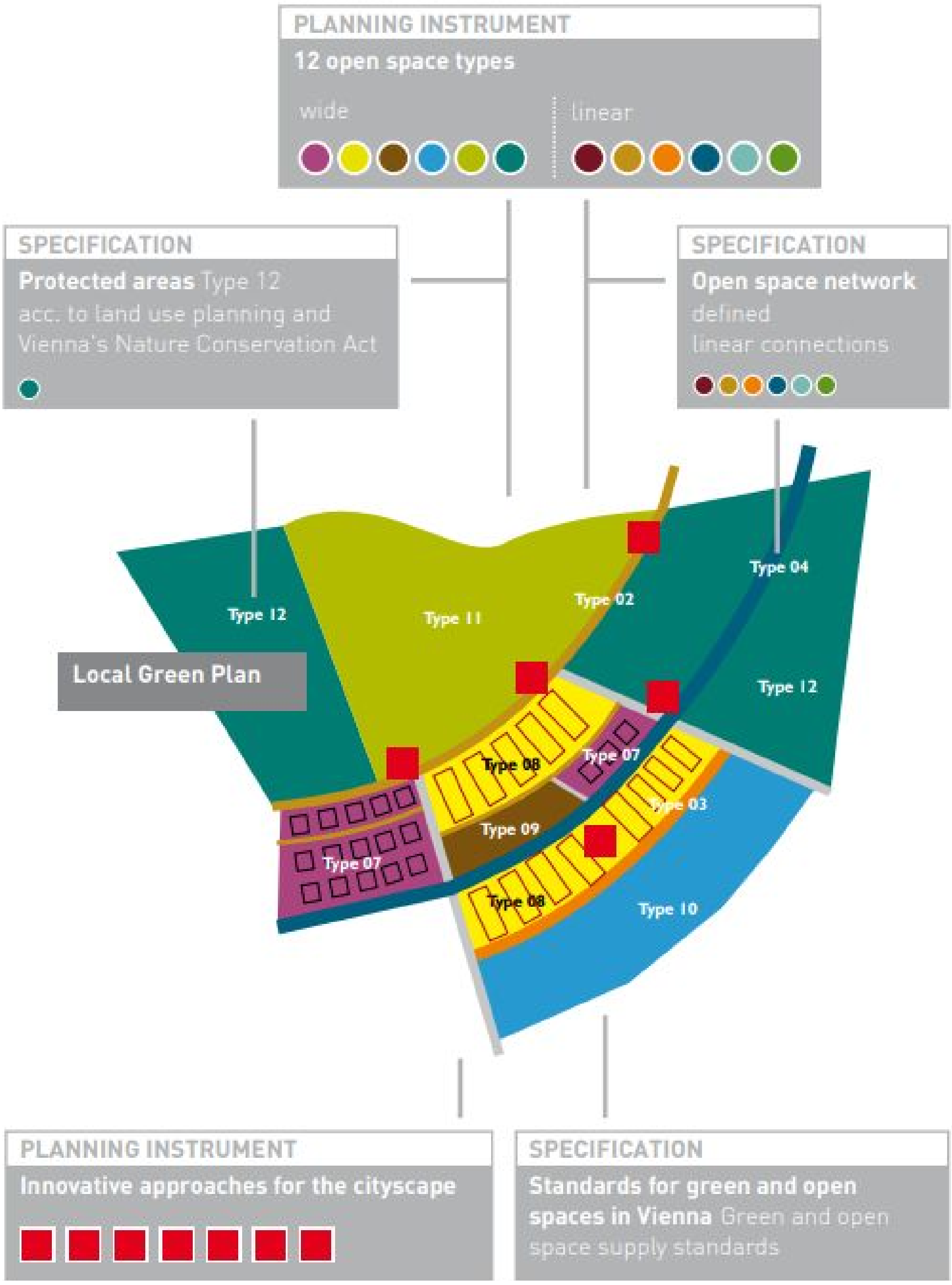
Donau-Auen Nationalpark, Schloßplatz, Orth an der Donau, Austria. source: Google Earth



Rendezvousberg, 1210 Vienna, Austria. source: Google Earth

Now, to asses open spaces' supply sufficiency, the Local Green Plan is used which is one of the methods in urban planning for standardisation and serves also as a tool for quality assurance procedures, and designs land use plans. The City of Vienna planned to establish three extensive recreational zones: "Norbert-Scheed-Wald," "Lobau Foreland," and "Rendezvousberg," to enhance the green belt around Vienna. by connecting to other green infrastructures, technically these areas will establish Vienna’s open space network and connect the city to densely populated urban zones. As previously stated, the green open spaces strategy takes advantage of both traditional and innovative greening techniques like green roofs and facade to adapt to climate change and consequently mitigate to urban heat island impacts. The following scheme depicts the Local Green Plan for vienna (Stadt wien, n.d.).

Figure 13: Local Green Plan Scheme. Source: (Urban heat strategy for vienna, 2018).



Linear open space type

District		Planning type	Fields of action
1  **Location:** Ringstrabe		Type 03 Streets with adjacent green spaces	Greened streets enhance open space, improve amenity function, and strengthen adoption. Realisability depends on land use and development plans, considering ecological and traffic safety aspects.

District		Planning type	Fields of action
2  **Location:** Lassallestrabe		Type 02 Green street	Greened streets enhance amenity function, socio-spatial value, and adoption, while ensuring realisability in land use and development plans. Environmental and traffic safety considerations are considered.

District		Planning type	Fields of action
6  **Location:** Inner Mariahilfer Straße, pedestrian zone		Type 01 lovely streets and pedestrian zones	Tree locations enhance streetscapes, upgrade street spaces, strengthen ecological components, and promote individual responsibility through innovative public space adoption methods like façade greening.

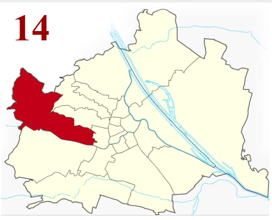
District		Planning type	Fields of action
19  **Location:** Green axis along Schreiberbach		Type 04 Green axes	Green structures in rural areas, particularly shore areas, can be renaturalized, used for urban expansion, and preserved as fresh air corridors, with necessary braces for bridges.

Linear open space type

District		Planning type	Fields of action
23  **Location:** Liesing River		Type 05 Greenways	The focus is on enhancing green space connections for urban climate, landscape balance, and biotope network, transforming them in a nature-inspired manner, improving pedestrian and bicycle passability, and ensuring environmental connections.

District		Planning type	Fields of action
21  **Location:** Marchfeld canal		Type 06 Green corridors	Superordinate green space connections are crucial for everyday life, urban fabric structuring, ecosystem services, and nature conservation. Maintain existing corridors, connect insufficient green spaces, and optimize overall function.

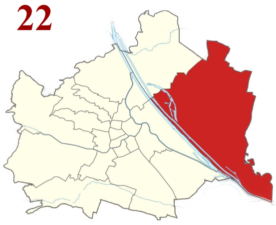
Wide open space type

District		Planning type	Fields of action
14  **Location:** Wolfersberg		Type 07 Open spaces with restricted access	Innovative temporary opening strategies and high-quality green spaces at building sites are being implemented to comply with Vienna's Building Code, ensuring culturally appropriate design.

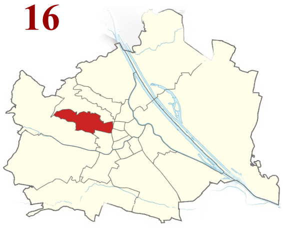
District		Planning type	Fields of action
21  **Location:** Donaufelder Straße		Type 08 Semi-public green space	The goal is to maintain public passability by avoiding gated communities, ensure neighborhood-related green space through competitions and cooperative planning, and ensure high-quality green and open spaces at building sites according to Vienna's Building Code.

Wide open space type

District		Planning type	Fields of action
5  **Location:** Bruno-Kreisky Park		Type 09 Parks	Local players are collaborating on compensation measures and extensive transformation of zones in Vienna's parks and gardens, ensuring quality and promoting contemporary landscape architecture.

District		Planning type	Fields of action
22  **Location:** Field at the Süssenbrunner Straße		Type 10 Multi-purpose land	The requirement for open spaces in agricultural production areas, including fallow land, necessitates the exploration of resource-efficient building options, particularly in areas with high-quality soils.

District		Planning type	Fields of action
21  **Location:** Rendezvousberg		Type 11 Module green space	The zone aims to protect green space and agricultural production by securing land, ensuring development goals, designing landscapes, valuing fallow land, protecting development potential, and developing new strategies.

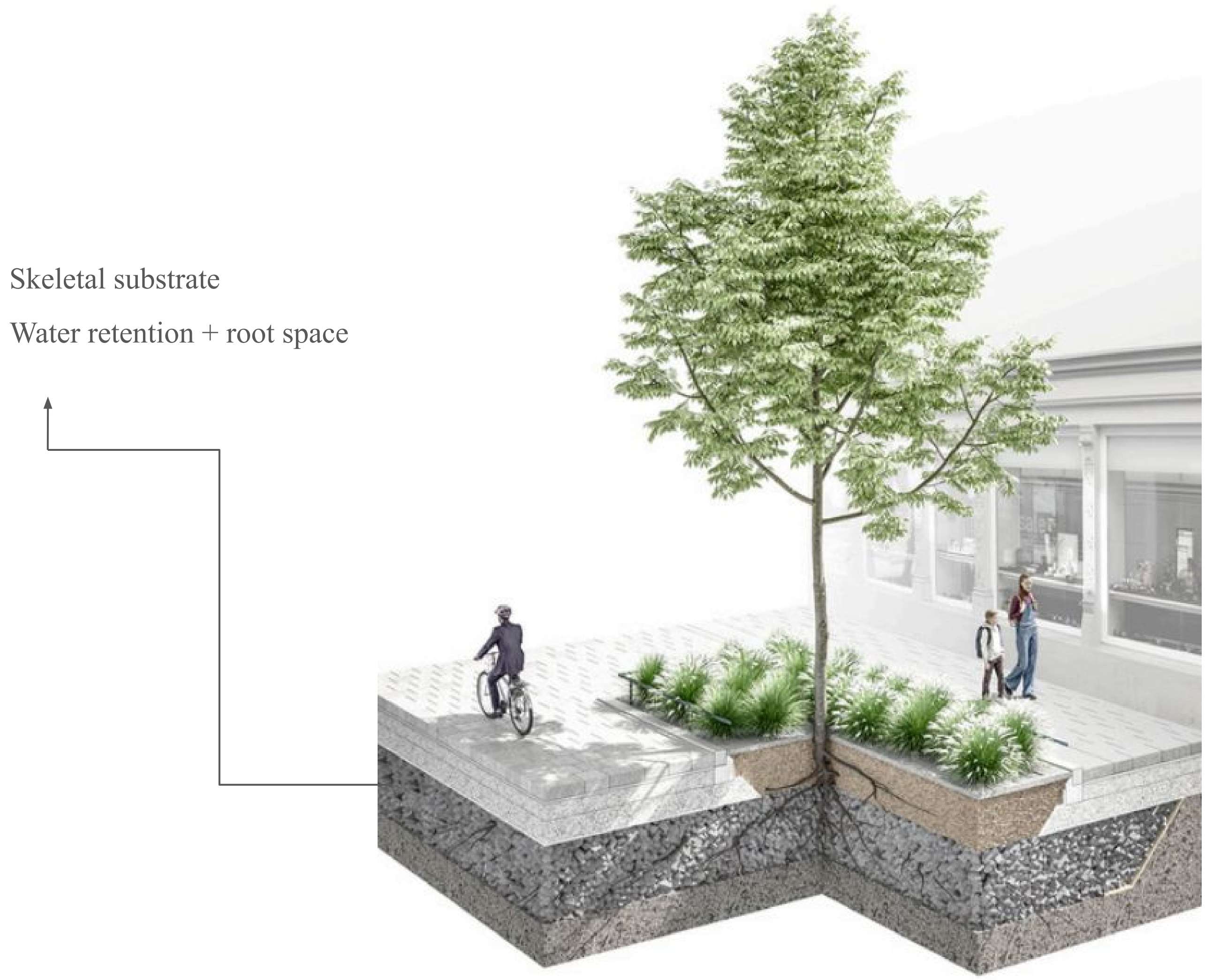
District		Planning type	Fields of action
16  **Location:** Vienna Woods		Type 12 Protected areas	Vienna's Nature Conservation Act and Building Code protect areas used for agriculture, forestry, and gardens, with the focus on ensuring protection status and promoting further development due to public interest.

Project 2 : Aspern Seestadt

Aspern Seestadt is Vienna's famous landmark and one of Europe's largest urban development projects. Featuring a central lake, vast green spaces, and superior transportation connections, it is intended to be an example of a future climate-resilient urban district of Vienna.

The "Sponge City" dual infiltration rainwater management model was implemented at Lakeside Crescent Quarter at Seestadt to enhance tree conditions and control rainwater runoff. The technology directs rainwater into underground gravel beds, nourishing robust trees for extended longevity and enhanced shade. Upon completion, approximately two-thirds of the site will be set up with such equipment (Aspern Seestadt).

Figure 14: Sponge city. Source: (Seestadt, 2024).

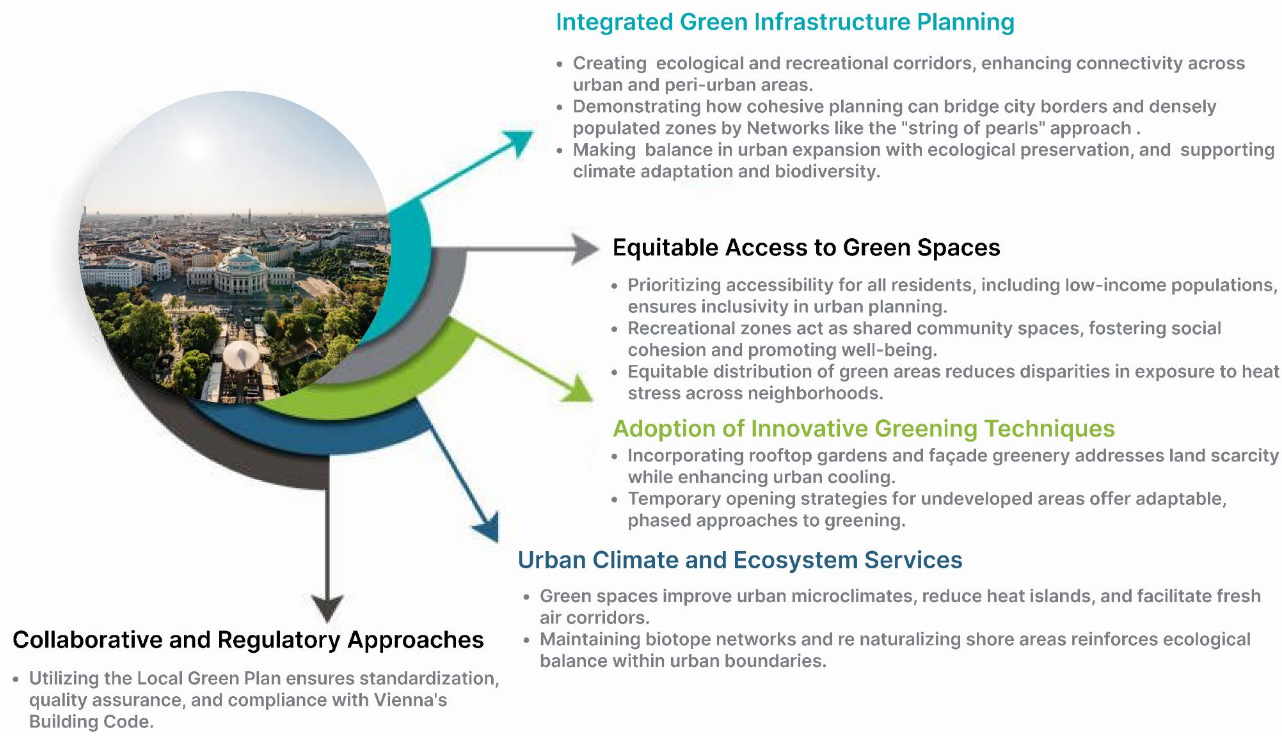


Lesson Learned

Green and open spaces and Aspern Seestadt

Vienna's green space strategy seeks to mitigate urban heat islands and enhance urban resilience through the incorporation of open spaces into urban infrastructure. The city has established an integrated network of recreational spaces, connecting them to the Donau-Auen National Park, so facilitating fair access to cooling zones for inhabitants. This technique preserves ecological equilibrium via biotope networks and air corridors. Vienna's creative greening strategies, including rooftop and façade gardens, along with the Local Green Plan as a quality assurance instrument, exemplify its flexibility to climate change. Strategies such as provisional openings, cooperative planning for compensatory measures, and public competitions guarantee culturally suitable and superior green places. Incorporating greenery into transportation infrastructure, such as landscaped streets and tree-lined boulevards, improves the aesthetic and ecological value of urban environments. This comprehensive approach to urban design brings together environmental preservation, social-spatial cohesion, robust and efficient infrastructure. In addition, the "Sponge City"rainwater management model in the lakeside Crescent Quarter drains rain water into underground gravel beds, thereby technically it is beneficial for trees and reduces Urban Heat Island. The project also features green spaces, parks, and public areas, promoting air quality and social resilience. This integrated approach to green infrastructure and urban planning reduces heat generation.

Figure 15: Summary of Green and open spaces and Aspern Seestadts in Vienna. Source: Personal elaboration.



CHAPTER 4

CASE STUDY: PARIS

- Territorial and climate overlook description
- Climate action plan
- From lesson to project
- lesson learned

Territorial and climate overlook description

Territorial climate overlook description

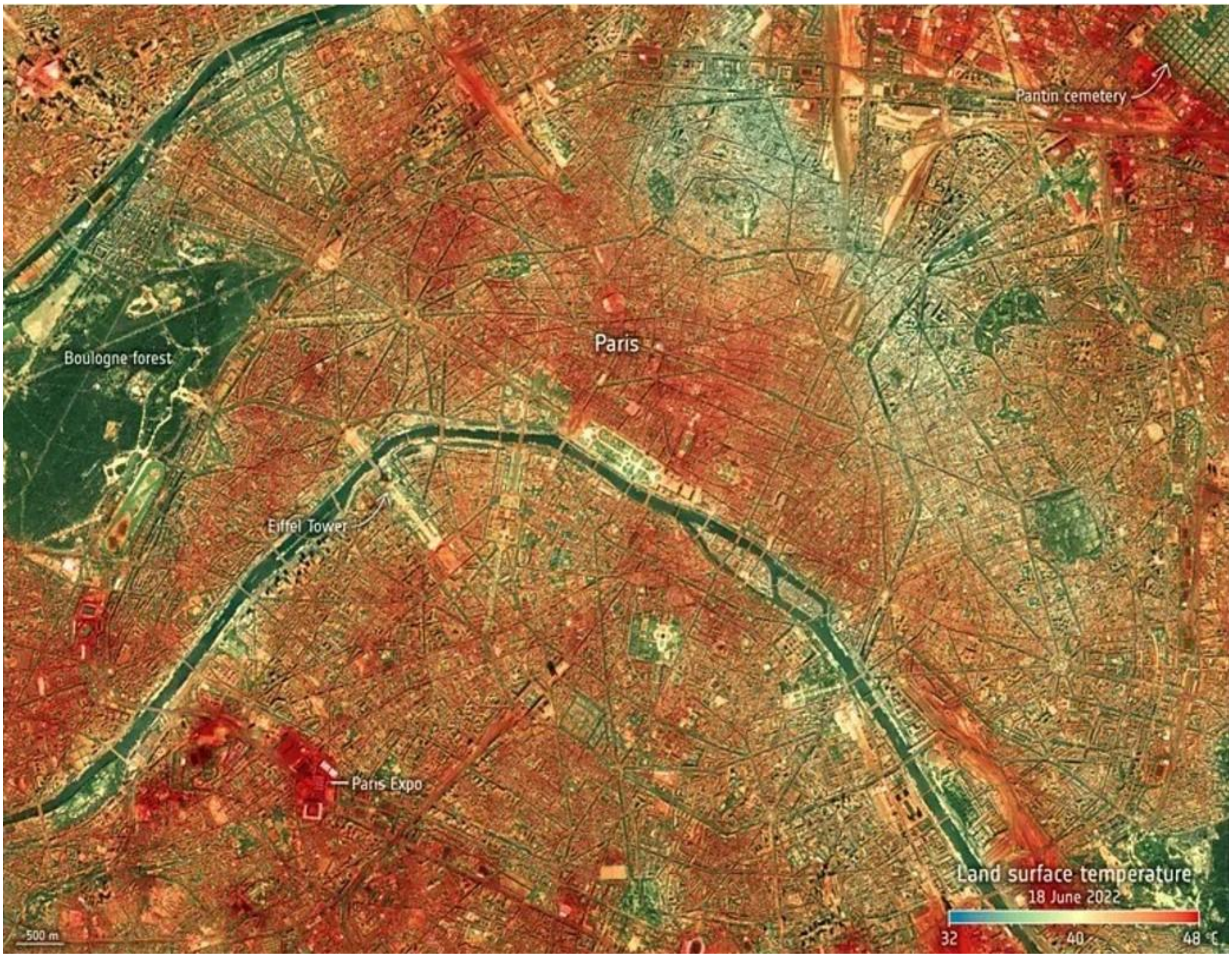
Paris, the capital of France, is a megacity with over 11 million residents, located in the north of the country along the Seine River, surrounding by forests and wood and agricultural areas, and impacted by both continental and oceanic climates (Masson et al., 2013; le Roy et al., 2020). The city consists of 20 arrondissements, each possessing its own mayor, town hall, and distinct features. Map 8 represents the municipal districts of Paris. In map 9 also the morphology of Paris is depicted.

Map 8: Paris municipal districts. Source: personal elaboration.

Map 9 : Paris' Urban Fabric. source: (Webdav, 2011).

Climate change is anticipated to cause a rise in annual temperatures in France by 1 to 4°C relative to the existing average of 12.4°C. Along with an increase in heat waves, occurring up to 25 days annually, in contrast to the current frequency of 1 day. These heat waves are intensified by the urban heat island phenomenon, which is influenced by various urban parameters: urban morphology, permeability, and human activity. The 2003 heat wave resulted in 70,000 fatalities in Western Europe, with Paris observing exacerbated effects due to the urban heat island phenomenon (Karam et al., 2024; de Ridder et al., 2017; Poumad`ere et al., 2005; Fouillet et al., 2006; Keller, 2015). Map 10 shows the surface temperatures of Paris throughout a heat wave in June 2022.

Map 10: The surface temperature of Paris. Source : (European Space Agency, 2022).



Map 11: Vegetation rate on the blocks in Vienna. Source: (Apur, 2022).

Climate Action PLans

Paris climate action plan 2025

According to city of Paris (2018), urban heat island effect in Paris presents a considerable risk to vulnerable groups, such as children, the elderly, and the homeless. To address this, the city must adjust to climate change by designating **additional areas for nature reserves** and **water bodies**, establishing **"cool islands and pathways,"** and encouraging **greenery on rooftops, roadways, and plazas**. Moreover, **enabling access to bathing locations**, **water sources,** and c**ool gathering spots** is essential. Essential initiatives comprise the establishment of 300 supplementary cool islands by 2030, the creation of "Schoolyard Oases" including vegetation, the planting of 20,000 new trees, the development of 40 water areas, and the construction of new pools and open water swimming locations.

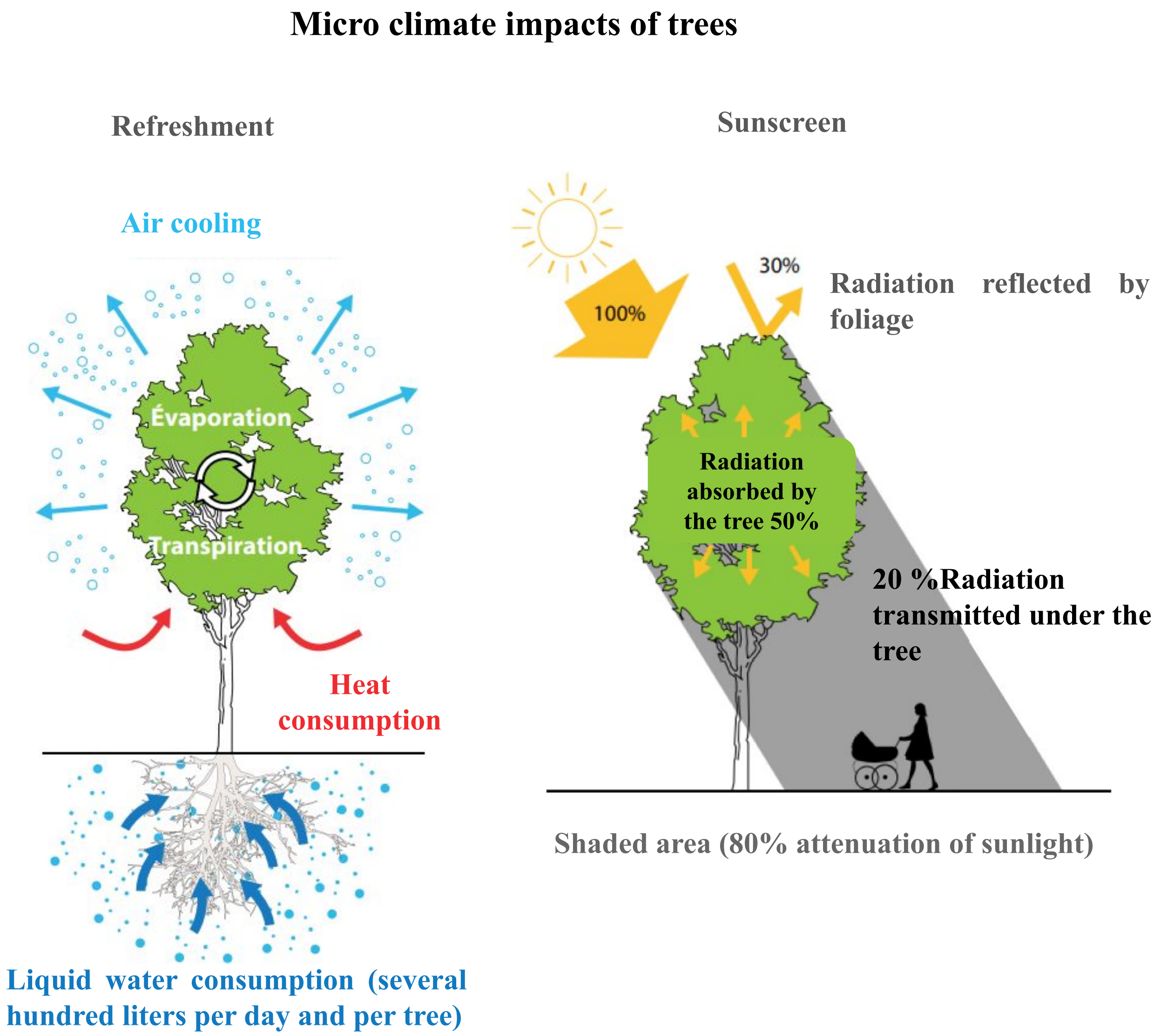
Paris is combating rising temperatures by enhancing its grey infrastructure with greenery, planting trees, and establishing rooftop gardens in order to reduce the urban heat island effect. The city has incorporated around 70 hectares of green infrastructure and rooftop gardens to mitigate the urban heat island effect. The city granted a "license to green" to motivate individuals to grow plants additional trees and gardens on unoccupied land. The dense infrastructure network of Paris, primarily composed of concrete and asphalt, results in a noticeable urban heat island effect, resulting in elevated temperatures compared to adjacent rural areas. To reverse this trend, the city has initiated greening initiatives to make the city's infrastructure more permeable and absorbent, improving air quality (C40 Cities, 2015).

The cool islands of Paris are easy-access areas for inhabitants and visitors to get away from the summer heat. Over 800 spaces constitute the network (C40 Cities Climate Leadership Group, Nordic Sustainability, 2019).

Urban Trees

Climate adaptation strategies in Paris aim to balance city functions with measures to avoid overheating. These strategies include four categories: vegetation, soils, buildings, and anthropogenic heat. Vegetation creates shadows and evaporates water, while soils store solar energy and the water cycle. Buildings' summer comfort requires questioning energy performance and common practices in design. Anthropologic heat can aggravate UHI. By addressing these factors, cities can better adapt to extreme heat waves and maintain a resilient climate. Row trees, green walls, and spontaneous vegetation play a crucial role in cooling the city by providing sun protection and evaporating water in the soil. However, their climatic effects are limited due to their own footprint. Choosing the right tree species for plantations is complex, as morphology plays a significant role in providing ample shade. Row trees are particularly resilient in harsh urban conditions. Following scheme shows the trees' micro climate impacts.

Figure 16: Micro climate impacts of trees on UH. Source: (C40 Cities Climate Leadership Group, Nordic Sustainability, 2019).



Row trees thrive in urban environments, where they require water and insolation. To survive, they need protected soil from compaction. Traditional Parisian cast iron tree grids offer an effective method of compaction protection, benefiting the roots flush at the foot of the tree. Trees in cities adapt by taking advantage of leaks from water or steam networks to find necessary elements for survival. To cope with urban constraints, they can adopt methods such as mycorrhization, cutting the soil between row trees, and planting at the foot of row trees. However, critics should be aware of the delicate operation of cutting root tissue beyond the pit reserved for them during planting, as roots quickly colonize areas suitable for water collection. De-waterproofing between trees also may result in bare soil, leading to compacted soil and sterilization of the surface soil.

Following scheme shows impacts of the urban microclimate on tree development in comparison with the forest environment.

Figure 17: Comparison of Urban microclimate impacts and forest environment on tree development. Source: (C40 Cities Climate Leadership Group, Nordic Sustainability, 2019).

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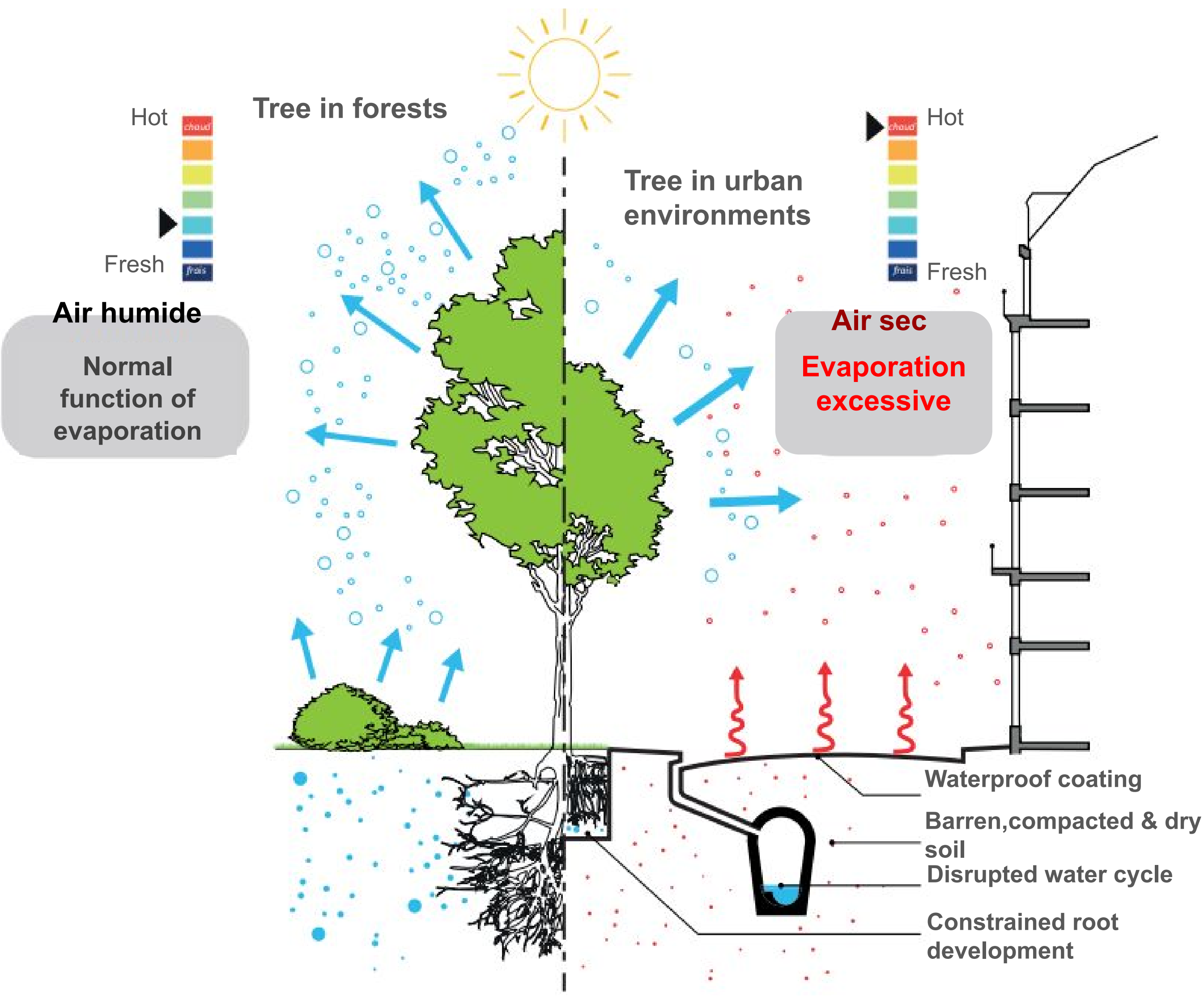
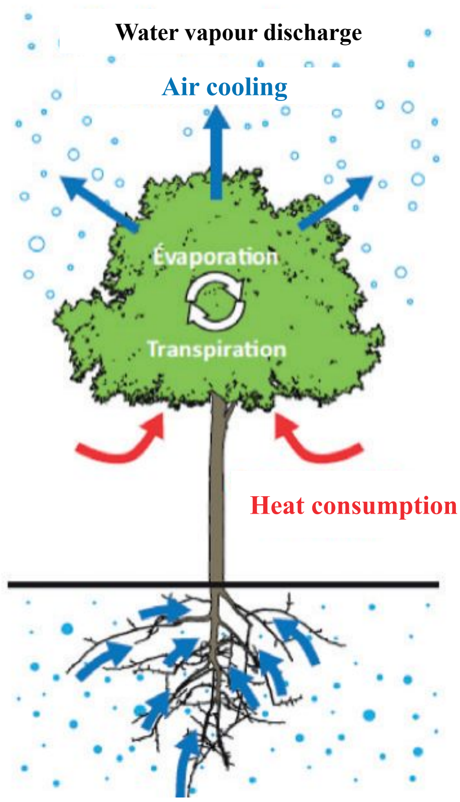


Principle of operation of the evapotranspiration of a tree.

Turf plants regulate temperature by absorbing water from the soil through endothermic processes. This procedure aids in sustaining appropriate temperature levels and preventing overheating. The plant's operation relies on the availability of water in the soil, enabling it to sustain low surface temperatures. During the night, the plant continues to evaporate water from the soil.

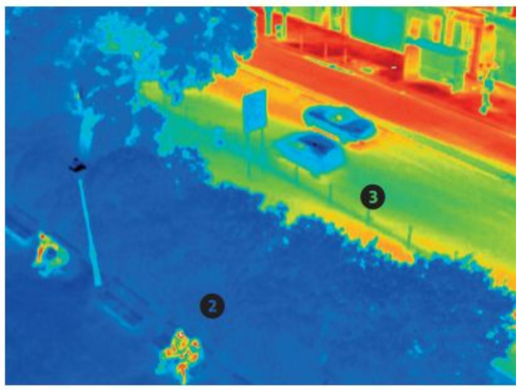
Figure 18: Water vapor discharge

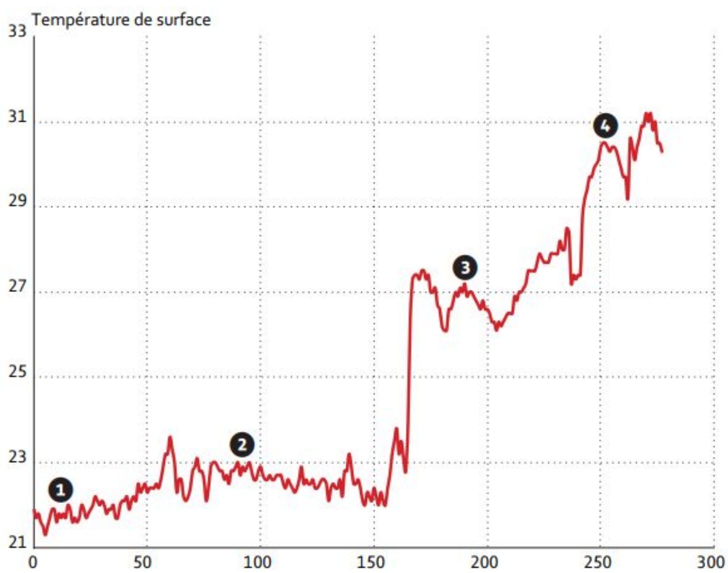


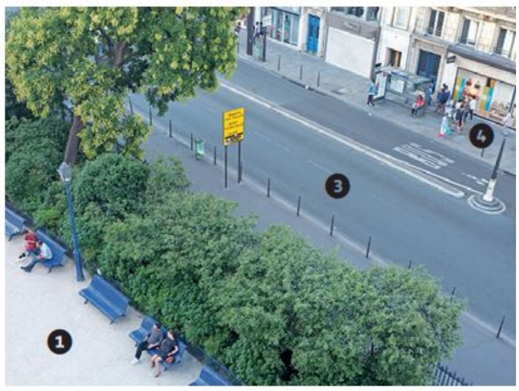
Following figures show the surface temperature differences of a series of materials at the end of the day,

location: Square St-Jacques and the Rue de Rivoli (Paris 4th)

1 **Stabilized (22 °C)**
2 **Stabilized (22 °C)**
3 **Asphalt pavement (27 °C)**
4 **Granite sidewalk (32 °C)**

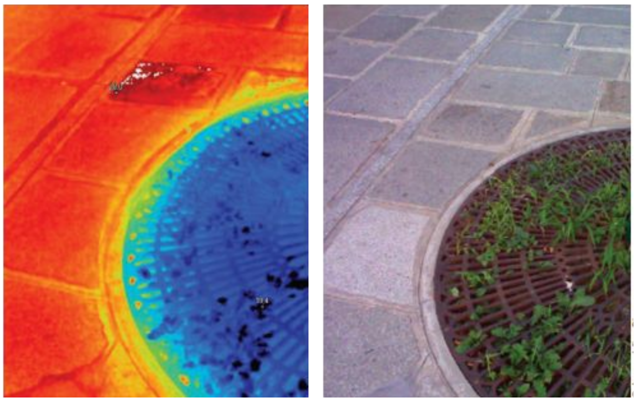






Tree species also are traditionally used at a rate of one species per section of road in landscape design. However, mixing species within the same section is not widely practiced. This practice promotes biodiversity, limits disease spread risks, and mitigates the effects of extreme events like floods, salting, and surface pollution. It also helps limit the concentration of pollen in allergenic species, as not all species have the same sensitivity to these events.

Refreshment of tree base



Shaft alignment

Permeable strip compacted by trampling: water infiltration is no longer ensured

Green walls

Green walls in Paris are a climate solution that incorporate vegetation on buildings' facades, primarily consisting of ivy or Virginia creeper. These vegetation, which is a tiny 0.3% of the wall surfaces, provide effective street cooling and thermal protection for housing, especially on high floors. The vegetation interacts directly with pedestrians, allowing them to walk along a wall with a temperature close to ambient. The cooling effect is claimed by residents as it provides healthier, less dry, and fresher air. However, vegetation on street facades is rarer due to the mineralization of building feet. The benefits of green walls are well documented, including improved air quality and reduced heat release.

Spontaneous interstitial vegetation

Interstitial and spontaneous vegetation, which emerges in defects and nooks, is often seen as a sign of a dirty city and a lack of maintenance. It breaks with the landscape order of cities, where plants are placed under house arrest. These plants show the adaptation of certain species to urban environments, often invasive, and can colonize entire façades. Their presence raises questions about urban practices and the measures to deal with summer overheating. It is crucial for planners and cities to allow for unexpected biodiversity and ecological cooling services, allowing for a more sustainable urban landscape.

Gardens, vegetation in the heart of the block

The quality of soil is essential for the ecological services of water cooling and recycling, especially in gardens and urban areas. Layered forest ecosystems optimize rainwater recycling and exhibit greater resilience to water stress. The dynamic characteristics of soil enhance these benefits. To do this, soils with biological properties must be cultivated, structures should be strategically set up, and gardens should support all plant layers. Inadequately compacted soils, abundant in organic matter, promote interactions between plant and animal species, enhancing water recycling, decreasing infiltration, and optimizing water pollution filtration. Direct infiltration into embankment soil lacking of ecological quality leads to excessive water accumulation, failing to support the ecological cycle or profit from phytosanitary purification.

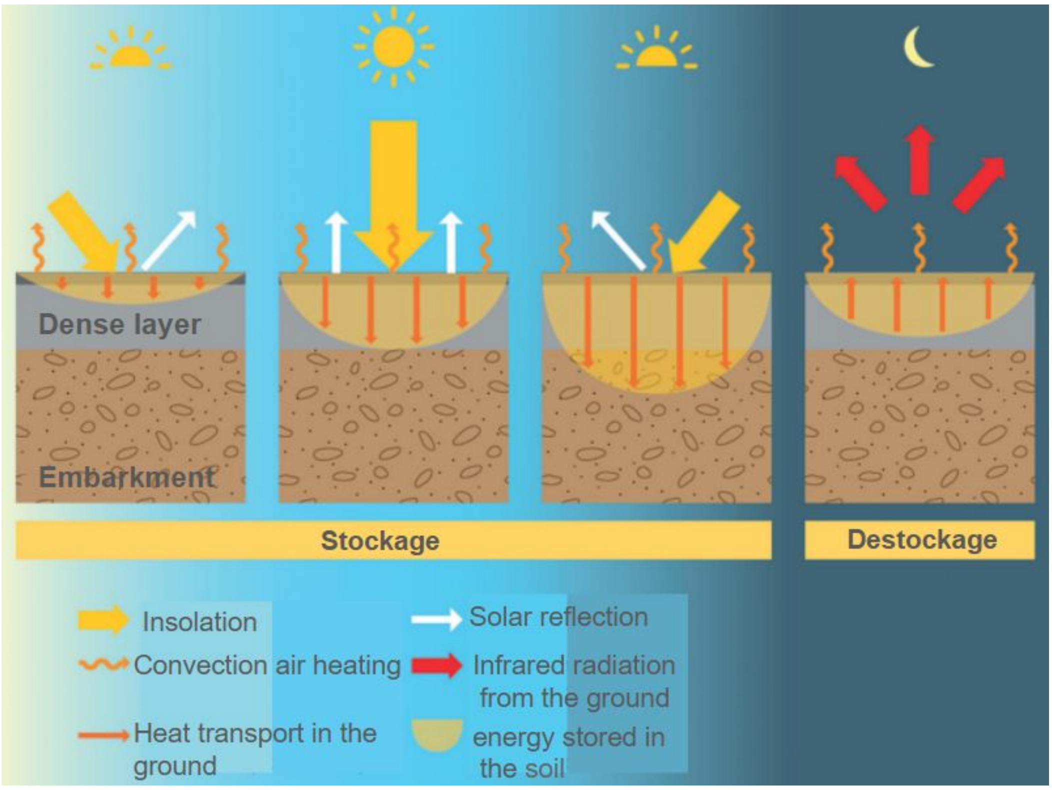
Flooring

Floor coverings comprised of mineral or binder-based coatings which are capable of creating urban heat islands, they also known as universal heat islands. The surface layer functions as a solar collector that transmits solar energy into sublayers that store and release it during night cooling. These soils resist mechanical stresses from public spaces as well as waterproof the soil to redirect surface water into sewer networks. The expansion of public space uses and the urgent need of surface waterproofing are underlying factors in the moderation of urban heat islands. Overall, floor coverings play a crucial role in promoting sustainable urban living (Apur.org).

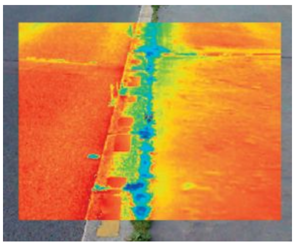
Subsurface Energy Storage and Its Role in Urban Heat Island Dynamics

The dynamics of energy storage within underground systems can be articulated as follows: At daylight, newly deposited materials are illuminated, and energy is transmitted underground. At midday, insolation increases, surface heating persists, and underground storage reaches a notably active phase. At sunset sunstroke diminishes, while surface temperatures gradually increase, attaining a peak in basements. Underlays might be likened to energy reservoirs that accumulate at the end of the day. dependant upon the characteristics of the subsoil materials. The nocturnal phase involves the depletion of energy from materials, a concept that can also pertain to asphalt-covered pavement, which was not examined in the experiment.

Figure 19: Solar energy storage and destocking cycle through flooring. Source: (Apur, 2020).



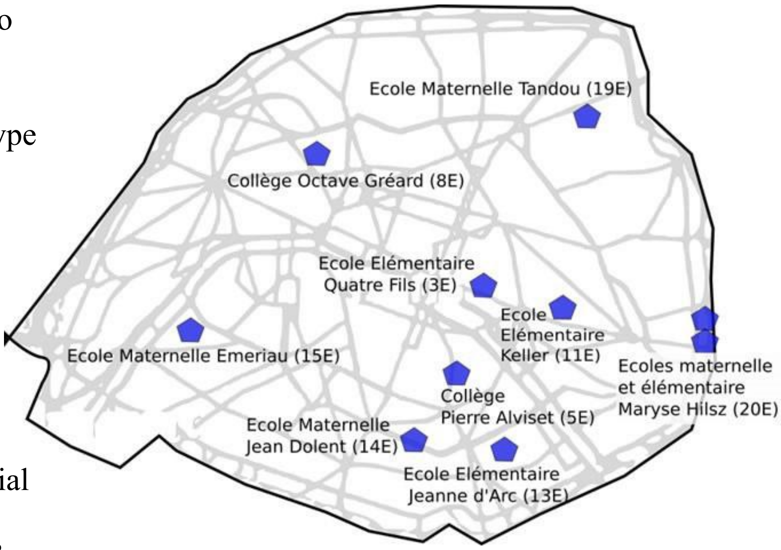
Plants facilitate atmospheric cooling when adequately irrigated. Vegetated roadways or sidewalks are not owing to incompatibility. Vegetation may be present in public areas, such as imperfections in materials or joints of paving stones, which enhances the climatic condition of pavements and frequently indicates inadequate maintenance.



From Plans to Project

Project 1 : Paris Oasis Schoolyard Programme, France

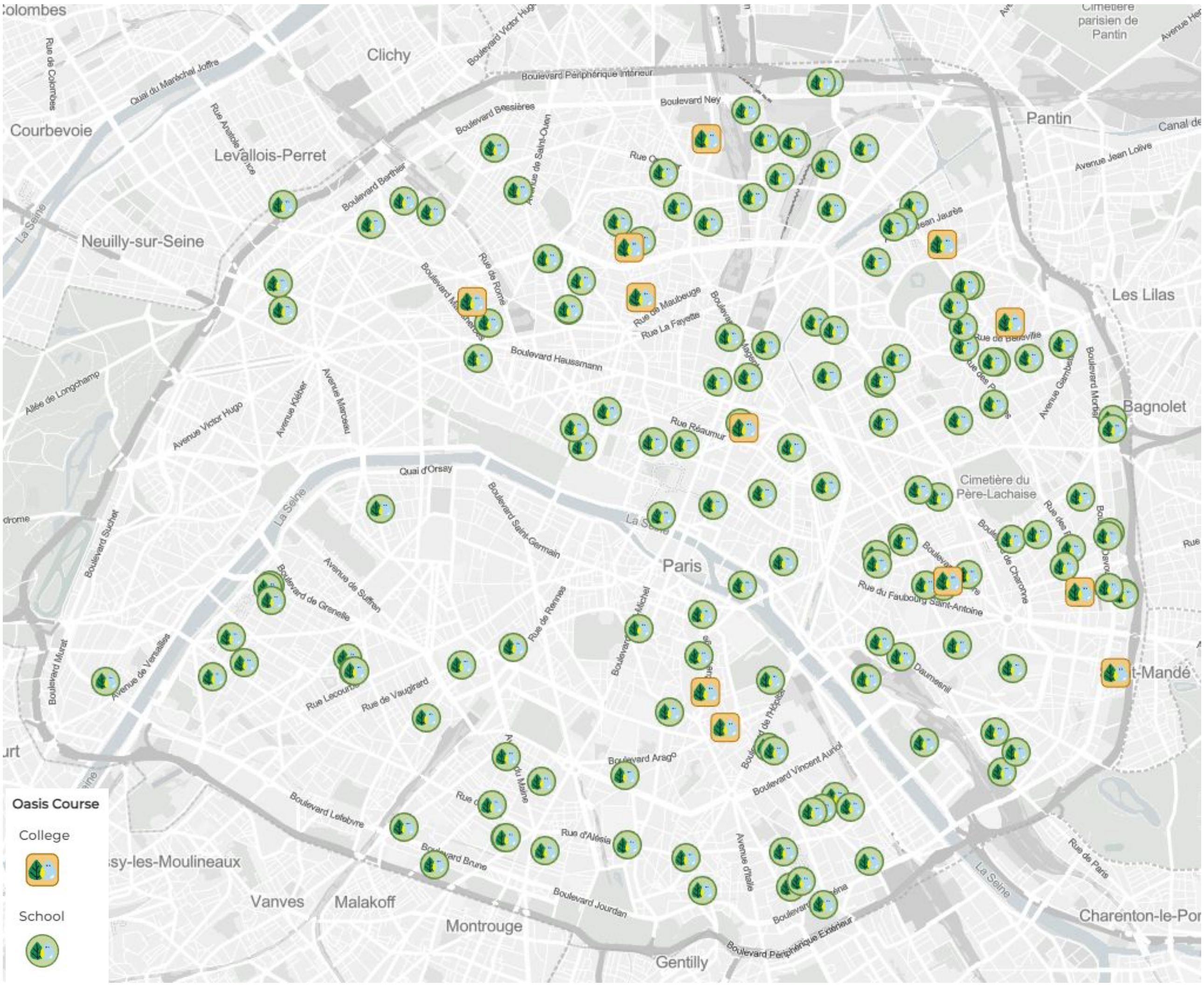
The city of Paris launched the "OASIS" program to alleviate heatwave vulnerabilities, turning schoolyards into green areas that are accessible to disadvantaged populations. Ten prototype schoolyards demonstrate effectiveness through co-design and collaboration, influencing the program's citywide expansion.The "Oasis" Schoolyards initiative aligns with Paris' Resilience Strategy, aiming to promote socio-spatial inclusion, public environmental health, and climate change mitigation. source:(Climate Adapt, 2020).



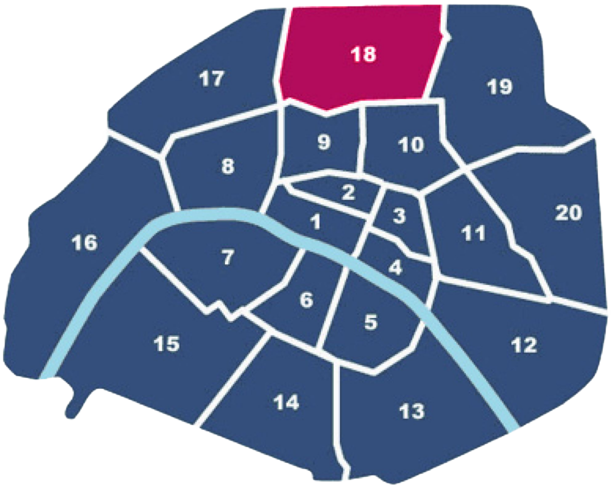
Objectives	Governance level	Adaptation approaches	Solutions
• Reducing heat island effect. • Creating healthy, stimulating learning environment. • Education about climate change risk. • Creating cool spaces for vulnerable populations. • Creating meeting spaces for solidarity.	local	•Cost-benefit Analysis and Maintenance • Environmental considerations. • Just resilience. • Adaptation measures. • Mitigation strategies. • Nature-based solutions. • Replication/upscaling potential. • Societal aspects.	• Increasing vegetated areas through tree planting and lawns. • Introducing natural elements or eco-innovative products. • Using light-colored, low-carbon footprint substrates for cooler grounds. • Using rainwater for evapotranspiration and water games. • Using artificial installations like solar air-conditioning for energy efficiency.

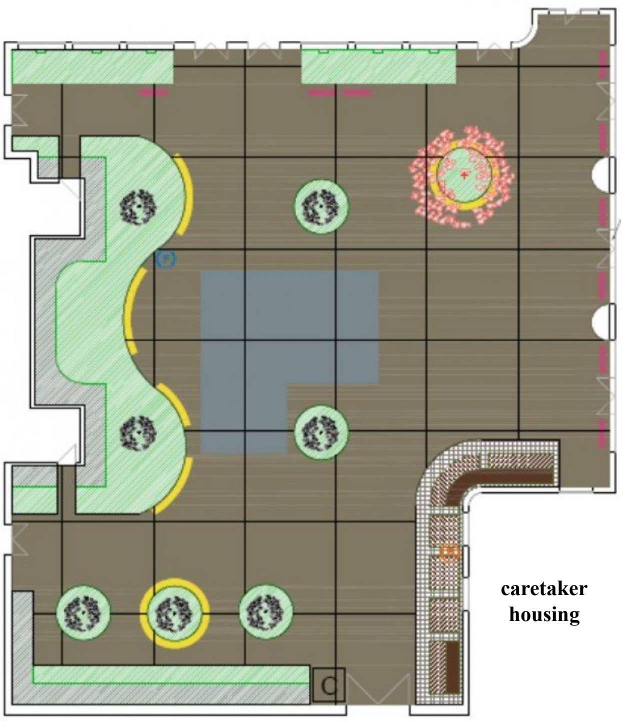
AS mentioned earlier, the OASIS Schoolyard initiative in Paris intended to establish green, accessible, and inclusive schoolyards that serve as "cool islands" inside densely built up areas. The project's result was a transition from asphalt-covered, sports-focused schoolyards to greener spaces that respond to the needs of all children. The project engaged the school community, local people, and sector specialists in participatory processes to guarantee the final designs' suitability from environmental, social, and educational aspects. The project resulted in the transformation of 10 UIA schoolyards throughout Paris, fostering active participation from children and educators, engaging parents and the wider community, and ensuring adequate training for Municipal Departments. This comprehensive approach prompted a transformation in our perspective regarding the design, utilization, and maintenance of schoolyards, highlighting the importance of multi-tiered and cross-sector collaboration (Urban Innovative Actions- Oasis Project, 2023).

Map 12: The expansion of OASIS project from a neighborhood pilot to the city scale and beyond. Source: (Urban Innovative Actions- Oasis Project, 2023).



Nursery school, 12 rue de Torcy (18th district., Paris)





Objectives

- Promoting Climate Change Education
- Reduce local heat island effect.
- Create healthy, stimulating learning environment.
- Educate residents on climate change risk culture.
- Provide fresh refuges for vulnerable populations.
- Create communal meeting spaces.

Actions

Schoolyard gardens offer cooling benefits through a light-colored, low-carbon footprint substrate and modular porosity. Evapotranspiration of rainwater facilitates ground cooling, whereas trees, green walls, and roofs offer shade. Vegetable gardens promote environmental consciousness and energy conservation. Artificial structures and recreational areas enhance cooling methods, hence decreasing energy usage.

Transferability of the result

The results of this program suggest that urban development can adapt to climate change through natural development, considering social and climate challenges, anticipating infrastructure evolution, and implementing nature-based solutions for heat waves (Oppla, 2018).

Catalogue of collection of green spaces in Oasis Schoolyard Programme in different districts in Paris. Source : (Conseli d'architecture, d'urbanisme et de l'environment, n.d.).

Riblette Elementary Schools
20th arrondissement - Paris (75)

Gréard College
8th arrondissement - Paris (75)

Jean Dolent Kindergarten
14th arrondissement - Paris (75)

Jean Dolent Kindergarten
14th arrondissement - Paris (75)

Pierre Alviset College
5th arrondissement - Paris (75)

Emeriau Kindergarten
15th arrondissement - Paris (75)

Maryse Hilsz School Group
20th arrondissement - Paris (75)

Keller Elementary School
11th arrondissement - Paris (75)

Jeanne d'Arc Elementary School
13th arrondissement - Paris (75)

Tandou Kindergarten
19th arrondissement - Paris (75)

Lacordaire Kindergarten
15th arrondissement - Paris (75)

Blanche school group
9th arrondissement - Paris (75)

Providence Elementary School
13th arrondissement - Paris (75)

Quatre-Fils Elementary School
3rd arrondissement - Paris (75)

City of Flowers Kindergarten
17th arrondissement - Paris (75)

Hippolyte Maindron school group
14th arrondissement - Paris (75)

Asseline Elementary School
14th arrondissement - Paris (75)

Breche aux Loups Elementary School
12th arrondissement - Paris (75)

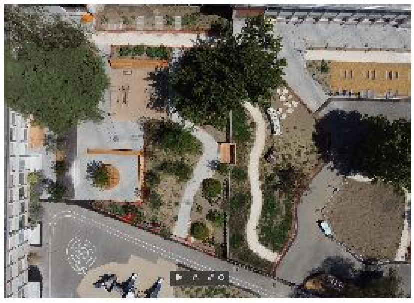
Brussels comprehensive school
9th arrondissement - Paris (75)

Maurice d'Ocagne Kindergarten
14th arrondissement - Paris (75)

Georges Brassens College
19th arrondissement - Paris (75)

Charenton Elementary School
12th arrondissement - Paris (75)

Jacques Prévert Elementary School
BORDEAUX - Gironde (33)

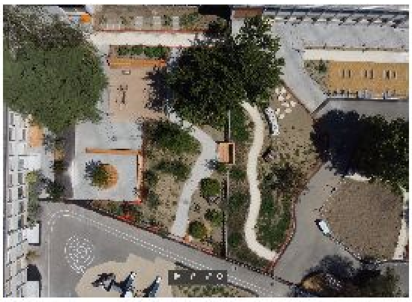


Novel School
ANNECY - High Knowledge (74)

Benauge Elementary School
BORDEAUX - Gironde (33)

Multi-reception area Quai des Enfant
BORDEAUX - Gironde (33)

Alphonse Dupeux Kindergarten
BORDEAUX - Gironde (33)



Novel School
ANNECY - High Knowledge (74)

Raymond Queneau College
5th arrondissement - Paris (75)

Bercy Kindergarten
12th arrondissement - Paris (75)

Achard Kindergarten
BORDEAUX - Gironde (33)

Jacques Prévert Elementary School
BORDEAUX - Gironde (33)

Jacques Prévert Elementary School
GUERET - Creuse (23)

Ornano Nursery
BORDEAUX - Gironde (33)

Raymond Poincaré Elementary School
BORDEAUX - Gironde (33)

Saint-Bruno Elementary School
BORDEAUX - Gironde (33)

Albert Barraud Nursery
BORDEAUX - Gironde (33)

Menuts Elementary School
BORDEAUX - Gironde (33)

Lac III Kindergarten
BORDEAUX - Gironde (33)

Jean Macé Elementary School - Toulouse
TOULOUSE - Haute Garonne (31)

Schoolyards of the Ampère school group
CALUIRE-ET-CUIRE - Rhone (69)

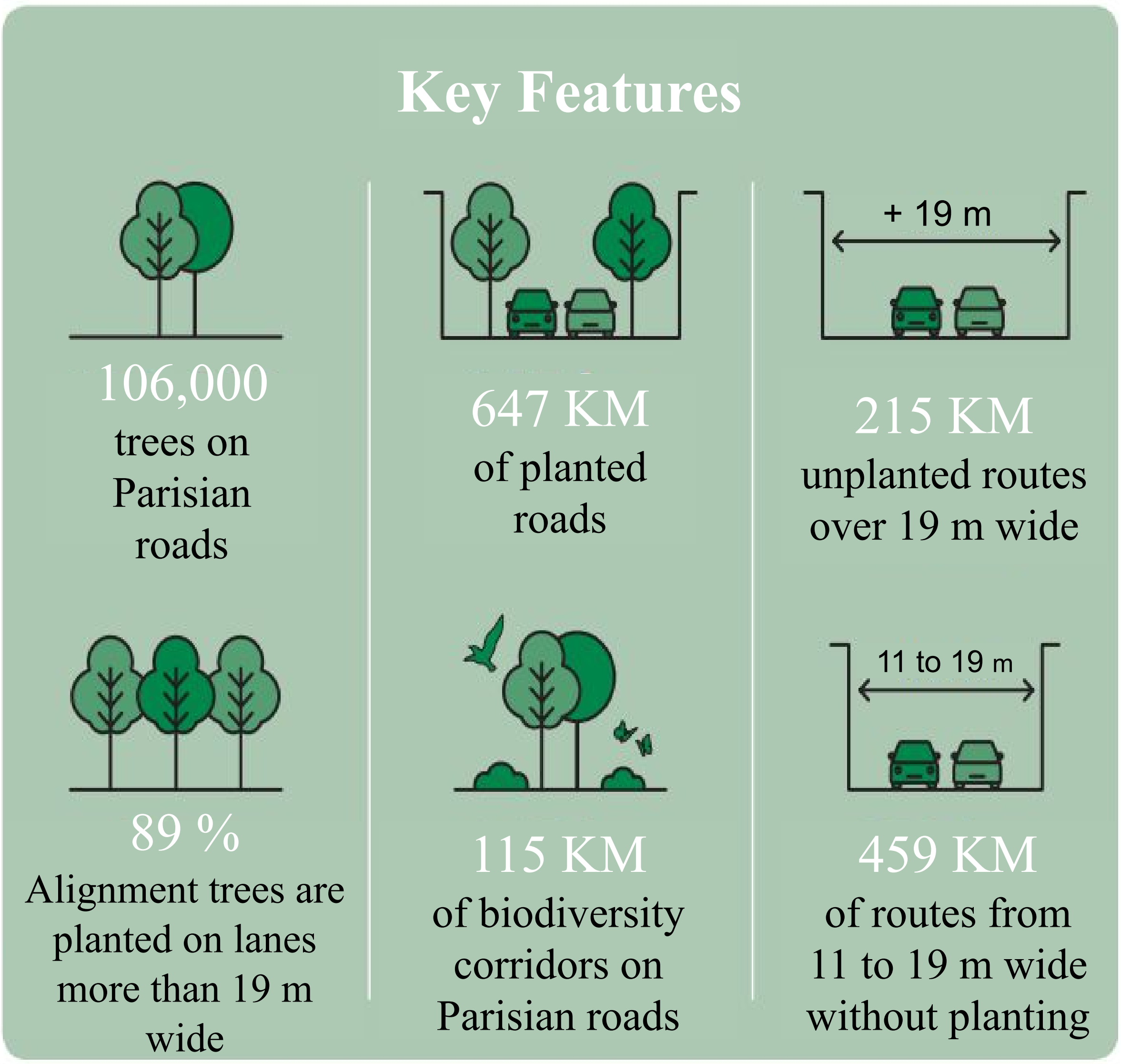
Kindergarten and Elementary School
SAINT-SULPICE-LE-DUNOIS - Creuse (23)

Paris has effectively implemented the OASIS approach in more than 130 schoolyards, creating significant interest among school administrators, Parents and teachers. The project puts specific emphasize regarding the crucial rule of participatory initiatives in addressing the long-term challenges posed by climate change. It integrates technical innovation with active user centric engagement, with the objective of establishing environmentally sustainable spaces through cost-effective solutions that are widely replicable and manageable. This approach is versatile and can be applied across different contexts without demanding high-tech technological equipment or specialized technical knowledge. Thereby providing opportunities for young people to engage with nature and adopt sustainable living practices, Paris is striving to cultivate critical thinkers and leaders who will contribute to the development of sustainable cities and communities.

Project 2: Street Trees

Paris has committed to greeting for 20 years, and its main objective is to make 40% of its territory permeable and vegetated by 2040 and achieve 2% increase in the canopy index by 2030. There are specific plans which have reinforced this commitment; namely, the Climate Plan, Biodiversity plan, and Paris Rain Plan. Moreover, sites for planting plants and revegetation have been identified in the city in accordance with morphological and historical criteria, ecological corridors, heat island effect reduction, vegetation deficiency areas, urban centrality, and opportunity criteria. Temporary developments also have transformed public spaces, promoting a common basis for future exchanges and choices.

Figure 20: key features of Paris street's tree project. Source: Apur, 2020, pp.5

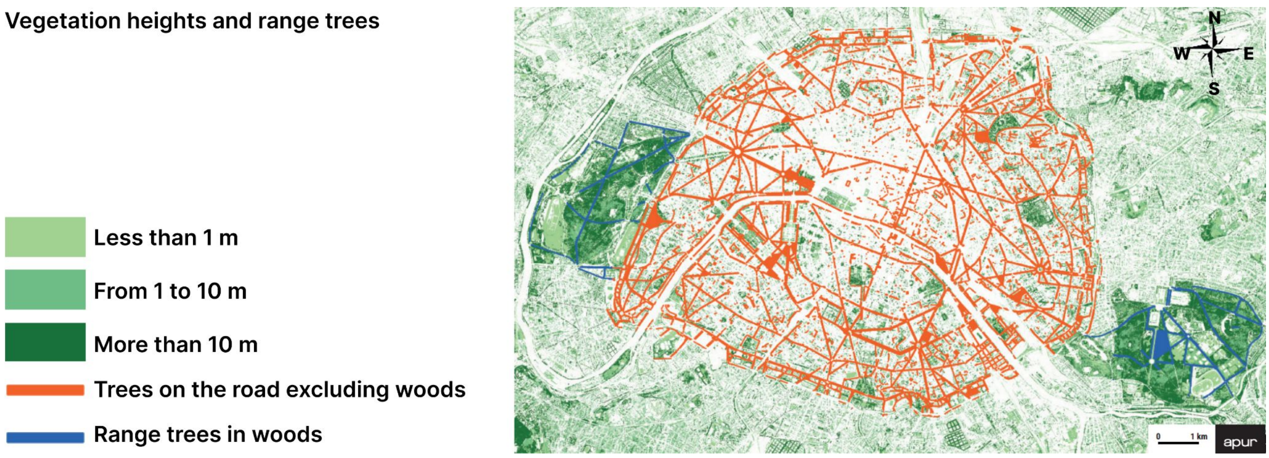


Project 2: Street Trees

Paris' Tree Heritage Overview

- Over 500,000 trees planted on Parisian roads.
- 300,000 trees in Bois de Boulogne and Vincennes.
- 47000 trees in municipal parks, gardens, and squares.
- 30,000 trees in extra-muros and intra-muros cemeteries.
- 9,000 trees in municipal establishments.
- 6400 trees on Boulevard périphérique embankments.
- 4700 trees in sports facilities.

Map 13 : Vegetation heights and range trees in Paris. Source: (Apur, 2020)

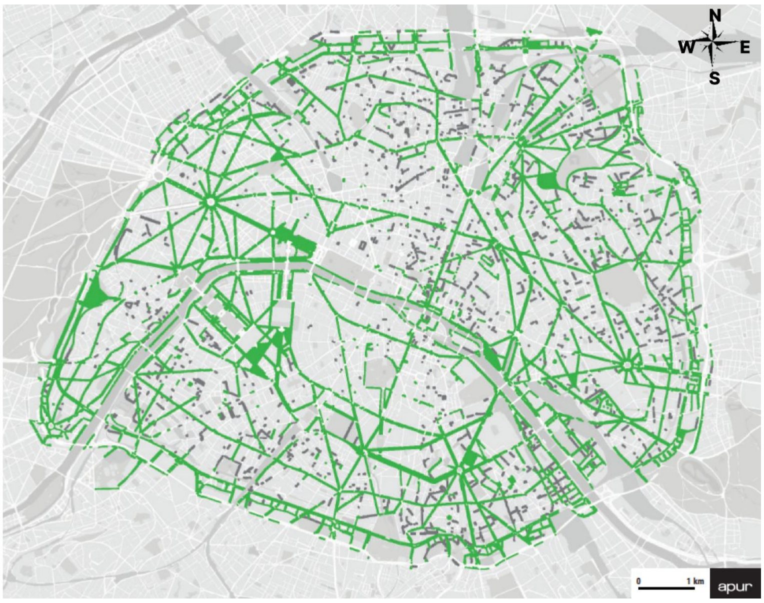


Trees over 19 m wide

In 2019, 89% of the trees planted on the street, i.e. more than 91000 trees, were planted on roads with a width of more than 19 m. In Paris, these wide lanes cover a linear length of 723 km, i.e. 43% of all 1696 km of Parisian roads, excluding woods and Boulevard périphérique. The analysis of data from the City and Apur shows that the length of lanes over 19 m wide is planted with trees over 508 km, i.e. nearly 70% of the total length of lanes over 19 m. These plantings can be made up of double alignments, on either side of the road, such as Avenue d'Ivry (13th), or single alignments on either side, such as Boulevard Voltaire (11th). But these plantations are not all continuous and 13% of the linear length of roads over 19 m wide are not planted, which represents 458 km of wide treeless lanes in Paris, such as rue Lafayette (9th), rue de Rome (17th) or rue Monge (5th). Following figure represents these information.

Map 14: Trees on a lane over 19 m wide. Source: (Apur, 2020).

Trees on a lane over 19 m wide



Trees on a lane 19 m wide

Other trees on the road

The plantations, on these roads of more than 19 m wide, are mainly made up of trees of great development. Today, there are more than 80 different species of trees, dominated by classic species such as: Plane trees (39%), Chestnut trees (15%), Lime trees (11%), Sophoras (9%), Maples (4%), Hackberry trees (3%), Ash trees (2%), Byzantine hazelnuts (2%), and Flowering pear trees (2%). Furthermore, more than 89% of the trees in Parisian alignments are planted on roads more than 19 m wide

Following picture shows the way these trees are located in different district in Paris.

Double row of chestnut trees on Avenue d'Ivry (Paris 13th), width 20 to 30 m

Bilateral alignment of plane trees on Boulevard Voltaire (Paris 11th), width 30 m

Bilateral alignment of sophoras on the rue de Tolbiac (Paris 13th), width from 20 to 30 m

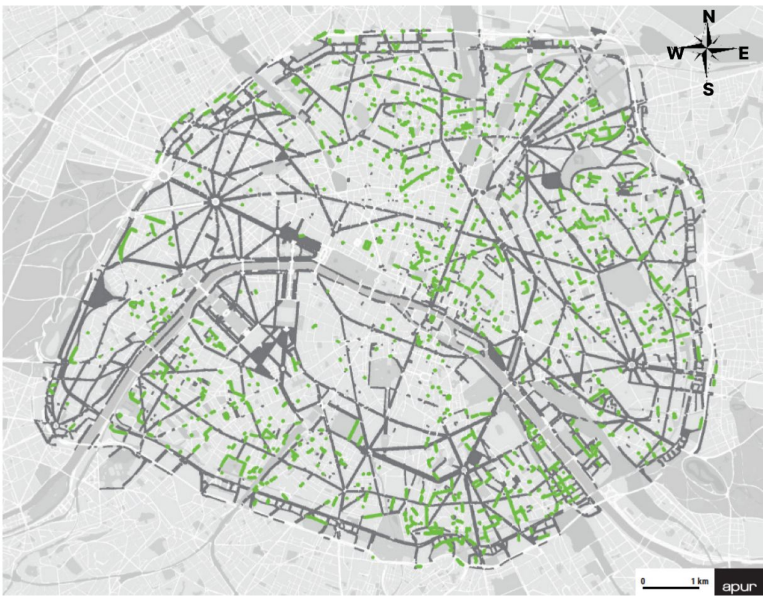
Unilateral alignment of hackberry trees on the rue de Bretagne (Paris 3rd), average width 19.5 m

Trees on lane of 11 to 19 m

In Paris, 9.5% of the trees, approximately 12,000, are planted along roads that are 11 to 19 meters wide, which accounts for 35% of the total road length (589 km). Of these, only 130 km (22%) are actually planted with trees. The majority of these trees are medium-developed (45%) and small-scale (36%), with nearly 80 different species represented. Notable species include flowering pear, cherry, and apple trees, as well as shiny privet and Portuguese laurels. Additionally, there are some large trees (19%), primarily plane and chestnut trees. The tree plantations vary in type, including unilateral alignments and occasional plantings in various locations.

Map 15 : Trees on the lane of 11 to 19 m. Source: (Apur, 2020).

Trees on the lane of 11 to 19 m,



Trees on track of more than 19m wide

Other trees on the road

Trees on a lane of less than 11 m wide

In Paris, 1.5% of alignment trees are found on roads less than 11 meters wide, which constitute 23% of the city's total road length (384 km). These narrower roads have trees planted along approximately 2% of their length (9 km). There are distinctions between roads with widths of 9 to 11 meters that may have occasional vegetation and those under 9 meters that typically lack greenery, except in specific areas like façades or squares. Over sixty tree species are present, with maples, flowering pears, hornbeams, chestnuts, and cherry blossoms making up over 50% of the total. Large trees can be planted in narrow lanes adjacent to open spaces, while medium and small trees may appear based on specific conditions. Future chapters will outline criteria for prioritizing road greening in Paris, focusing on historical significance, ecological benefits, and improving local environments, especially near schools.

Map 16: Trees on a lane less than 11 m wide. Source: (Apur, 2020).

Planted and unplanted routes over 40 m wide

Roads over 40 m wide These roads, over 40 m long, represent 360 km, or 21% of the Parisian road network. 68% of them are planted.

Map 17 : Planted and unplanted routes 40 m wide. Source:(Apur, 2020).

Tracks between 36 and 40 wide

The Parisian road system, covering 27 km, has 36-40 m lanes, covering 2% of the road. However, 85% of these roads are planted in double alignment, unlike the Alphand project's double alignment on both sides. Only a few streets have double alignments, while others have asymmetrical planting.

Map 18 : Planted and unplanted routes between 36 and 40 m wide. Source: (Apur, 2020).

Tracks between 26 and 36 wide

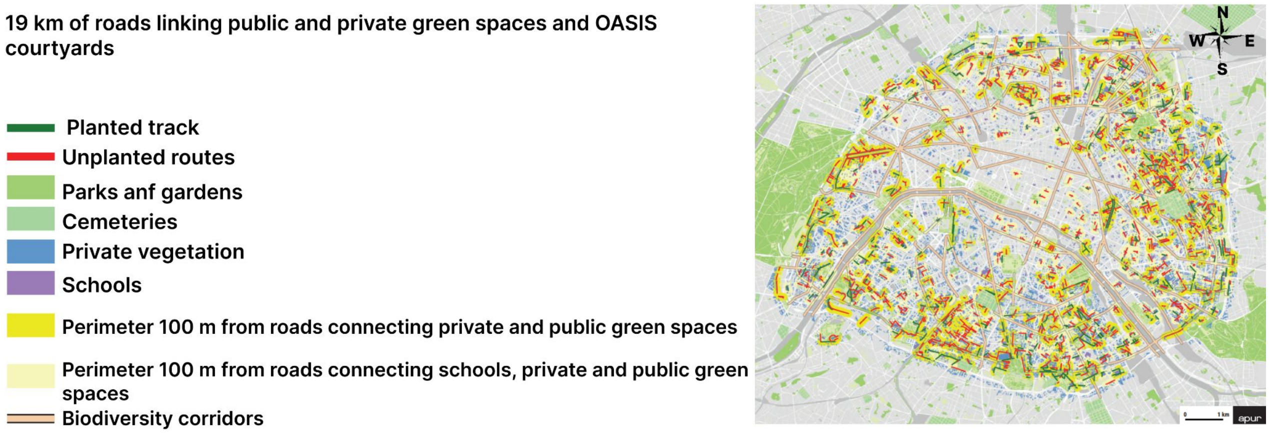
The Parisian road, covering 136 km, has 26 to 36 m lanes, covering 8% of the road. 82% of these lanes are planted, with major structuring and planted axes such as the sequence of boulevards Haussmann, Bonne-Nouvelle, Saint-Martin, Saint-Michel, Saint-Germain, Raspail, René Coty, de Maine, du Général Leclerc, Malesherbes, de Villiers, Niel, Mac Mahon, Kleber, des Ternes, Diderot, Philippe Auguste, and the ensemble formed by Boulevard Ornano, Barbès, Magenta, and Voltaire. The 24 km not planted are small discontinuities in the alignments, except for Avenue de l'Opéra, which aimed to preserve an unobstructed perspective on the Opéra de Paris' façade.

Map 19 : Planted and unplanted routes between 26 and 36 m wide. Source: (Apur, 2020).

Green Pathways: Connecting Urban Nature with Roads, Courtyards, and Biodiversity Corridors

Greening roads simultaneously serving public and private parks and gardens and schools This set of 195 km of roads constitutes a coherent theoretical basis, in connection with ecological continuities, with the potential to create neighbourhoods that are permeable to biodiversity. These neighbourhoods could, moreover, be subject to an intensification of their vegetation rate, on the ground and/or on the buildings, via regulatory or incentive schemes, and see their traffic calmed by the establishment of meeting areas and pedestrian streets.

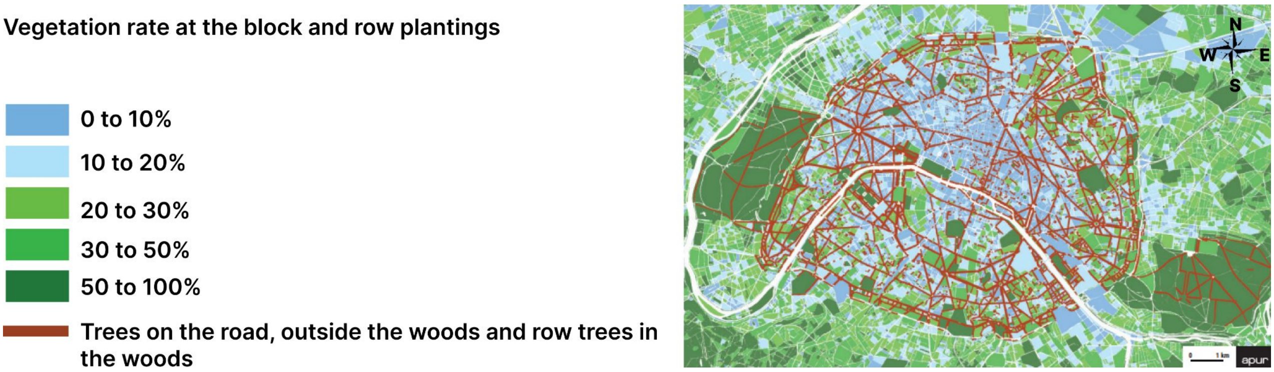
Map 20: 19 km of roads linking public and private green spaces and OASIS. Source: (Apur, 2020).



Vegetation rate at the block and row planting

Paris has an average vegetation cover of 21% per block, with the lowest vegetation cover in central neighborhoods on the right bank. The highest vegetation cover is found in the 14th, 16th, 19th, and 20th districts, with over 25%. The rate of greening fluctuates based on the type of space, with woods having 70% vegetation cover, parks and gardens at 68%, cemeteries at 50%, outdoor sports fields at 34%, public road spaces at 20%, and other public facilities at 18%. The vegetation deficiency threshold is set at 20% of the vegetation rate, covering 60% of the surface area of Parisian blocks, excluding woods. The dense, mineral cities does not have natural advantages, for instance shade, thermal microclimate, breezes, rainwater absorption, higher air humidity, dust fixation atmospheric pollutants, especially in the suburbs and Haussmannian neighbourhoods. The Île-de-France Green Plan puts more emphasis on how the existence of small green areas and trees are able to improve the quality of living environment in these neighbourhoods. Details of the plan are shown on the map below.

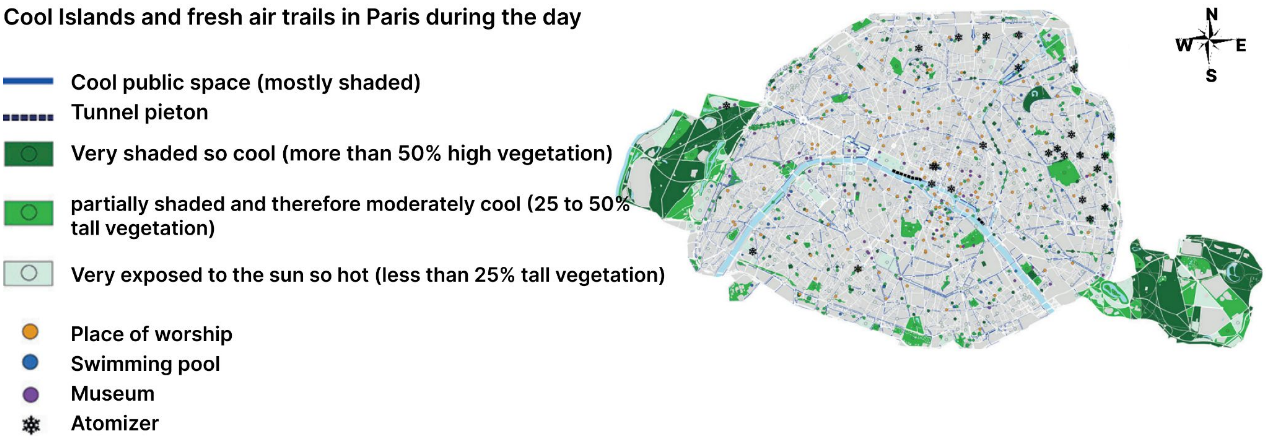
Map 21 : Vegetation rate at the block and row planting. Source: (Apur, 2020).



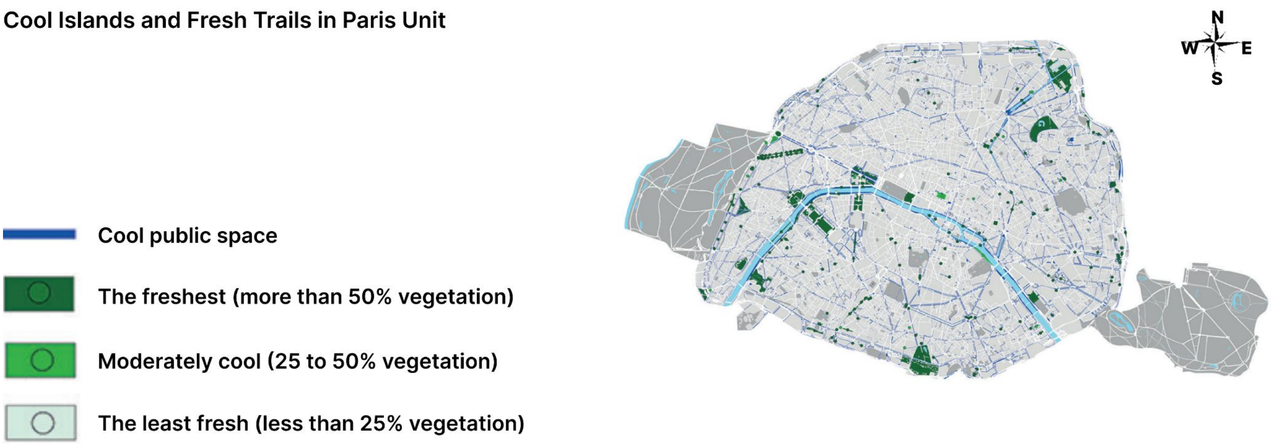
Climate and thermal comfort

In 2019, Paris had 922 cool places accessible during the day, 218 of which were also open at night.

Map 22 : Cool islands and fresh air trails in Paris during the day. Source: (Apur, 2020).



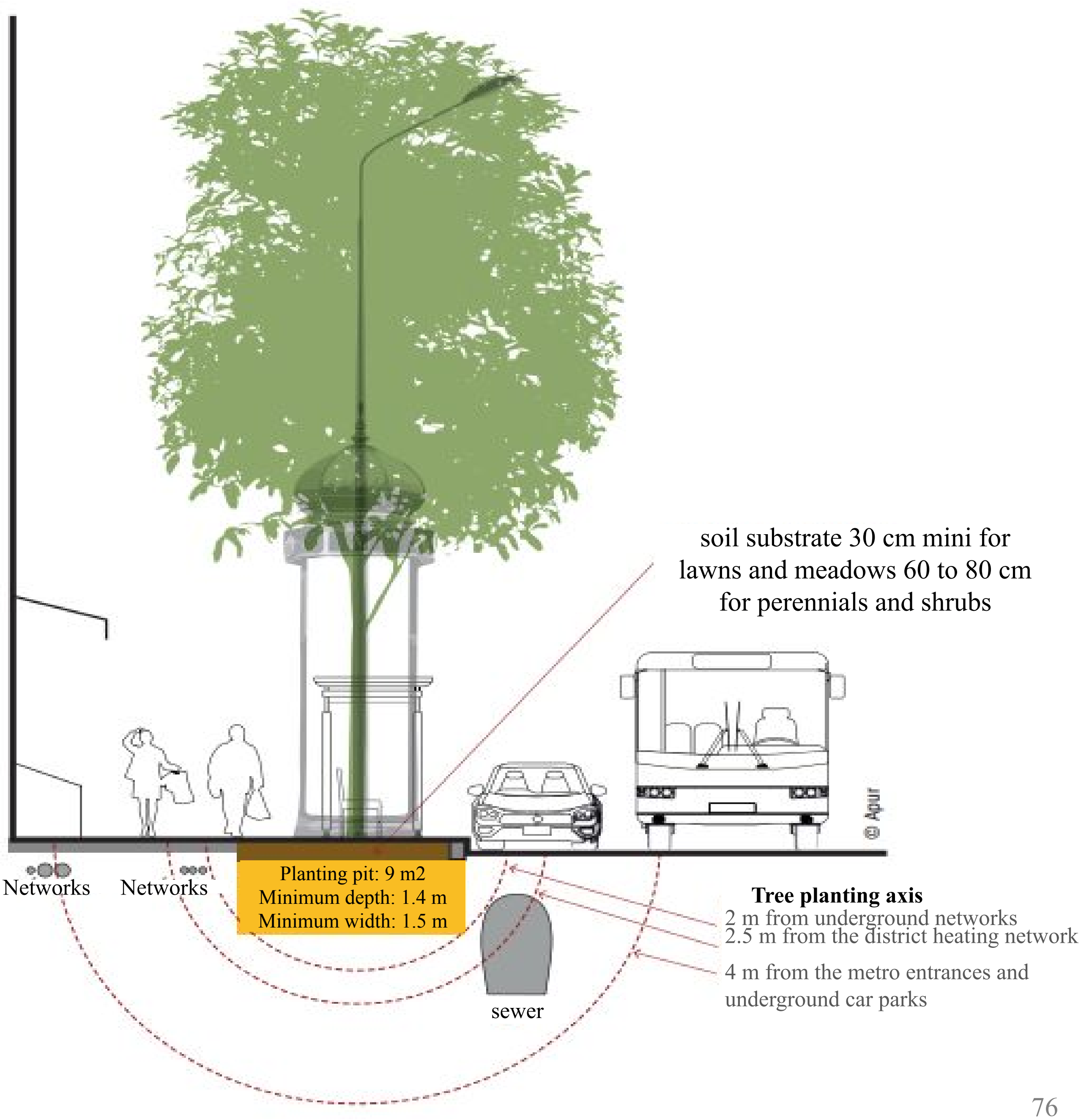
Map 23 : Cool islands and fresh air trails in Paris unit. Source: (Apur, 2020).



Minimum distances to underground networks and structures

According to the City of Paris. tree planting must be implemented in public spaces close to various constructions, including metro entrances, underground car parks, and border separations. Potential tree planting locations have been identified and have been divided into three categories: namely, road spaces, open pavements, and surface parking spaces. The distance from facades indicates suitable areas for small and medium-sized trees, whereas areas for large trees can be identified. The analysis does not consider network depth, but the identified open spaces can serve as a basis for identifying priority roads or sectors.

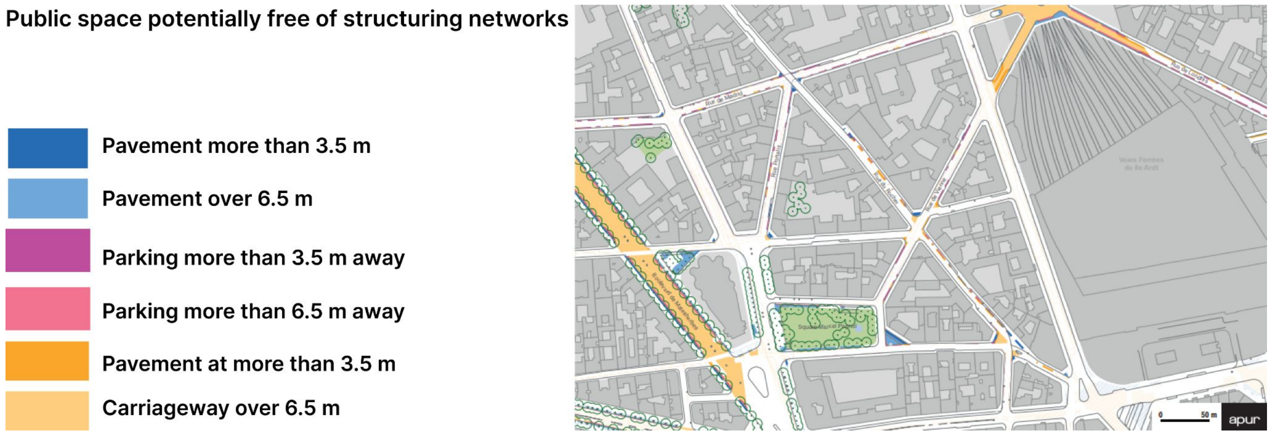
Figure 21 : Minimum distances to underground networks and structures. Source: (Apur, 2020).



Saint-Lazare and Rue de Londres (8th and 9th district)

The analysis of the Saint-Lazare sector (8th) reveals 15m wide roads with potential for tree planting. The east bank of rue du Rocher could refresh Racine high school's sidewalk, while the south-facing banks of rue de Madrid and rue de Londres could be planted for sunlight. The planting of rue de Vienne could strengthen the ecological link between Square Mar.

Map 24: Public space potentially free of structuring networks. Source: (Apur, 2020).



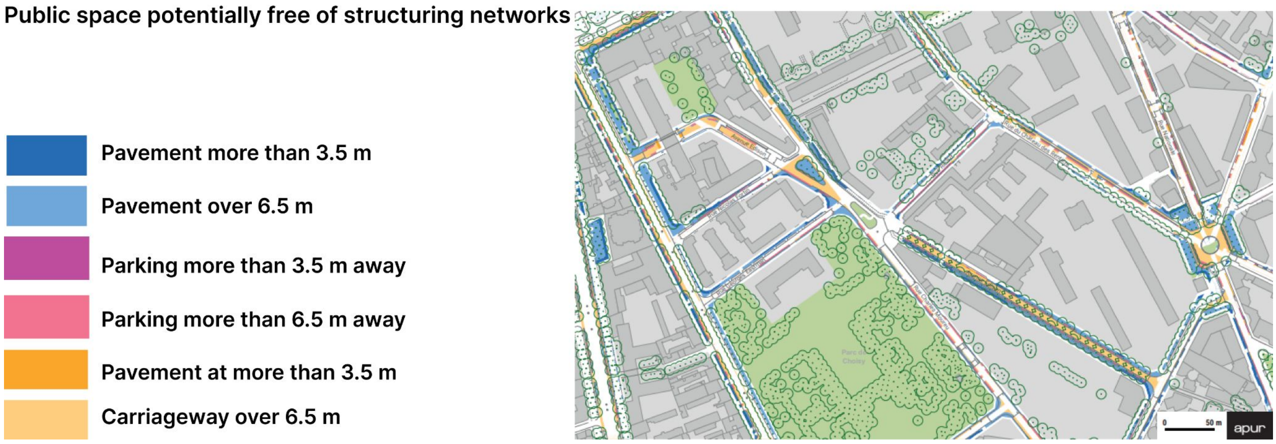

Rue du Rocher (Paris 8e)


Rue de Londres (Paris 8e et 9e)

Rue George Eastman and Rue Charles Moureu (13th district)

The public space around Choisy's park reveals a network of roads with potential for planting, challenging the formation of ecological continuities in Japanese steps and sound. These routes, including Rue Nicolas Fortin, Rue George Eastman, Rue Charles Moureau, Avenue Edison, Rue du Château des Rentier, Rue Nationale, and Rue Clisson, are particularly exposed to sunlight.
Subsequent map and pictures present the details.

Map 25 : Public space potentially free of structuring networks. Source: (Apur, 2020).



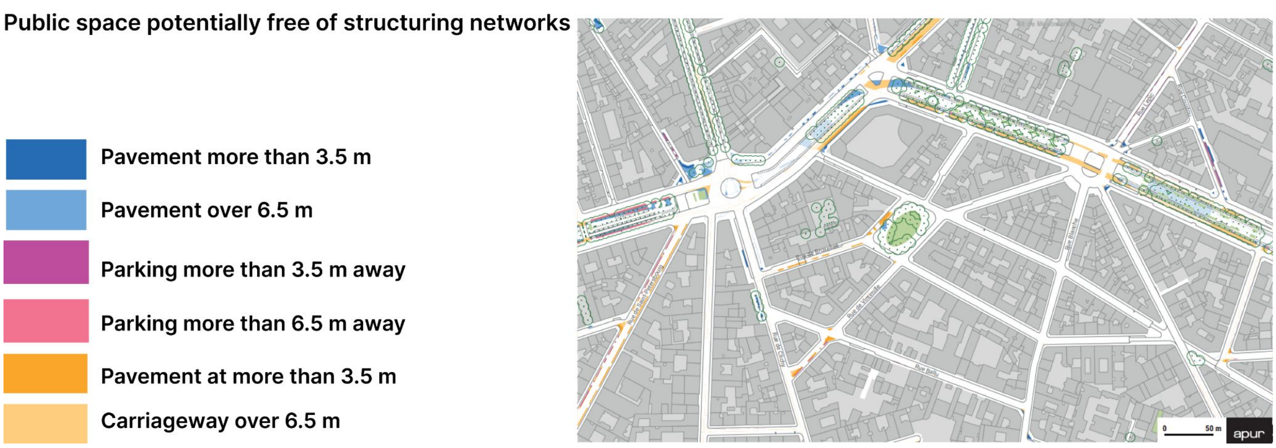
Rue George Eastman (Paris 13e)

Rue Charles Moureu (Paris 13e)

The south of the Place de Clichy (9th district)

The lack of space for trees in the Square Hector Berlioz area has led to a preference for shrub beds, perennials, and herbaceous plants. Potential spaces south of the rue de Vintimille and on the rue de Saint-Pétersbourg, particularly on the surface parking lot, are being developed, highlighting the significant landscape and climatic interest in this area.

Map 26: Public space potentially free of structuring networks. Source: (Apur, 2020).



Rue de Saint-Pétersbourg (Paris 8e)

Rue de Vintimille (Paris 9e)

To sum up, greening in paris enhances quality of life, biodiversity development, and air quality. Parisian roads have 106,000 trees, with 68% of tracks over 19m wide planted. Guideline for green space in Paris.2020 identifies sites for revegetation based on morphological and historical criteria, urban biodiversity corridor development, heat island effect reduction, and vegetation deficiency. Additionally, initiatives on the Seine banks, ring road, green belt, cycling axes, underground infrastructure and the gates of Paris are also taken into consideration. These advancements will transform public spaces and provide a foundation for future exchanges and decisions.

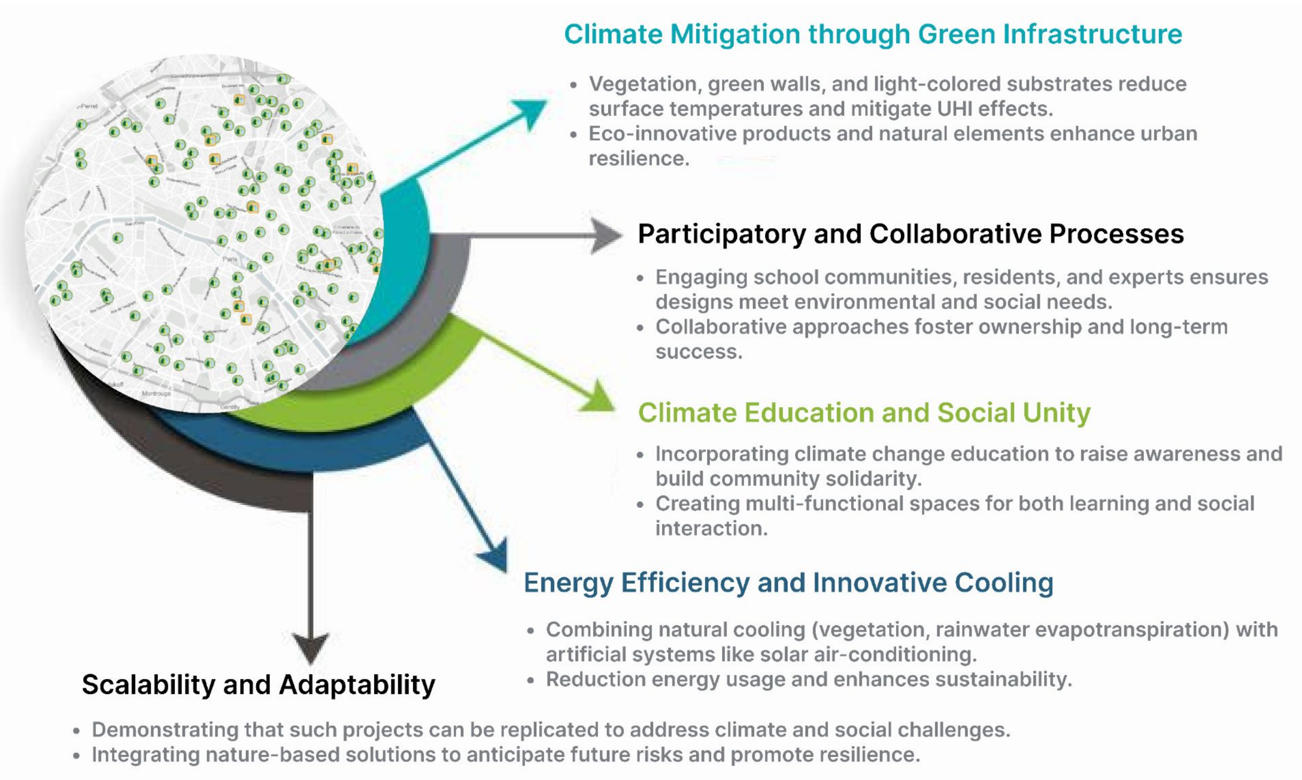
The Paris Climate Adaptation plan seeks to establish 300 extra cool islands, known as "Schoolyards Oases," and plant 20,000 new trees by 2030. The OASIS project supports Nature-Based Solutions, develops Eco-innovative products, as well as renders climate-friendly urban planning easier. The OASIS project supports Nature-Based Solutions, develops Eco-innovative products, as well as renders climate-friendly urban planning easier. Furthermore, the project leads to micro-local government by integrating neighborhood-level interventions and approaches for local stakeholders' empowerment. The expanding green sector is in line with the emphasis on sustainable development and includes a significant social dimension.

Lesson Learned

Paris Oasis Schoolyard Programme,

The OASIS Schoolyard initiative in Paris seeks to mitigate the urban heat island impacts by converting typical asphalt-covered schoolyards into green, climate-resilient spaces. In this project trough using Nature-Based solutions, for instance planting vegetations, designing green walls and making light-coloured substrates, the project lowers surface temperatures and also enhances evapotranspiration which in the long run it brings about reduction of urban heat islands impacts. The project also fosters collaboration with school communities, local residents, and sector experts, ensuring designs align with environmental and social needs. In order to increase public awareness and develop solidarity amongst different group of people, the project additionally integrates climate change education and communal spaces. Moreover, the project also combines natural cooling techniques with artificial installations with the aim of enhancing energy efficiency and reducing dependency on conventional cooling systems. The project achievement illustrates that cities can implement similar initiatives to address climate and social concerns across different contexts, improving equity and resilience.

Figure 22: Summary of oasis Schoolyard. Source: Personal elaboration.



Street Trees

One of the most important lessons learnt through Paris' strategy is the adaptability of green infrastructure to different urban landscape. Tree planting strategies are different according to road width, and highlighting how urban planners are able to use constraints effectively in order to achieve maximum canopy coverage. Additionally, the wide range of tree species (more than 80) supports biodiversity while at the same time ensuring resilience to climate variability, with putting more emphasis on the importance of species selection in urban planning process. Furthermore, giving priority to greening initiatives adjacent to schools, historical sites, and neighborhoods with limited resources highlights the fact that how crucial it is that everyone has to have right to have access to cooling and environmental advantages. These actions illustrate how urban greening, can simultaneously address environmental, social, and cultural challenges, offering a holistic solution to urban heat mitigation when it is guided by thoughtful planning and equitable principles.

Figure 23: Summary of Street Trees. Summary: Personal elaboration.

CHAPTER 5

CASE STUDY: MADRID

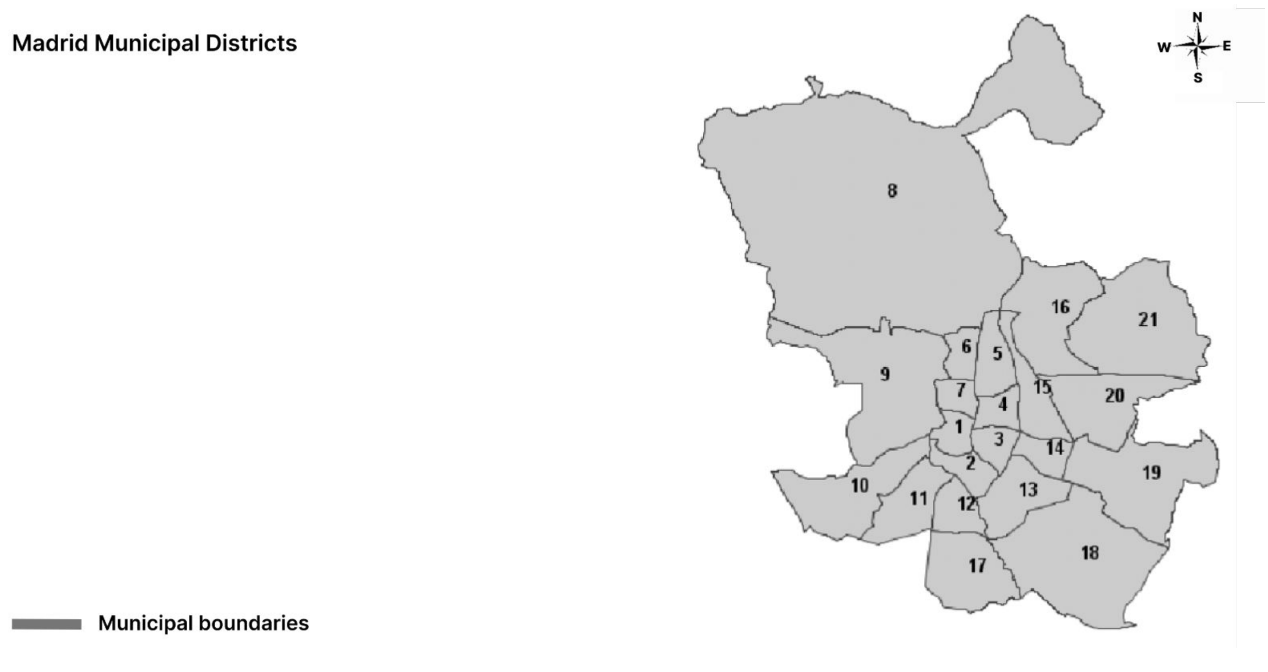
- ❖ Territorial and climate overlook description
- ❖ Climate action plan
- ❖ From lesson to project
- ❖ lesson learned

Territorial and climate overlook description

Territorial climate overlook description

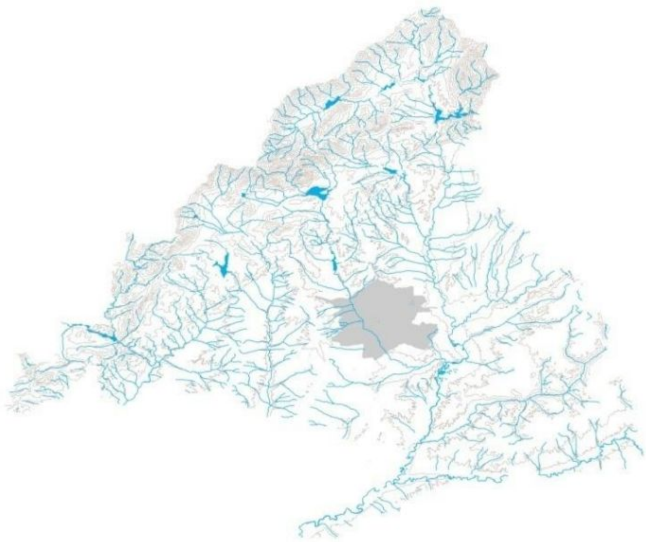
The Madrid metropolitan area is situated in the central part of the Iberian Peninsula (40° 25' N, 3° 41' W) on relatively flat terrain that slightly slopes to the south, approximately 40 km southeast of the the center System mountain chain (Yagüe, Zurita, & Martinez, 1991). Madrid is characterized by a temperate Mediterranean climate which winter and summer are the driest seasons, whereas precipitation predominantly occurs during autumn and spring (Hurduc, Ermida, Trigo, & DaCamara, 2024). Furthermore, Spain has undergone rapid urbanization, with the percentage of the population residing in urban areas rising from 60% in 1960 to over 80% by 2020. This has resulted in intensified construction of buildings, road ways, and infrastructure which exacerbate the Urban Heat Island effect in major cities especially in Madrid (Fernández & Navarro, 2024). According to Data.europa.eu, Madrid is divided into 21 districts (distritos), which are further subdivided into 131 neighborhoods (barrios). Map 25 shows Madrid's municipal district and map 26 represents the forming power of hydraulic gradient with dividing and valleys in Madrid.

Map 27: Madrid municipal boundaries. Source: elaborated by Grindlay, Ochoa-Covarrubias, & Lizárraga, 2020.



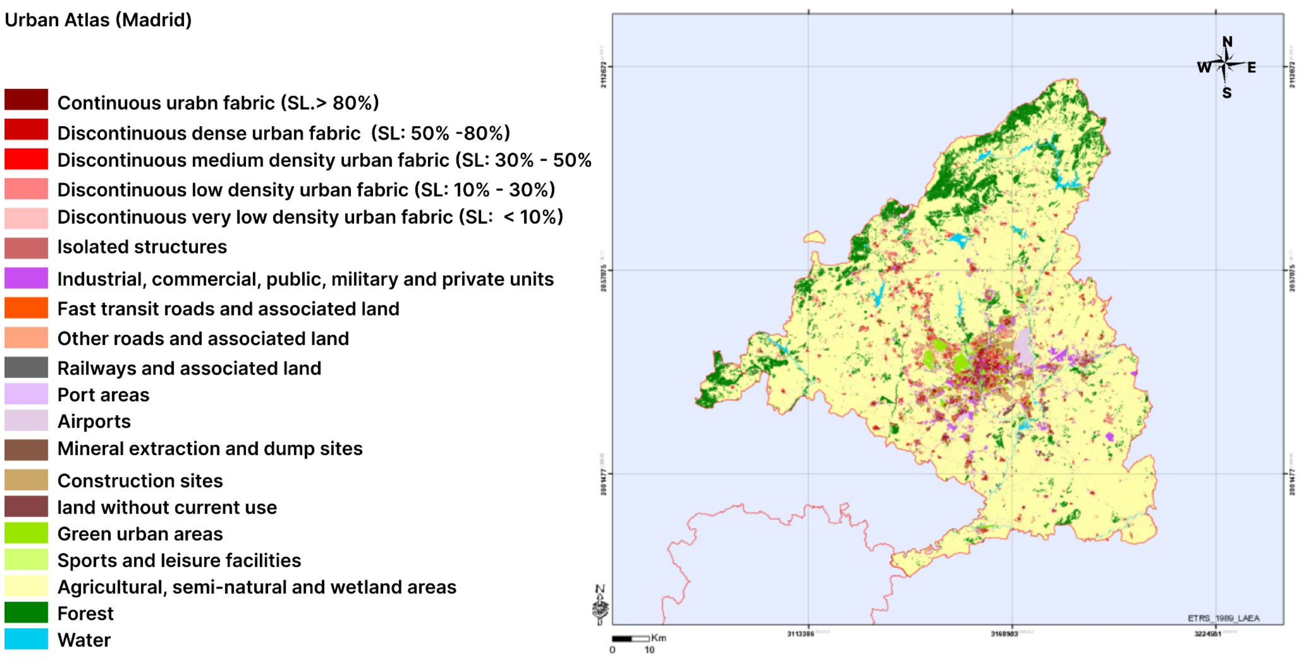
In addition, The Comunidad de Madrid is divided into a mountainous north and south area, with river basins spanning the province. The Jarama River, with its tributary, Manzanares, crosses Madrid City in the Guadarrama mountain range. Map 26 represents the forming power of hydraulic gradient with dividing and valleys in Madrid.

Map 28: Formation of hydraulic gradient power with divides and valleys in Madrid. elaborated by Jorge Bernabeu-Larena, 2016.



Map 27 depicts the Madrid's Land cover details.

Map 29: Madrid's urban land cover . source: Madrid's Urban Atlas, 2020.



Following maps shows the Island of daytime coolness and nighttime heat in the metropolitan area of Madrid, which obtained from surface temperature (Source: detailed study of the urban climate Madrid. 2016).

The urban heat island (UHI) phenomenon in Madrid has expanded in both size and frequency over the last 30 years, with peak temperature records occurring in regions exhibiting an intensity exceeding 4ºC.

However, the intensity of the Urban Heat Island effect does not appear to be escalating, with peak levels of 5-6 ºC. The expansion of urban areas has enlarged the UHI domain; nevertheless, it appears to have no effect on intensifying regions that have already attained their maximum, perhaps due to the consolidated urban fabric during the past thirty years (Núñez Peiró, Sánchez-Guevara Sánchez, & Neila González, 2017).

Figure 10 illustrates trend in annual maximum temperatures in Madrid which means that the number of warm days can approach 40% of the annual days, in the worst-case scenario.

Figure 24: trend in annual maximum temperature. Source: detailed study of the urban climate Madrid, 2016.

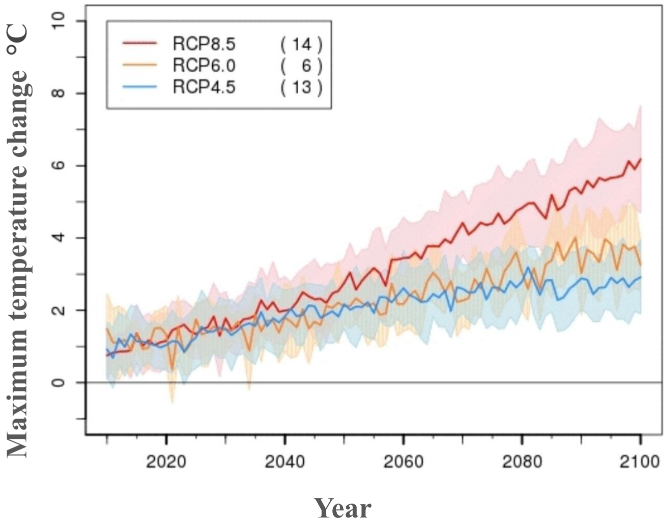
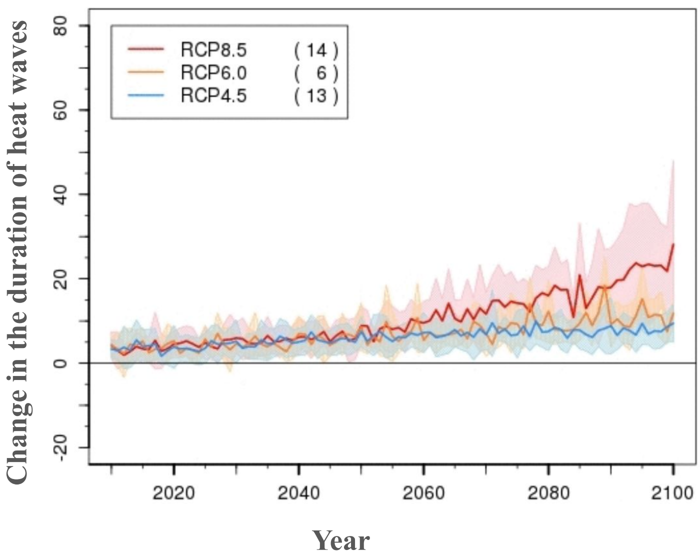


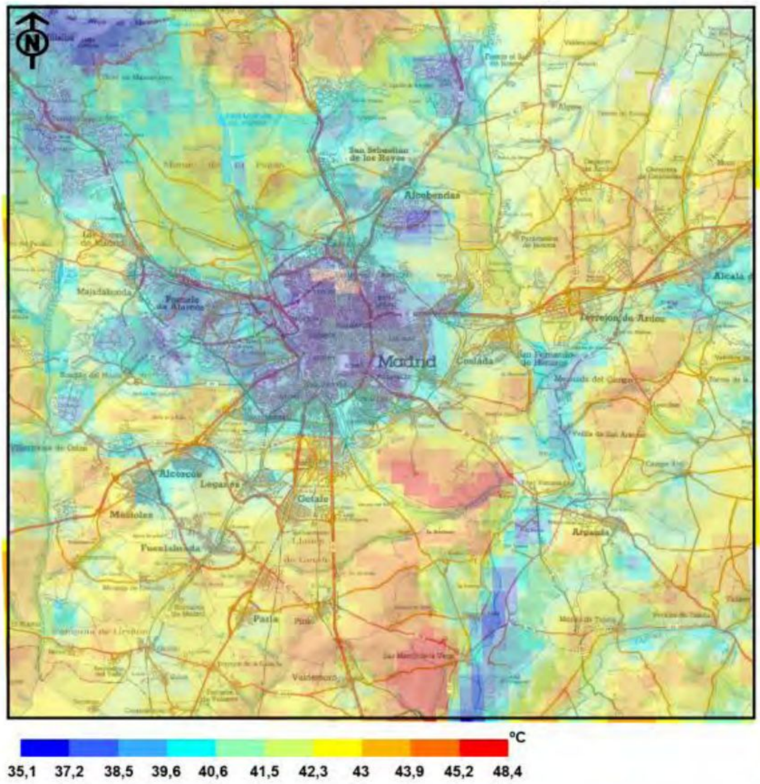
Figure 11 is a general data about community of Madrid which indicates that the duration of heat waves could be closer to 20 days till 2100.

Figure 25: Figure 37: Trend in the duration of heat waves . Source: detailed study of the urban climate Madrid. 2016.

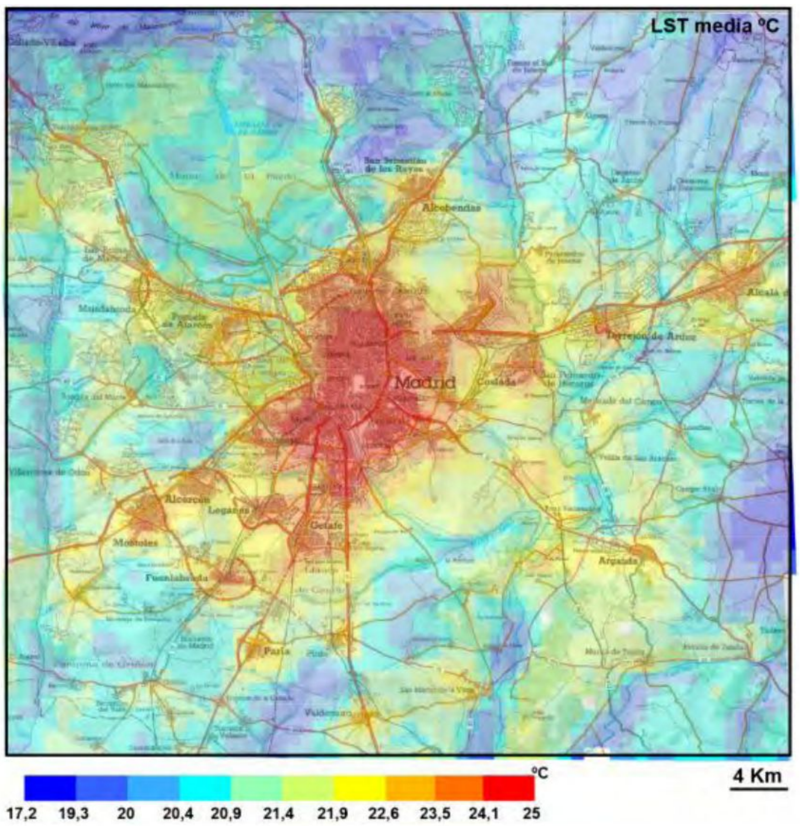


Besides, map 28 and 29 show the Island of daytime coolness and nighttime heat in the metropolitan area of Madrid, which obtained from surface temperature, respectively.

Map 30: LST Daytime in Madrid. Source:detailed study of the urban climate Madrid, 2016.



Map 31: LST Nighttime in Madrid. Source:detailed study of the urban climate Madrid, 2016.



Climate Action Plans

Madrid 360 strategy

The Madrid 360 (2022) which is Environmental Sustainability Strategy aims to transform Madrid into a more sustainable city, improving quality of life, fostering a low-carbon economy, and enhancing security and resilience against climate risks. The strategy focuses on reducing greenhouse gas emissions to mitigate the effects of climate change, in response to the European Union's binding target of reducing net greenhouse gas emissions by at least 55% by 2030.

Every year, the Madrid City Council publishers the inventory of Greenhouse Gases which demonstrates a gradual decrease trend in emissions from different number of sectors. The city has established plans and policies that aim to reduce emissions; these are often tend to combine with other municipal plans for urban regeneration, mobility, and air quality. The trend shows significant reductions in emissions per capita in the municipality, with direct emissions from the "RCI" sector decreasing by 11.9% and those from road transport by 34%.

Urban emissions are predominantly linked to the residential, services, and transportation sectors, which comprise 90% of reductions. Emphasizing renewable energy production and advancements in these sectors helps mitigate emissions. Nonetheless, social and financial constraints provide considerable difficulties. Attaining a carbon-neutral city necessitates collaboration among governmental, corporate, and social sectors in every facet of the process. In order to overcome these obstacles, it is essential to establish flexible governance frameworks, harmonize policies, and implement agile finance and methods for budgeting. Institutional coordination and economic evaluation are essential for evaluating returns and executing interventions. Tools for assessing the impacts of climate change and providing immediate data regarding their effects on its citizens are crucial.

The economic analysis reveals that many identified actions, particularly those for mobility, offer economic benefits and a long-term return on investment of over 50%. These measures not only save money but also provide health benefits. Climate action focuses on reducing GHG emissions, but the consequences of global warming also require response to existing threats and impacts. The Madrid City Roadmap aims to achieve neutrality by 2050 while increasing capacity to adapt to climate change's adverse effects and promoting resilience to climate risks.

Although the Madrid City Council is developing a Roadmap to address climate change, focusing on municipal coordination, climate approach integration, and innovative financing mechanisms, collaboration with local agents, regional and national administrations, and research centers is crucial for achieving all objectives. International urban networks and initiatives are also highlighted to support cities' leading role in the global climate change challenge.

Climate actions based on Urban Climate of Madrid 2016

Promoting permeability through punctual revegetation,

Maintaining rainfed agriculture

Designing naturalized morphologies,

Revegetating degraded open spaces,

Rehabilitating valleys and slopes in municipal margins.

These measures aim to widen riparian forests, maintain rainfed agriculture, restore metropolitan thermal buffers, and facilitate natural thermal fluxes. The assessment of compensatory thermal elements considers roofs, roads, empty spaces, bare facades, and naturalizing tree pits and floors. Corrective actions include using reflective materials on roofs, landscaping roads, using low water-requiring vegetation for disconnected spaces, implementing structures on facades, and using creeping species to densify tree pit covers or marginal lands. Urban planning regulations should also include measures adapted to each neighborhood's thermal risk level to improve thermal comfort (Fernández García et al.,2016).

Roadmap to climate neutrality for the city of Madrid

The City of Madrid has developed a "Roadmap to Climate Neutrality for 2050," published in March 2021, which aims to reduce greenhouse gas emissions by 65% by 2030 and achieve climate neutrality by 2050. This initiative aligns with national and European policies and emphasizes resilience to climate risks. A working group, including social organizations, is set to review and update the Roadmap to ensure equity and inclusiveness in its measures.

The Roadmap is supported by the Madrid 360 Environmental Sustainability Strategy, which focuses on improving air quality and combating climate change through urban transformation, mobility, and administration. At the national level, Spain's Urban Agenda and various strategic plans aim to coordinate climate action, promote renewable energy, and enhance resilience.

Madrid's Recovery, Transformation, and Resilience Plan includes 105 transformative investments in urban areas, focusing on mobility, energy generation, digital transformation, green spaces, and social cohesion. Additionally, the Autonomous Community of Madrid is preparing its own strategy for energy and climate by 2030, complementing local and national efforts towards climate neutrality (Madrid 360 (2022).

Arup's Urban Heat Study and strategies

According to Arup's Urban Heat Study, Researchers in Madrid identified 500,000 children and elderly people experiencing evening urban heat island (UHI) phenomena with temperature surges of 7°C or greater, resulting in significant temperature fluctuations within urban areas, with downtown Madrid experiencing about 8°C higher than the adjacent El Retiro Park which is a short distance away.

Arup research provides five tested strategies to mitigate urban heat islands in Madrid: increasing tree canopy cover, creating more permeable surfaces, using every space possible, establishing cool islands, and sparking behavior change. Trees can lower temperatures and reduce heat-related mortality, while permeable surfaces absorb less heat than impermeable ones. Open spaces, including roofs and streets, can be used to build resilience by greening facades, using white paint to reduce heat absorption, and using reflective and solar PV to cool buildings. Establishing cool islands, such as bringing back drinking water fountains, can improve health and become the main access point during droughts. Sparking behavior change can also help reduce air conditioning and decarbonize energy use. By implementing these strategies, cities can better adapt to the challenges of urban heat islands and improve overall health (Allen, 2023)

From Plans to Projects

Madrid's Río Park in 2015 and Calle 30 projects

The Madrid City Council established a priority for climate adaptation. It intends to emphasize nature-based solutions by substituting impermeable surfaces with green spaces and implementing water-permeable surfaces to mitigate the urban heat island effect, while simultaneously enhancing flood resilience. It aims at adding additional trees, shaded walkways, and utilize more reflective building supplies. Hence, Madrid Rio Park project and Calle 30 are prime examples of Madrid's climate adaptation.

To do so, the Madrid Río Project, a joint initiative between the city government and the city's citizens, aimed to reconnect the Manzanares River and its surrounding banks as public parks and green spaces. The project aimed to create new recreational zones along the river, engage citizens in its development, improve urban integration, and improve water conditions (The Madrid Río Project 2007-2015).

A comprehensive masterplan for the waterway in this project also encompasses:

- 12 new pedestrian bridges
- 6 hectares of public and sports facilities, social, communal, and artistic amenities
- urban beach
- children's areas
- the restoration of the river's hydraulic architectural heritage
- and significant advantages for the urban environment of Madrid and its residents
-

Figure 12 shows that the masterplan of the project which created 50 sub projects, they are situated along the river and united through the Salón de Pinos as the central axis.

Figure 26: The Madrid's Master plan. (Source: West8).

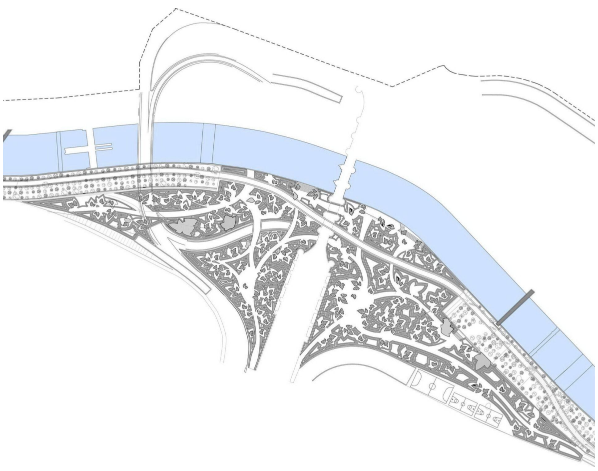
The primary outcomes of this initiative are as follows:

- The establishment of the 120-hectare park has strengthened the connection between the northern and southern natural regions of Madrid.
- linking river to the city
- renovating and integrating historical bridges, thereby fostering new spatial relationships between monuments and the city.

Additionally, a component of this project involved the creation of the salon de pions, a linear green space intended to connect the existing and newly constructed urban areas adjacent to the Manzanares River. Salon de Pions is situated predominantly above the motorway tunnel and shows a meticulously arranged "choreography" of 8,000 pine trees. The following graphic illustrates its design.

Figure 27: The tree planting design of the Rio project . (Source: West8)

Renovating and integrating historical bridges also was part of the project which the scheme is showed in the following:

As it is mentioned earlier the Manzanares River is transforming into a vital link between the city's urban interior and its territory. It aims to restore banks and incorporate landscape and territory elements, ensuring continuity and permeability. The river connects the city with other green spaces, creating an environmental corridor of nearly 3,000 hectares. It also serves as a migratory wildlife corridor, connecting northwest parks and southeast parks, providing a peaceful axis for birds and night shift animals. To accomplish this Six landscapes have been designed and crafted to form a cohesive entirety .And also a green corridor on the right bank of a 6 km tunnel features a dense topsoil landscape with a forest character, incorporating Aleppo pine species. The park connects riverside gardens, leisure areas, and a playground with sustainable materials, promoting continuity and connecting various activities. The park is attached to underground infrastructure, ensuring irrigation and tree anchoring (Hernández-Lamas,et al., 2016, pp 420).

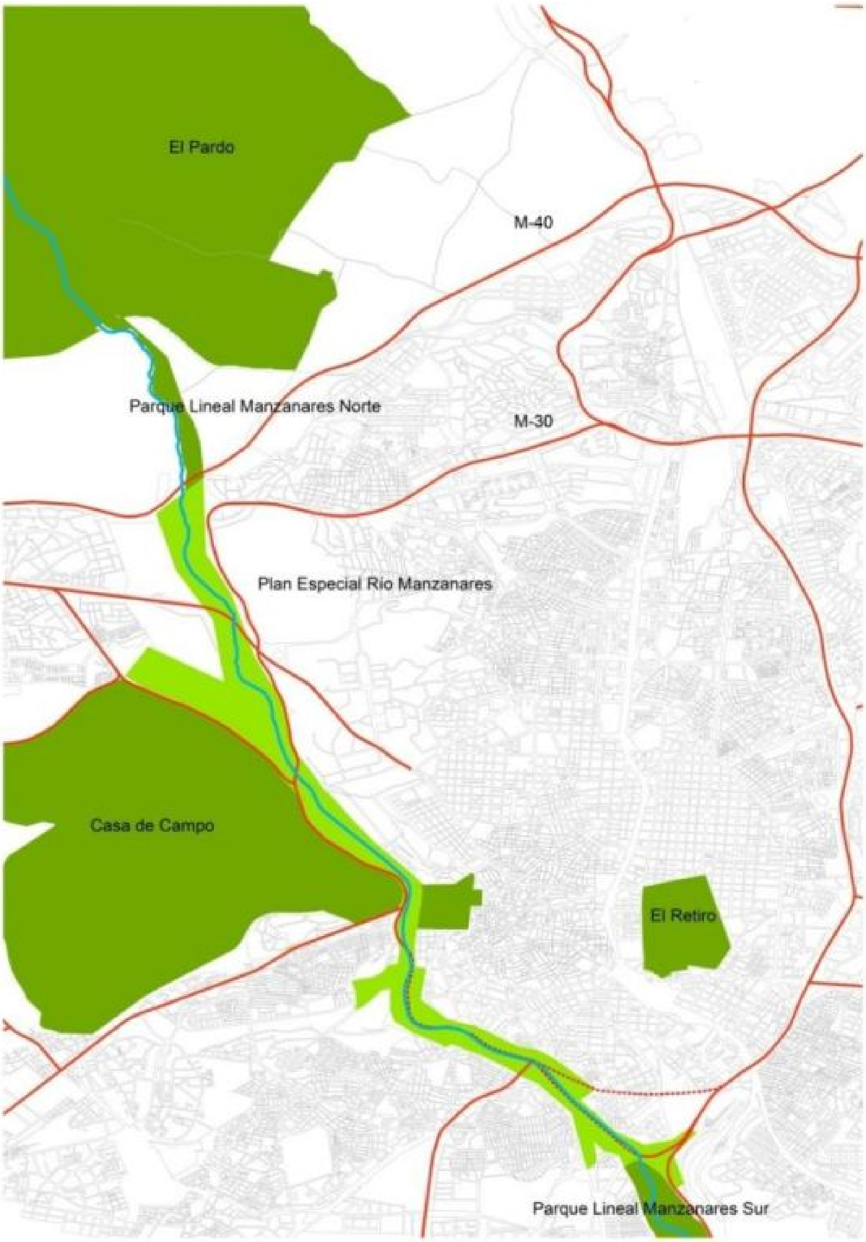


Figure 28: Madrid-Río and connection to other parks Source: elaborated by Jorge Bernabeu-Larena, 2016.

Catalogue of Madrid's Río Park Project

Lesson Learned

Madrid's Río Park in 2015 and Calle 30 projects

The Madrid Río Project highlights the importance of nature-based solutions, green infrastructure, ecological corridors, and sustainable materials in mitigating Urban Heat Island (UHI). The 120-hectare park and "Salón de Pinos" with 8,000 pine trees provide shade, lower temperatures, and support evapotranspiration, cooling the urban microclimate. The restoration of the Manzanares River and 3,000-hectare environmental corridor further cools the surrounding areas, promoting air circulation and biodiversity. The replacement of impermeable surfaces with water-permeable materials reduces heat retention and enhances stormwater management, addressing UHI and flood resilience. The use of shaded walkways and reflective materials on buildings lowers localized temperatures, improving pedestrian comfort and reducing heat exposure. The project also fosters social and spatial integration by bridging the northern and southern parts of Madrid with restored historical bridges, pedestrian-friendly infrastructure, and abundant green spaces. This urban planning approach can mitigate UHI while fostering inclusive and equitable urban environments, benefiting all communities.

Figure 29:Summary of Mdrid's Rio Park 2015 and Calle 30 project. Source: personal elaboration

CHAPTER 6

CASE STUDY: ATHENS

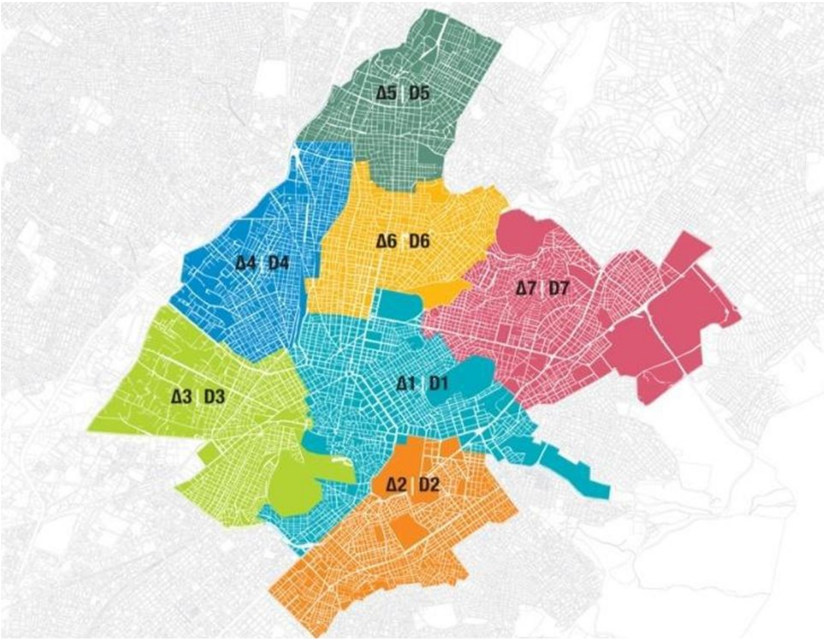
- Territorial and climate overlook description
- Climate action plan
- From lesson to project
- lesson learned

Territorial and climate overlook description

Territorial climate overlook description

Athens is the capital and largest city of Greece, encompassing a land area of 38.96 km² within its municipality and it has seven districts with 3.5 million population and 66 municipalities.

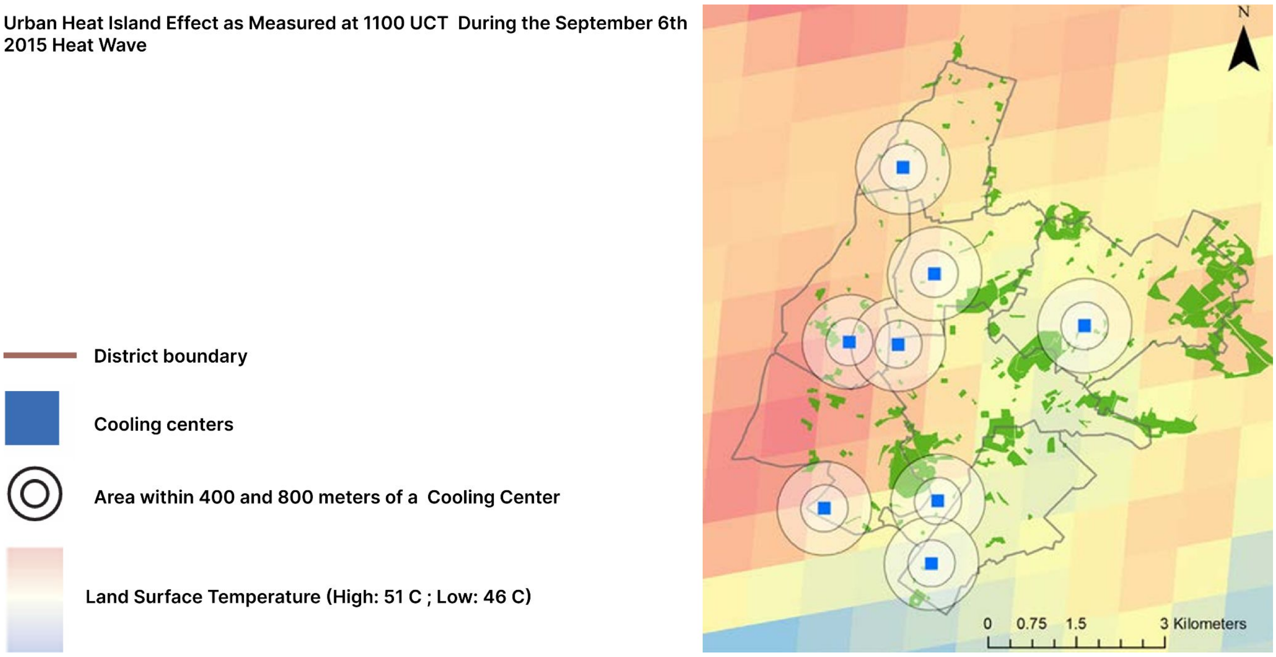
Map 32: Districts of Athen. Source: Bakogiannis, Kyriakidis, & Milioni, 2019.



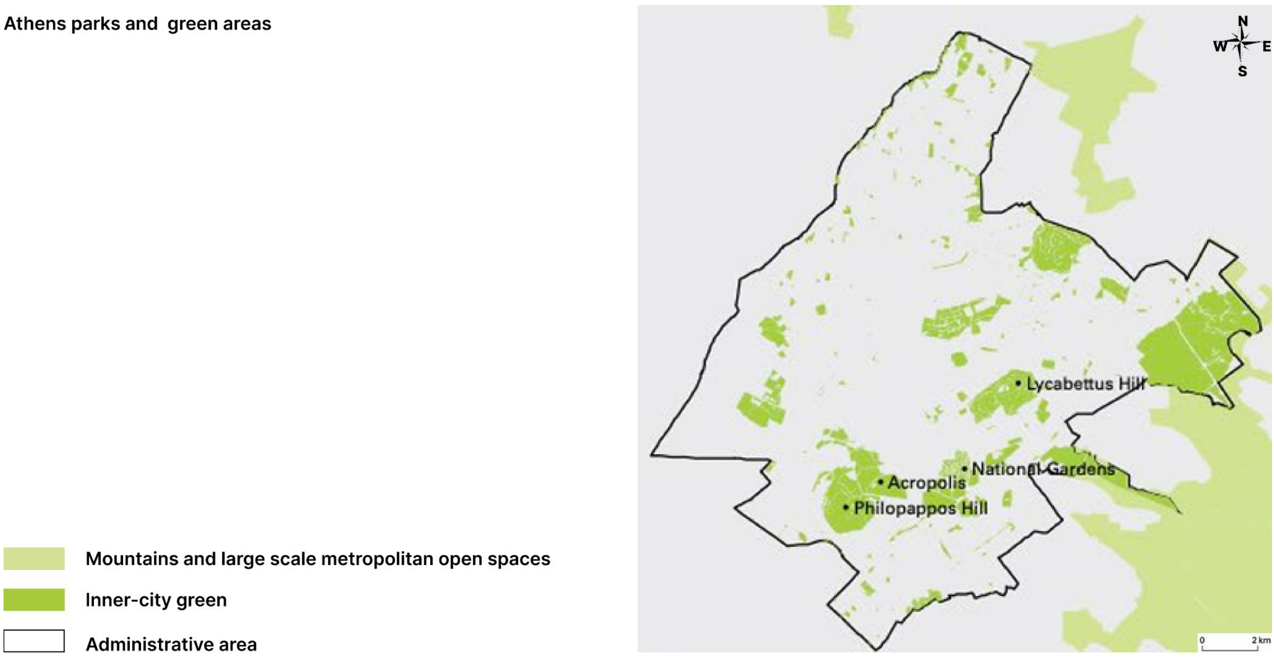
Athens has a Mediterranean climate which is characterized by hot, dry summers and warm, rainy winters, attributable to its position in the eastern Mediterranean. The spring months exhibit elevated temperatures, while the summer months can get quite hot with low precipitation. Autumn is temperate, characterized by reduced humidity and average high temperatures of approximately 29°C to 32°C. Precipitation rises but remains low in comparison to winter and the location of the city on the eastern Mediterranean coast affects its climate (Sadou Ammar & Sharples, 2024).

The urban heat island in Athens also is a significant phenomenon with strong spatial and temporal variability, peaking during summer when temperatures exceed 10°C between rural and central city areas (Founda & Santamouris, 2017). As a matter of fact Athens experienced considerable warming in recent decades, with summer temperatures increasing by +1°C each decade since the mid-1970s. The impact comes from global warming and urbanization. The urban heat island intensity in Athens hit 3°C from 1961 to 1982. The average seasonal temperatures have been estimated to be 5.4°C in summer, 3.2°C in autumn, 2.1°C in winter, and 3.1°C in spring. Daily air temperature disparities between the warmest and coolest regions fluctuate considerably, affected by meteorological factors (Roukounakis, Varotsos, Katsanos, Lemesios, Giannakopoulos, & Retalis, 2023). Athens resilience strategy for 2030 provided a map which represent the impact of Urban Heat Island. The map is presented in the following:

Map 33: Urban Heat Island effect in Athen during summer 2015. Source :Athens resilience strategy for 2030.



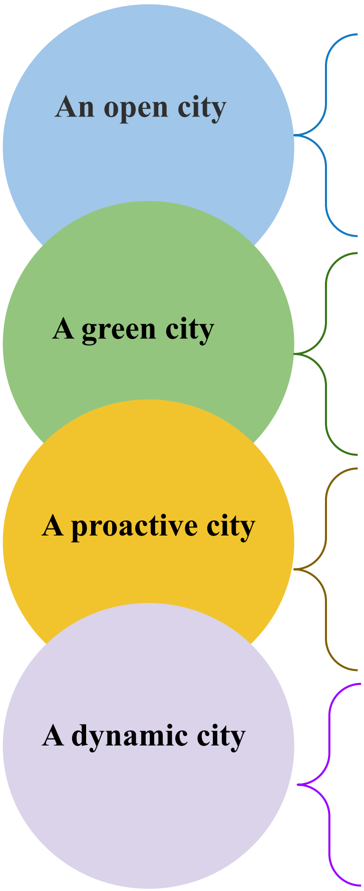
Map 34: Athens green area. Source : Eleni Myrivili, 2016.



Climate Action Plans

Athens resilience strategy for 2030

resilience strategies of Athens relies on four pillars: an open city, a green city, a proactive city, and a dynamic city. The open city seeks to attain effective governance, enhance communication and engagement with citizens, and promote data-driven policymaking and accountability. The green city incorporates natural systems into the urban fabric, fostering sustainable transportation, food production, and energy systems. The proactive city enhances its survival capabilities, fostering a secure environment for its inhabitants through strategic planning and effective communication. The dynamic city cultivates its resources to enhance well-being, foster creativity, stimulate entrepreneurship, and establish a new, inclusive identity. The city seeks to optimize current assets and promote jobs, cultivating a more inclusive and vibrant environment. Athens seeks to fulfill the human demand for proximity to nature while addressing climate change and environmental issues through the implementation of these initiatives (Athens resilience strategy for 2030).



- Become more Transparent and Accountable
- Enhance and streamline the city's processes
- Foster collaborations and stakeholder engagement

- **Integrate natural systems into the urban fabric**
- **Make our city cleaner**
- **Promote sustainable mobility and co-create public spaces**
- **Foster sustainable food systems**
- **Establish sustainable and equitable energy system**

- Integrate natural systems into the urban fabric
- Establish sustainable and equitable energy system
- Promote sustainable mobility and co-create public spaces
- Make our city cleaner
- Foster sustainable food systems

- Maximise existing City assets and support employment
- Enhance the City's identity and promote new types of belonging

A green city / Integrate natural systems into the urban fabric

Goal	Climate adaptation action plan	SDG Goals
Enhance green infrastructure in the city	• Maintenance and planting of existing green areas. • Enhancement of green infrastructure in public space regeneration. • Design and creation of "Green Corridors" for improved air circulation and walkability. • Regulatory procedures for establishing new green public spaces. • Development of pocket parks, parklets, green roofs, and vertical gardens. • Enhancement of urban farming in parks, public lots, and roof gardens. • Establishment of sustainable water and organic waste management. • Design and creation of "Blue Corridors" and other water elements.	
Built environment	• Regulate new pedestrian streets • Establish a regulatory framework for cool and sustainable materials in municipal public works • Design and develop shading and natural cooling solutions in urban planning and street furniture • Record and monitor underground tunnels and develop routes and shelters for future extreme heat waves or crises	
Public health protection	• Expand "cool centers" network for high temperature protection. • Establish public water fountains for accessible drinking water. • Establish regulatory measures for traffic management to protect air quality.	
Promoting High Temperature Awareness	• Use Treasure Phone, Web Application, and NFC tags to provide personalized information on health risks. • Guide high-risk populations to municipal "Cool Centers." • Link all heat-related data sources to the Municipal Portal. • Establish public awareness campaigns and activities. • Engage the private sector in these activities.	

Goal	Sustainable mobility roadmap	SDG Goals
Sustainable urban mobility plan	Athens is developing a sustainable urban mobility plan funded by the National Green fund, collaborating with the Technical University of Athens, and expected to be finalized by 2017.	

A green city / Integrate natural systems into the urban fabric

Goal	Sustainable mobility roadmap	SDG Goals
Sustainable urban mobility plan	Athens is developing a sustainable urban mobility plan funded by the National Green fund, collaborating with the Technical University of Athens, and expected to be finalized by 2017.	
Urban cycling plan (Promoting Cycling in Athens)	• Connecting North and South axes with new cycle lanes. • Creating new bicycle parking lots. • Implementing communication and information campaigns for younger ages. • Incorporating bicycles in city's tourist development.	
Extending pedestrian zones in the city	Implementation of a pilot project in the Athens Commercial Triangle, concentrating on pedestrian areas and extending them to adjacent districts. A large-scale traffic and mobility study is planned.	
Establishing electric bus lines	Athens plans to establish two electric bus lines to improve public transportation, one addressing a gap between districts and the other one connecting major city landmarks.	

From Plans to Projects

Project 1: The Rethink Athens project

The Rethink Athens project (funded by European Union) implemented holistic urban cooling strategies to address urban heat, resulting in cooler air, cooler surfaces, enhanced pedestrian comfort, and significant energy savings. The project used natural elements, reflective surfaces, and sustainable materials to create a system of cooling strategies. The project also used ENVI-met software to model and simulate the impacts of design choices on the city's microclimate, predicting how green spaces, water features, and pedestrian-friendly zones would affect air temperatures and comfort. The project also delivered long-term economic gains, cutting air conditioning usage by over 20%, demonstrating the sustainability of holistic urban cooling strategies (Revitalising the historic city centre of Athens, 2013).

The accessible city

Panepistimiou Street Transformation Project

- Transforms Panepistimiou Street into a pedestrian-oriented boulevard.
- Aims to create a Shared Space 2.0, balancing slow traffic and motorized movement.
- Linking Omonia Square and Dikaiosynis Square to the green boulevard structure.
- Creates two green urban squares with lush water elements.
- Connects National University, National Library, and National Academy into an urban park.

Figure 30: location of the Rethink Athens project, source: Google earth


The accessible city


The green and resilient city


The vibrant city

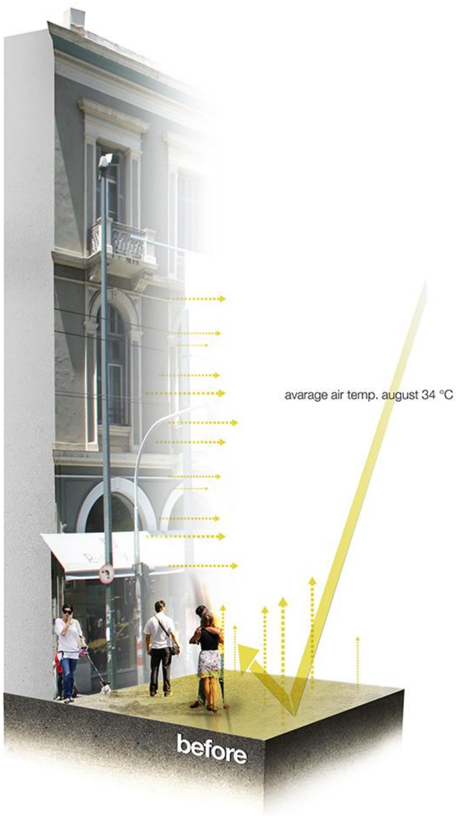
Green and Resilient City Concept in Athens

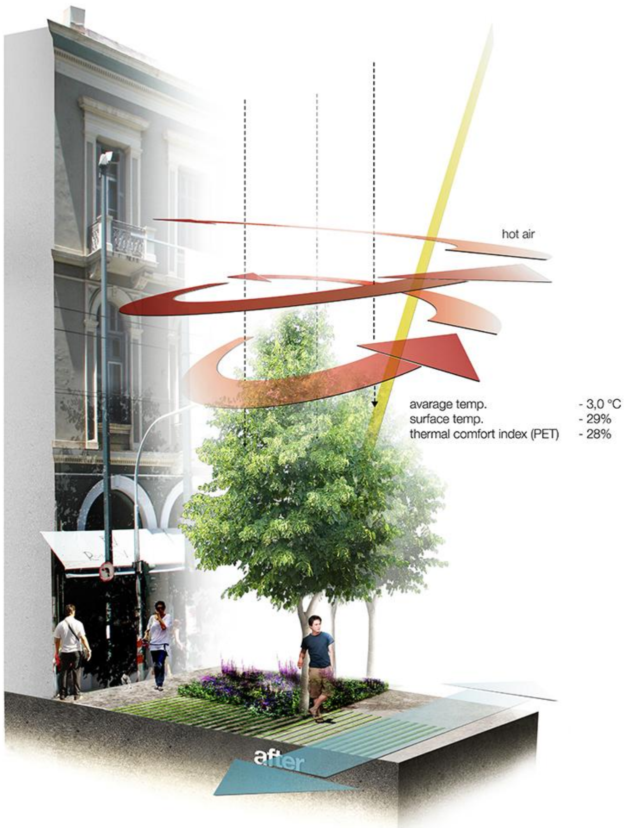
• Combines greening and sustainable water management to reduce urban heat.

• Panepistimiou Street to be central green spine.

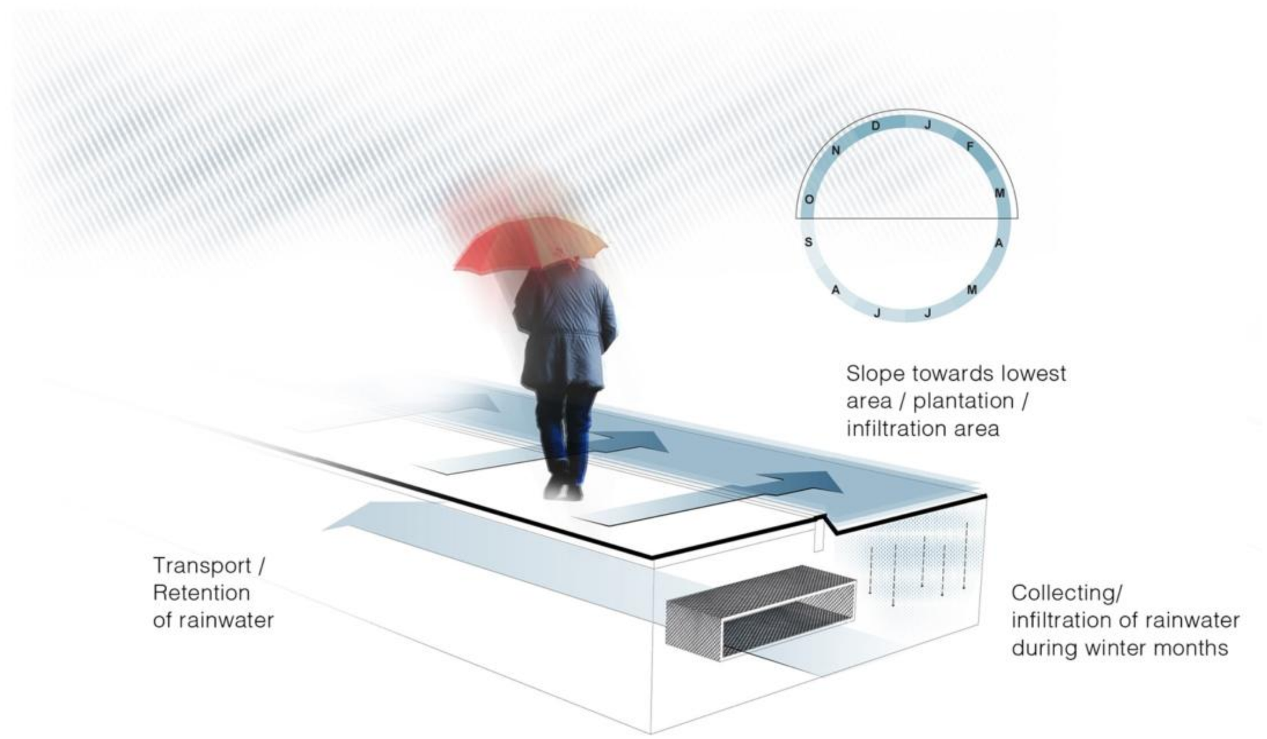
• Provides shade, shelter, and rainwater capture for sustainable re-use.

• Aims to further heat mitigation in Athens' public realm.

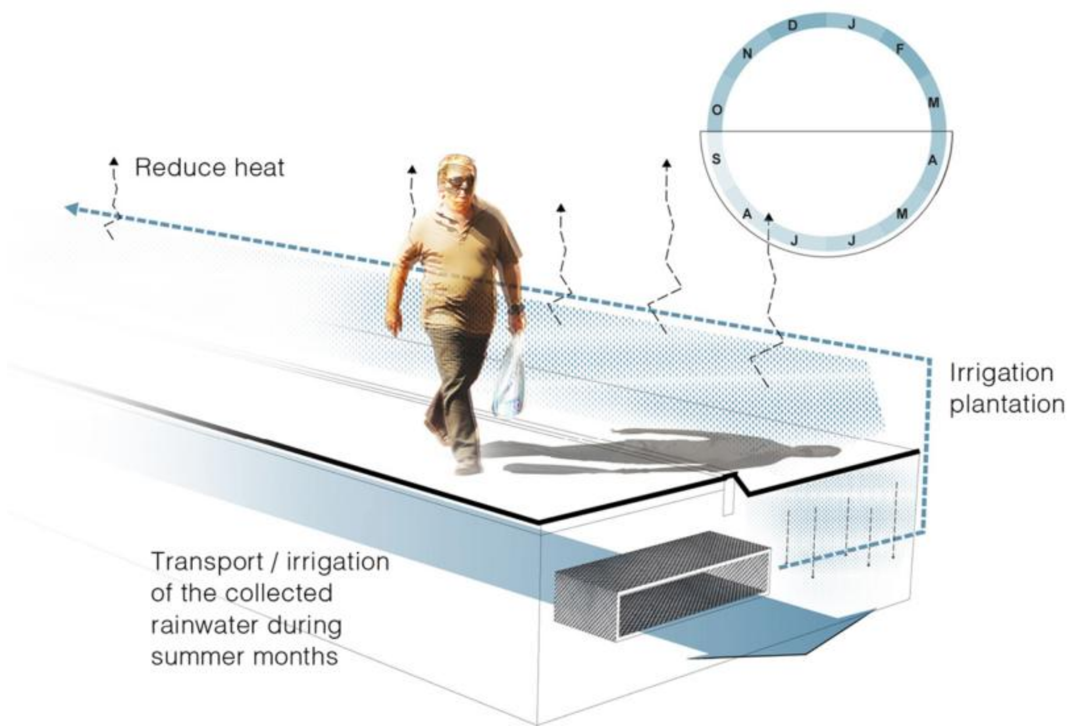




Retention



Irrigation



Project 2: Participation in two parks (Pedion Areos and Lofos Likavitou) with a green mass corridor

The project, begun in 2013, seeks to link two parks, Pedion Areos and Lofos Likavitou, through a continuous green mass that revitalizes the vegetation in an area beyond the old walls of Athens. The green corridor has protected trees, newly planted trees, a continuous surface inspired by olive tree branches, and artificial trees developed through bioclimatic activities (Urban Nature Atlas, 2021).

Challenges in Sustainable Development

• Climate action for adaptation, resilience, and mitigation (SDG 13).
• Mitigation of climate change.
• Restoration of habitats and biodiversity and green spaces (SDG 15).
• Environmental quality and air quality improvement.
• Regeneration, land-use, and urban development.
• Regulation of built environment.
• Promotion of natural landscape design for urban development.
• Improving health and wellbeing (SDG 5).
• Recreation opportunities.
• Preservation of natural heritage.
• Protection of cultural heritage.

Implementation Activities:

• Preservation of existing trees .
• Planting new trees.
• Creating a continuous floor pattern based on olive tree branches.
• Creating artificial trees for bioclimatic activities' purposes.
• Planting native species with lower resource consumption and better adaptation.
• Implementing sustainable agricultural practices with efficient irrigation and organic fertilizer.

Environmental Impact:

• Climate change and lower local temperature.

• Enhanced carbon sequestration.

• Improved environmental quality and air quality.

• Increased green space and habitat.

• Reduced biodiversity loss.

• Increased species presence

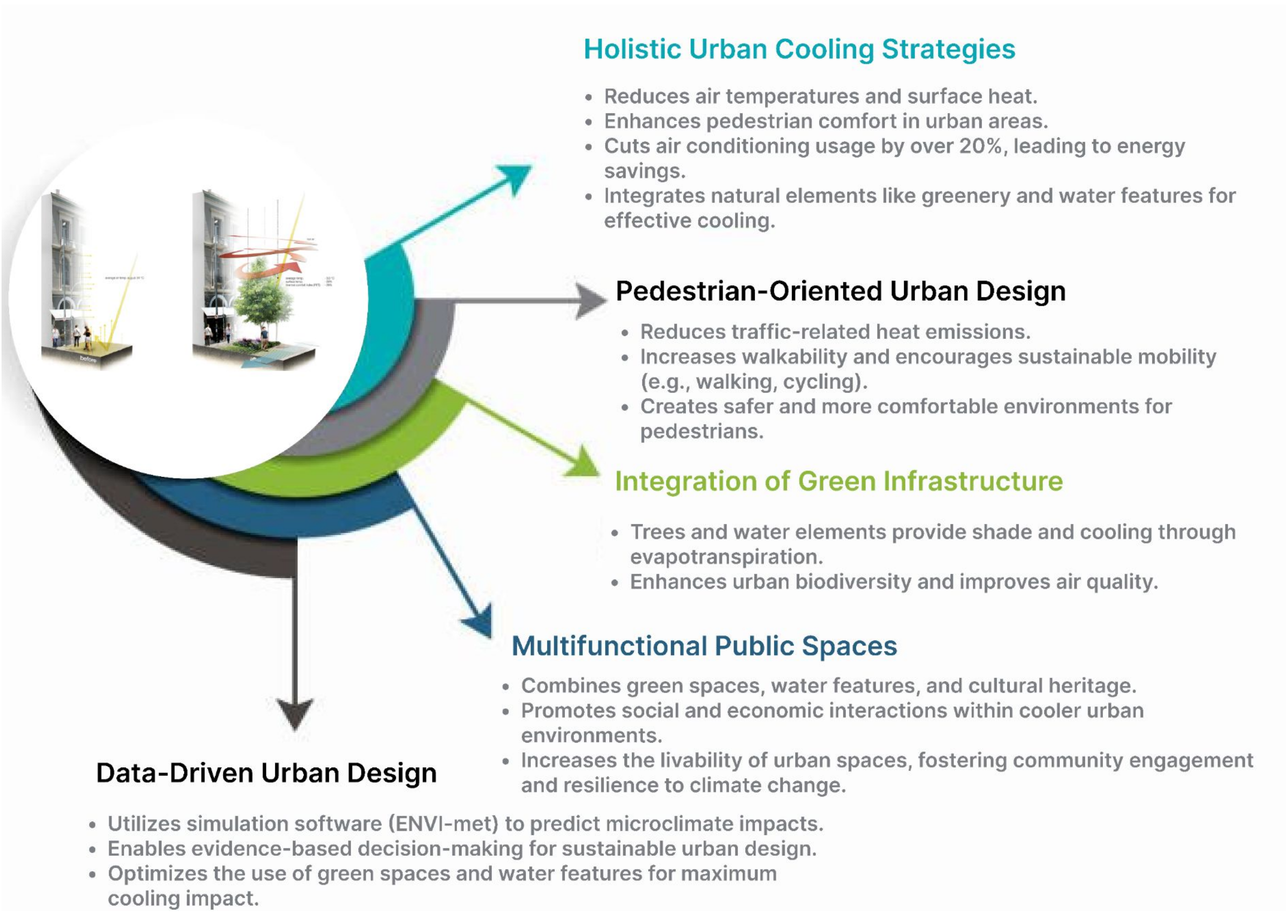
Figure 31: Park Pedion Areos and Lofos likavitou (source: Google earth)

Lesson Learned

The Rethink Athens project

The Rethink Athens Project and the Panepistimiou Street Transformation Project exemplify the advantages of cohesive urban cooling strategies. In order to lower surface temperatures, improve air quality, and enhance pedestrian comfort, The Rethink Athens project combines green areas, reflecting surfaces, water features and sustainable materials. The Panepistimiou Street Transformation project employs pedestrian-centric urban design to alleviate urban heat and improve livability. The initiative establishes eco-friendly urban plazas featuring aquatic components, fostering sustainable transportation and mitigating heat emissions. The project improves connectedness by integrating cultural and academic institutions with the urban environment. Both initiatives illustrate the significance of deliberate urban design in mitigating UHI effects and enhancing residents' quality of life.

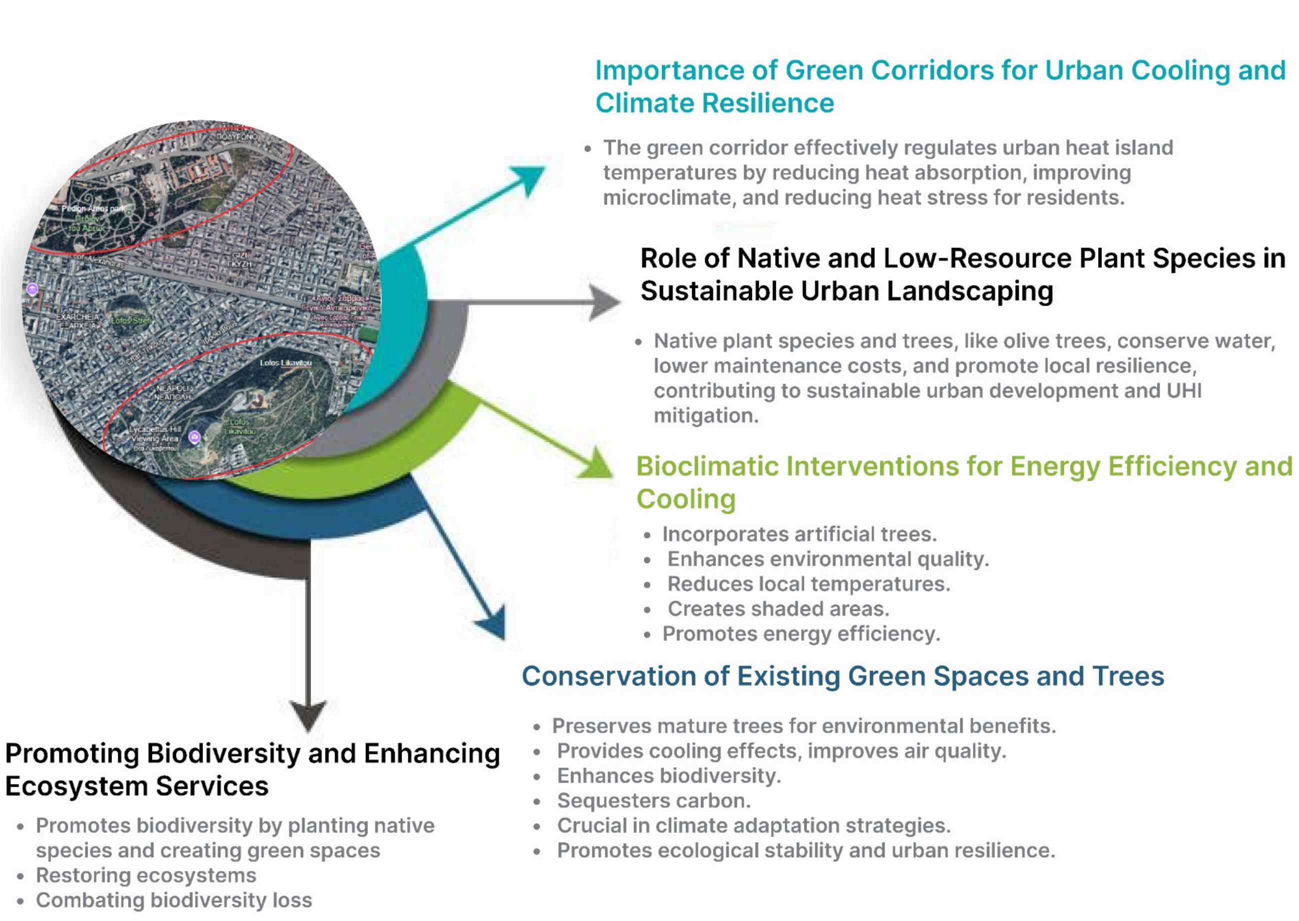
Figure 32: Summary of Rethink Athens project. Source: personal elaboration.



Participation in two parks (Pedion Areos and Lofos Likavitou) with a green mass corridor

The project focuses on creating a green mass corridor linking two parks, Pedion Areos and Lofos Likavitou, to strengthen urban cooling and climate resilience capacity. These corridors create shaded sections and expands the vegetation density, therefore controlling temperatures the urban heat island. Native and low-resource plant species are used in this project with the aim of reducing water consumption, fertilizers and maintenance requirements while at the same time promoting sustainable urban landscape. Bioclimatic interventions, such as artificial trees, improve environmental quality and reduce local temperatures. Maintaining mature trees in the project area enhances the environmental benefits of the green corridor, so generating immediate cooling effects, so improving air quality, enhancing biodiversity and carbon sequestration.The project also promotes biodiversity by planting native species and creating green spaces that support local wildlife. This helps maintain balanced urban ecosystems and improve environmental quality. On the whole, the project seeks to promote sustainable urban development and mitigate the impact of climate change.

Figure 33: Summary of lesson learned from Rethink Athens project. Source: personal elaboration.



CHAPTER 7

CASE STUDY: LISBON

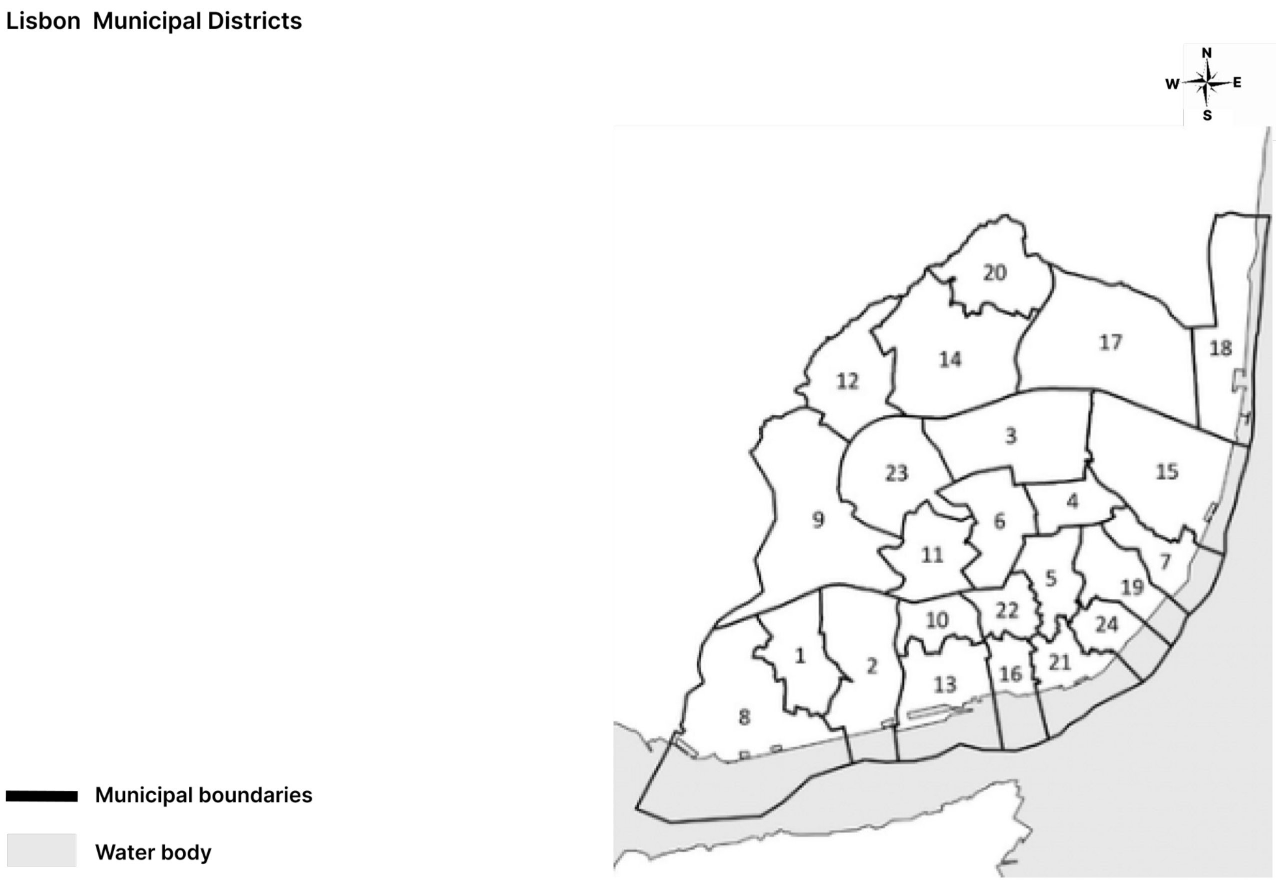
- ❖ Territorial and climate overlook description
- ❖ Climate action plan
- ❖ From lesson to project
- ❖ lesson learned

Territorial and climate overlook description

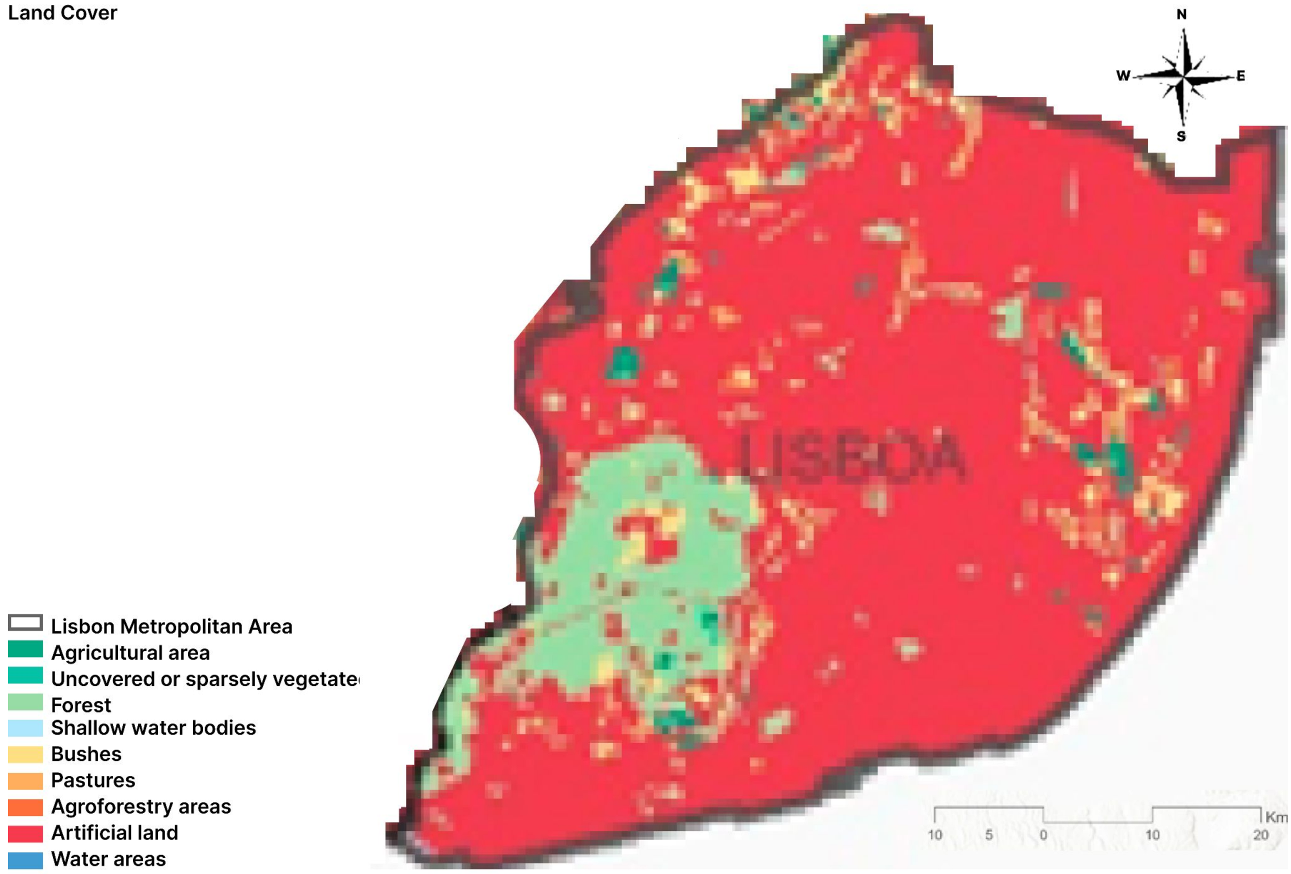
Territorial climate overlook description

Lisbon is situated on the western coast of Portugal, at a latitude of 38°43' N and a longitude of 9°9' W. The city is situated around 30 km east of the Atlantic Ocean. The right bank of the Tagus River. It encompasses an area of 84 km². It also is located in the Mediterranean hot-summer Mediterranean climate region (Köppen Csa class), however it is significantly influenced by the Atlantic which is located just a few kilometers to the west (Oliveira, Lopes, Correia, Niza, & Soares, 2021). Lisbon is explicitly divided into 24 municipal parishes, which is known locally as "freguesias." The main administrative entities of the municipality are the parishes, which each have local governments in charge of certain community services and activities. Map 33 shows Lisbon's municipal districts.

Map 35: Lisbon's municipal districts. Source: elaborated by Lestegás Tizón, Seixas, & Lois González, 2019.



Map 36: Lisbon’s Land cover map. Source: elaborated by Morgado & Cunha, 2023.

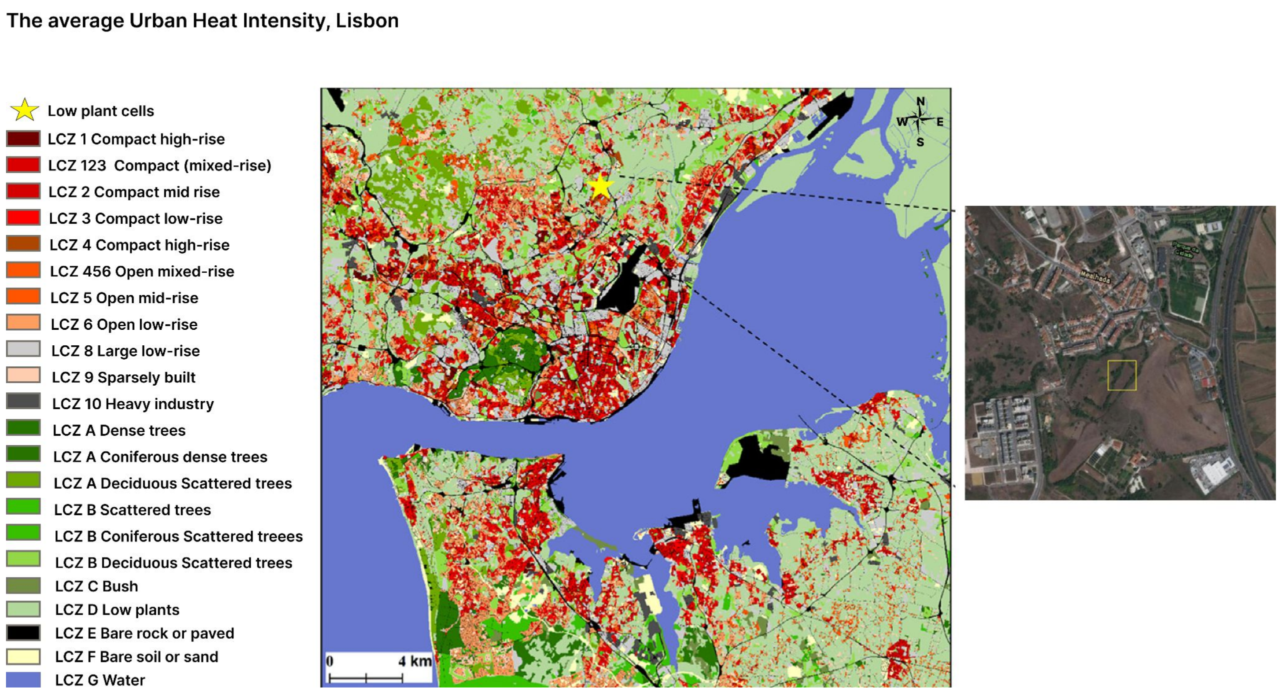


Lisbon, the largest city in Portugal, confronts increasing risks associated with climate change due to its geographical location and climate conditions. The annual average precipitation is declining, despite an increase in winter rainfall in the city. This results in extended droughts and increased seasonal flooding, diminishing soil water absorption and soil preservation. Simultaneously, average temperatures are rising by 1.4°C annually, with maximum temperatures potentially exceeding 5°C. Consequently, climate change will adversely affect the quality of life and health of Lisbon's citizens, as well as its urban green spaces (Climate Adapt, 2021).

Moreover, high-density urban regions and ventilation corridors in Lisbon contribute to average urban heat island effects of 1.7 °C and 0.2 °C, respectively. Land use also significantly influences the UHI effect in Lisbon, with continuous, vertical construction areas exhibiting the highest deviations, average +1.8 °C. In contrast, horizontal building regions exhibit an average deviation of +1.3 °C, whereas sparsely constructed, discontinuous areas demonstrate an average UHI effect of +0.2 °C. (Vilão & Ramos, 2024).

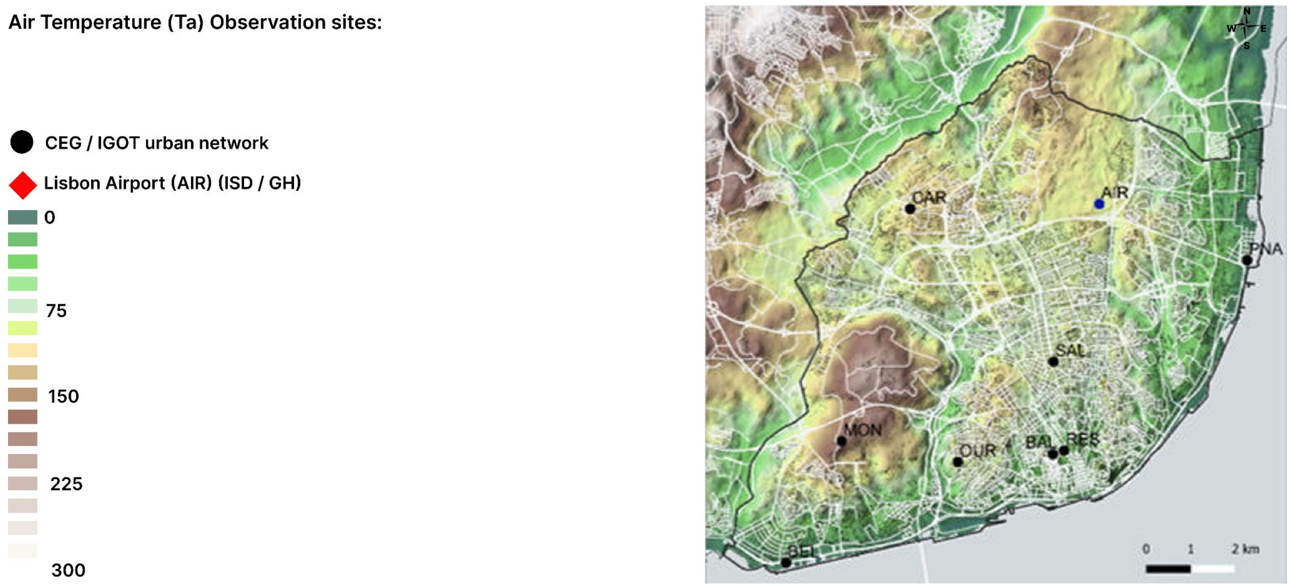
The following map is conducted by Reis, Lopes, and Nouri (2022) which illustrates the average urban heat intensity in Lisbon based on local climate zones (LCZ).

Map 37: Average Urban Heat Intensity in Lisbon

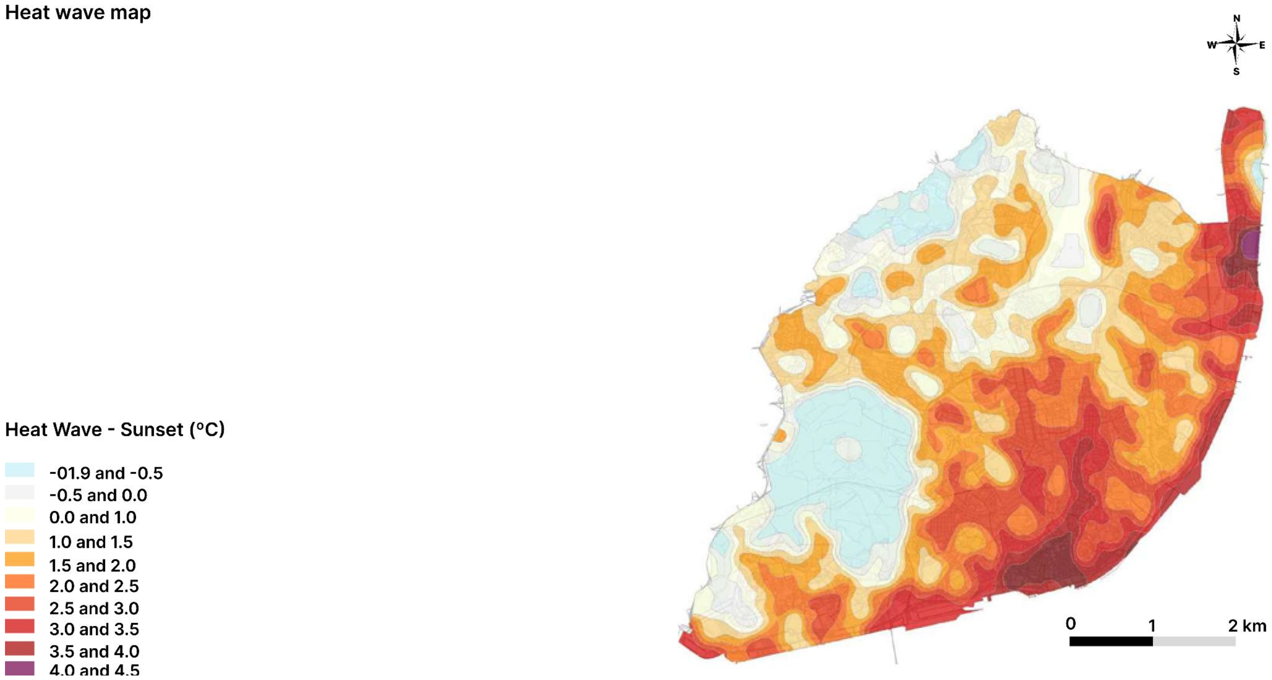


The following maps that shown in the research conducted by Oliveira, Lopes, Correia, Niza, and Soares (2021) relies on data sourced from the Institute of Geography and Spatial Planning a and Central of Geographical studies (IGOT-CEG). Figure 47 depicts the terrain elevation of Lisbon, with a particular emphasis on the Lisbon CEG/IGOT and AIR elevation levels. And figure 48 represents Lisbon's heat wave condition.

Map 38: Lisbon's terrain elevation

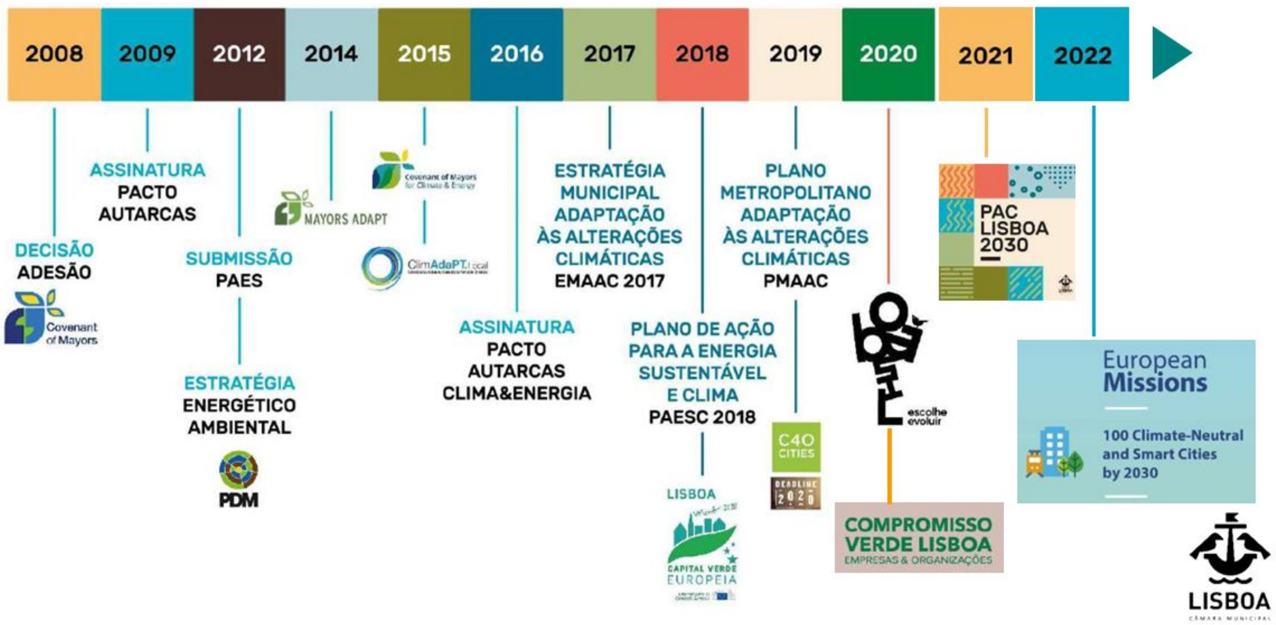


Map 39: Heat Wave map of Lisbon. Source: (Parks and Garden of Lisbon, 2022).



Climate Action Plans

Climate Action in Lisbon (Commitments and targets)



PAC Lisboa 2030

The main objectives of this Climate Neutrality Goals: are:

• Reduction of 70%-85% GHG emissions by 2050.

• Adaptation and resilience to extreme weather events.

• Inclusive and fair transition to tackle inequalities and energy poverty.

Name & Title	1- 2030 Lisbon Climate Action Plan (2030 PAC)
Description	Instrument for integrating and managing the city's policies on mitigation and adaptation to climate change, for eradicating energy poverty, and for promoting quality of life and well-being. It sets the target of reducing greenhouse gas emissions by 70% by 2030 compared to the base year of 2002, and between 85% and 90% by 2050.
Type	Action Plan
Level	Local
Relevance	High
Need for action	Comply with the proposed schedule and current legislation Alignment of CCC Lisbon 2030 with current policies at the local, regional, national, and international/EU scales.

Climate-neutral and climate-smart Lisbon in 2030

According to the rule 12 on this document, the municipal climate action strategy focuses on implementing adaptation measures to address Urban Heat Island, extreme temperatures, water scarcity, and floods. This includes consolidating nature-based solutions for water retention, implementing the "cool down the city" program to mitigate urban heat island effects, through establishing rules for green roofs and vertical gardens, enhancing soil permeability and the incorporation of trees in streets and squares, with the reinforcement of water bodies (Net Zero Cities, 2024).

The following table shows the climate neutrality and impact scenarios which is specifically works for Urban Heat Island adaptation and mitigation.

Sector	Systemic levers	Early changes	Late outcomes	Emission reduction
Transport & Mobility	Technology, Infrastructure, Financing, Investment, Social Innovation, Democracy, Participation, Learning, and Empowerment	• Prioritizing access to public transport. • Creating public spaces for soft modes. • Investment in electrification. • Creation of green micro logistics areas.	Public Transport Infrastructure Development • Exclusive infrastructure for public transports. • Expansion of PT railway network. • Creation of pedestrian/mixed areas. • Total conversion of public and commercial fleets to electric mobility. • Reduction in emission areas. • Reduction in city vehicle circulation. • New legal framework for vehicle circulation restriction. • Integration of real-time IT platforms on public transports.	608 ktCO2e - 72%

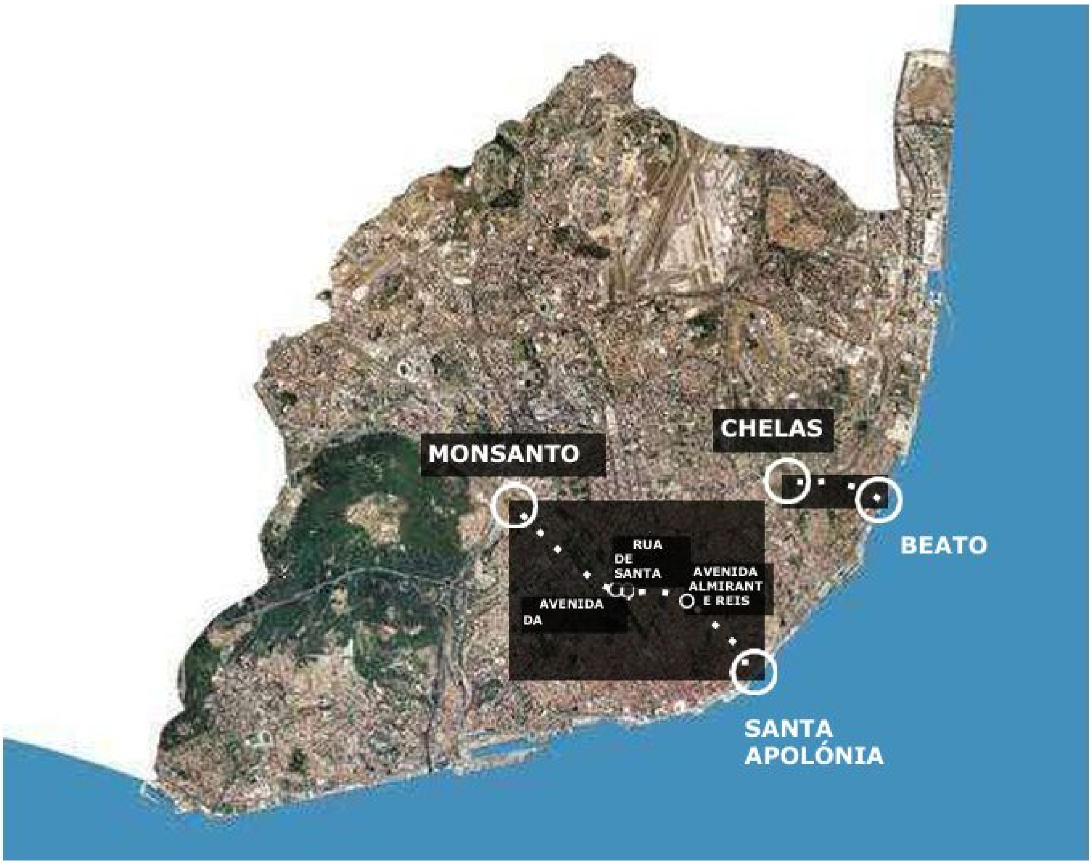
Green infrastructure	Technology, Infrastructure, Financing, Investment, Social Innovation, Democracy, Participation, Learning, Empowerment	Planting of alignment trees and shrubs Completion of connecting green areas (green corridors)	• City Green Space Creation • Renaturalizing depressed areas. • Increasing climate regulation through vegetation cover. • Safeguarding and promoting biodiversity.	-
Water	Technology, Infrastructure, Financing, Investment, Social Innovation, Democracy, Participation, Learning, Empowerment	• Improving Water Efficiency • Installing drinking fountains. • Utilizing recycled water.	•Recycled Water Network for Green Areas • Prepared for climate events. • Includes new permeable areas.	-
Spatial planning & public space	Technology, Infrastructure, Financing, Investment, Social Innovation, Democracy, Participation, Learning, Empowerment	• Public Space Adaptation • Incorporation of natural-based solutions like vegetation. • Adoption of water and energy efficiency measures.	• Public Space Intervention • Creation of protected areas for extreme events. • Implementation of climate shelters. • Energy transition in city's port services. • Increased resilience in extreme weather events coordinated at metropolitan level.	

Lisbon Drainage Master Plan 2016-2030

The Lisbon Drainage Master Plan (PDL) is a strategic plan designed to modernize the city's water infrastructure to accommodate increased precipitation intensity and frequency while guaranteeing water sustainability. The plan concentrates on two crucial drainage tunnels, one under Avenida da Liberdade and the other in Chelas-Beato, planned for to efficiently redirect extra rainwater into the Tagus River. It also include the construction of retention basins and green infrastructures to mitigate runoff and enhance water system management.

The PDL highlights the use of nature-based solutions, such green roofs and urban green spaces, to enhance hard infrastructure and mitigate urban heat islands (UHI). These green infrastructures manage metropolitan temperatures by absorbing heat, enhancing evapotranspiration, and generating additional shady places. The plan stands for for the reuse of treated wastewater for irrigation and urban cooling, enhancing water efficiency and alleviating the urban heat island effect during heatwaves. The anticipated outcomes comprise a substantial decrease in urban flooding, increased climate resilience, and strengthened urban livability.

Figure 34: The location of drainage tunnels. Source: (Lisbon Drainage Master Plan 2016 - 2030).



From Plans to Projects

Project 1: Life LUNGS 2019-2024

The LIFE LUNGS project encompasses six implementation actions:

1. Biodiversity meadows

   Biodiverse dryland grasslands, unlike grass requiring daily irrigation, adapt to seasonal changes while supplying sustenance for sheep and pollinating insects. This initiative encompasses the installation, enhancement, and management of biodiverse dryland grasslands in the Parque Bela Vista and Alto da Ajuda regions, serving as a climate-resilient alternative to traditional urban lawns.

2. Flock of sheep

   Sheep came back in Lisbon and are replacing traditional vegetation management machinery, enabling in soil conservation and blending into the ecosystem. Trained shepherds accompany them, engaging with the community to raise awareness and spread knowledge, therefore conserving the traditional practice.

3. Water management

   Water scarcity and intense precipitation events are two primary consequences of climate change in Lisbon. This initiative seeks to address these through water management strategies.

4. Planting trees and shrubs

   Green infrastructure is essential for climate adaptation, particularly in urban areas experiencing the urban heat island phenomenon. Integrating green infrastructure can enhance adaptation. Trees are a good solution for mitigating the heat island impact, as they lower surface temperatures. The extensive cultivation of trees and bushes in diverse locations, such as streets, can offer shade directly to building and walkways.

5. Open desk office

   The project seeks to optimize outcomes in more urban green spaces, whether controlled by the Lisbon City Council or privately, to improve climate change adaptation.

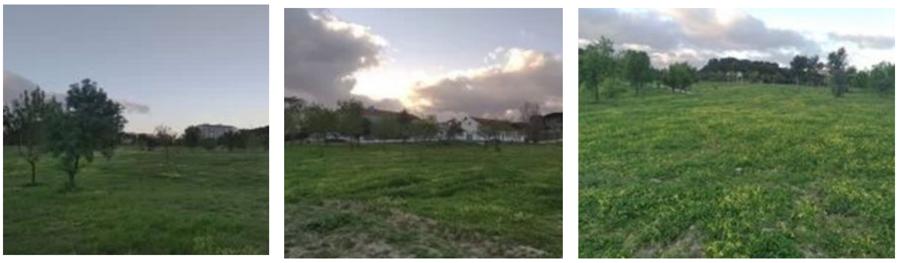
6. replication and transfer

to tackle climate adaptation challenges in European cities, particularly southern ones, by promoting green infrastructure and implementing practical measures. It also plans to replicate successful practices in other municipalities, like Málaga, to increase adaptation efforts across Europe.The project aims to maximize its results in other urban green areas, not directly covered by it, owned by Lisbon City Council or privately, to enhance climate change adaptation (Life LUNGS Project, 2021).

Figure 35: Life LUNGS actions' catalogue

Actions

Biodiverse meadows



Flock of sheep

Water management

Planting trees and shrubs

Project 2: City cooling project

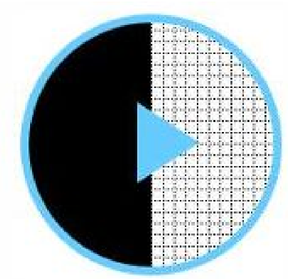
Micro-scale solutions that contribute to city cooling:

- More trees

  Trees absorb CO_2, a pollutant contributing to global warming, by evapotranspiration, generating humidity and cooling air, while also providing shade and a barrier against solar radiation.

- More pedestrian mobility
- less traffic

  Vehicle traffic releases heat energy through combustion in engines, causing anthropogenic heat and air pollutants that exacerbate heat retention in cities.

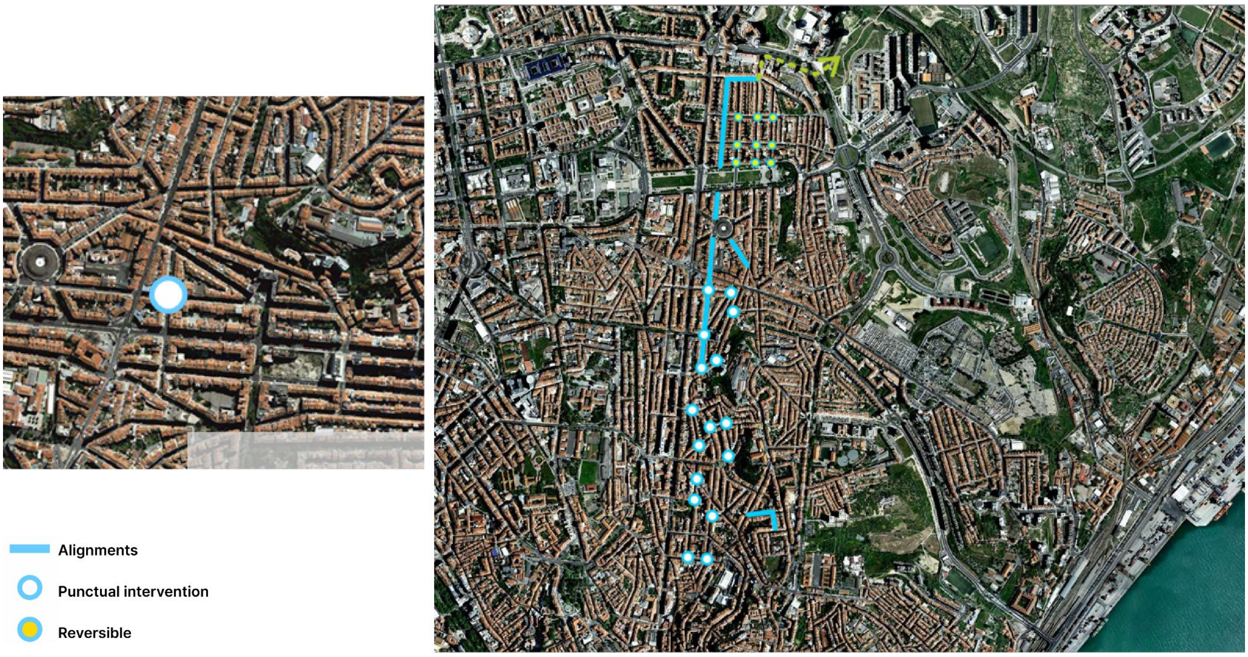


- More sidewalks
- less bituminous

  The use of lighter-colored materials on pavements can enhance the reflection of solar energy, thereby reducing heat absorption.

Source: Cooling the City Program, 2022.

Figure 36: The location of the city cooling project



The planting of eight trees in public spaces has improved air quality, thermal regulation, and pedestrian comfort. This has led to increased pedestrian space and improved access to local commerce. The adaptation of pedestrian crossings, the introduction of tactile flooring, and the relocation of public space elements have improved accessibility. Safety measures include reduced speed at intersections, reduced crossing distance, and increased visibility between drivers and pedestrians through mowing corners and bicycle parking.

Figure 37: Proposal of cooling the city project

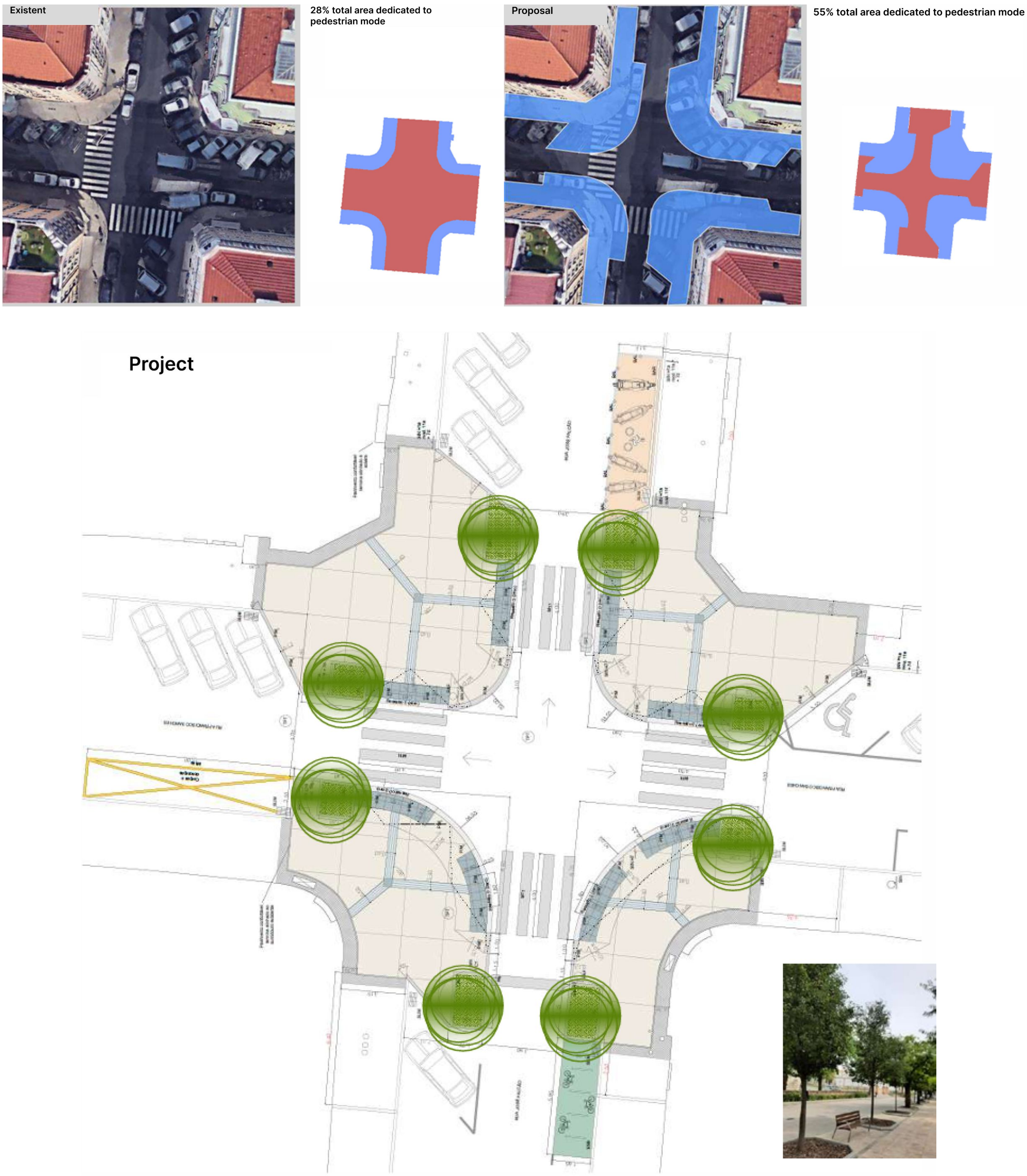


Figure 38: Punctual intervention on R. José Falcão / R. Cavaleiro de Oliveira

Figure 39: Punctual intervention on R. City of Manchester / R. Poeta Milton

Figure 40: Punctual intervention on R. José Falcão / R. Cavaleiro de Oliveira

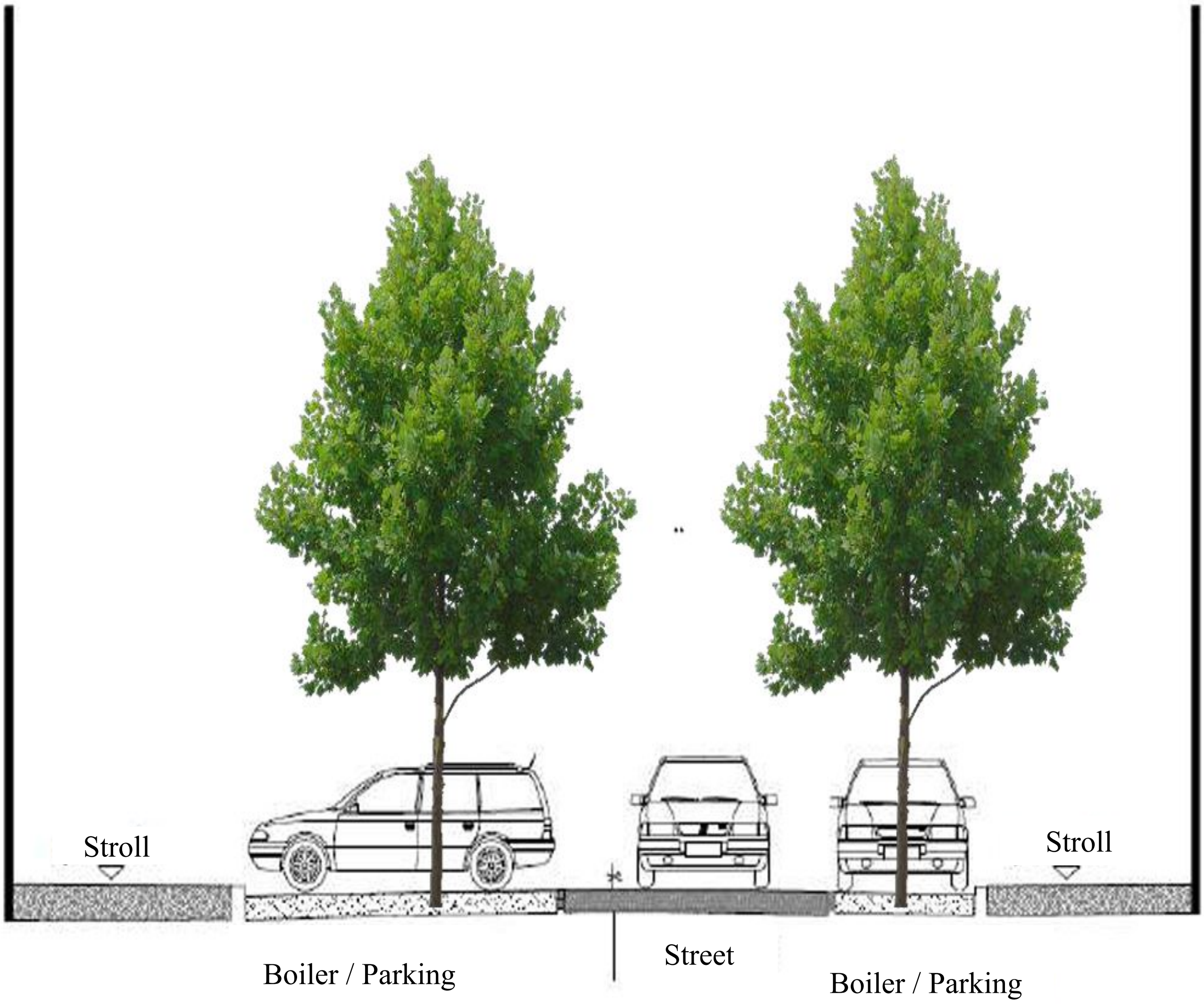


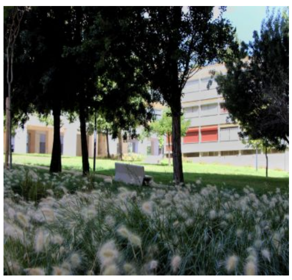
Figure 41: Reversible Intervention on R. Atriz Virgínia / R. Abade Faria

Project 3: Green Corridor

The new green corridor at Avenida Estados Unidos da América in Lisbon is a 10,000 m² project designed by landscape architect Gonçalo Ribeiro Telles to revitalize urban space and promote sustainable practices. The corridor features a continuous pathway with green elements like arboreous vegetation and blooming gardens, aiming to minimize maintenance and address climate change. The project promotes urban cooling, biodiversity, and reduced carbon footprint, and is part of Lisbon's expanding green infrastructure, enhancing urban livability and well-being (Green Corridor in Lisbon, 2022).

Figure 42: Green corridor plan

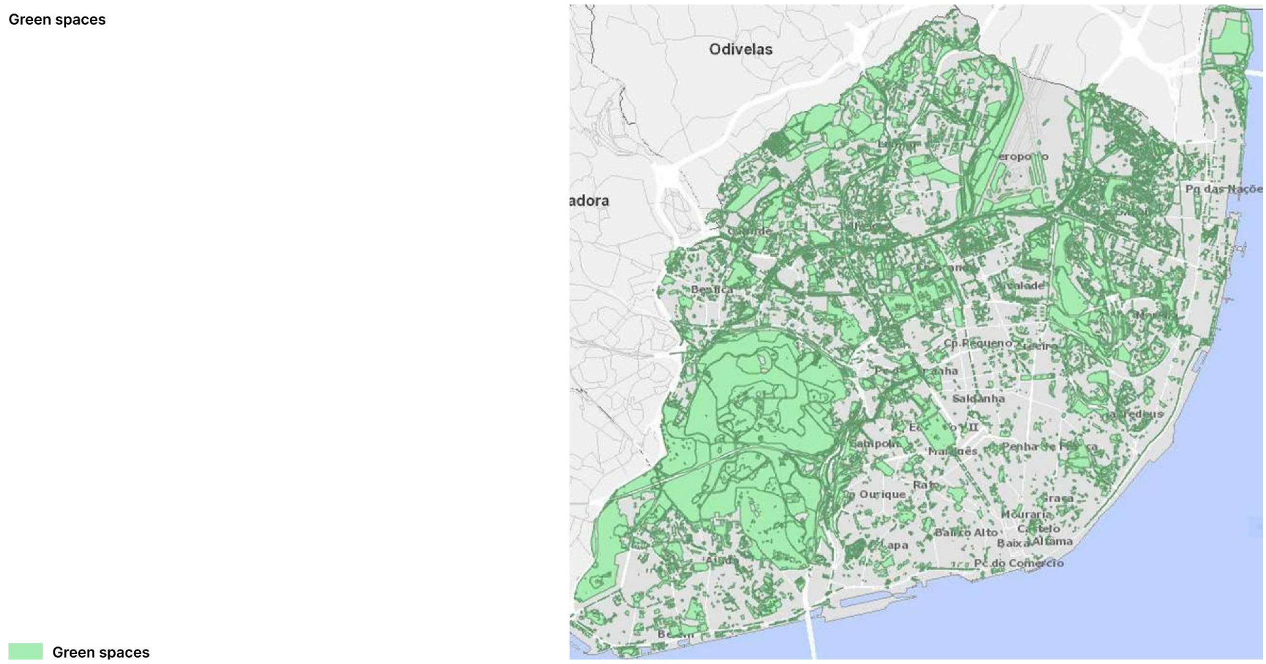






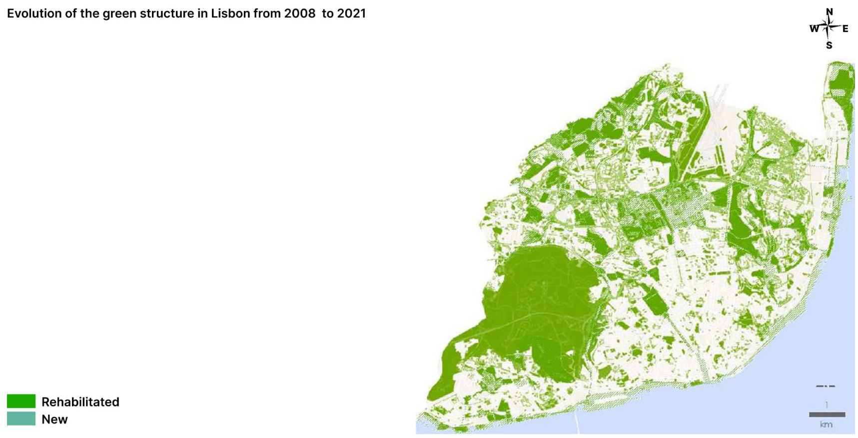
The Green Spaces mapped as for public or semi-public use in the Municipality of Lisbon occupy a gross area of approximately 2,900 ha, which represents about 30% of the area of the Municipality

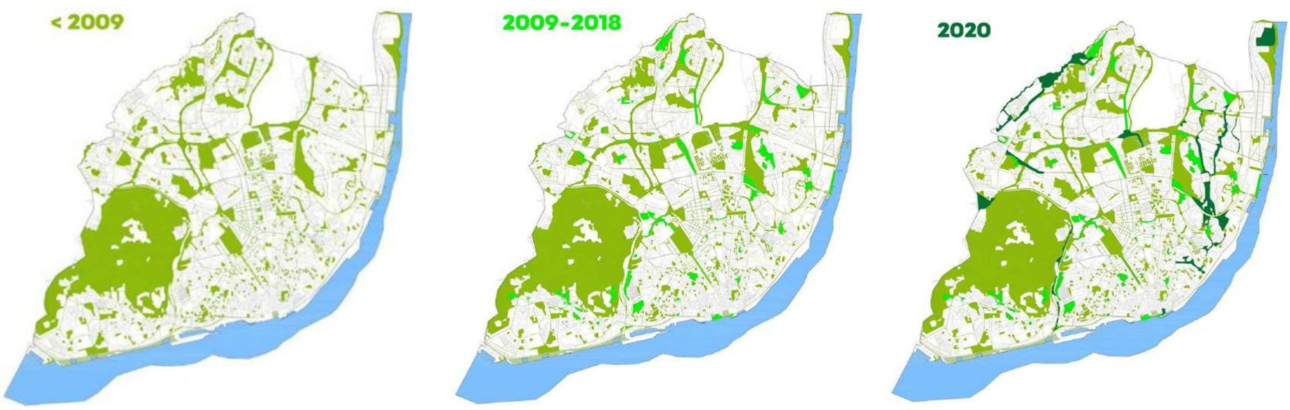
Map 40: Characterization of green spaces in Lisbon. Source:(Parks and Garden of Lisbon, 2022).



Map 41: Evolution of Green Spaces in Lisbon

According to Climate-neutral and smart Lisbon in 2030, lisbon has more than 350 ha green spaces in 2021 compared to 2008.

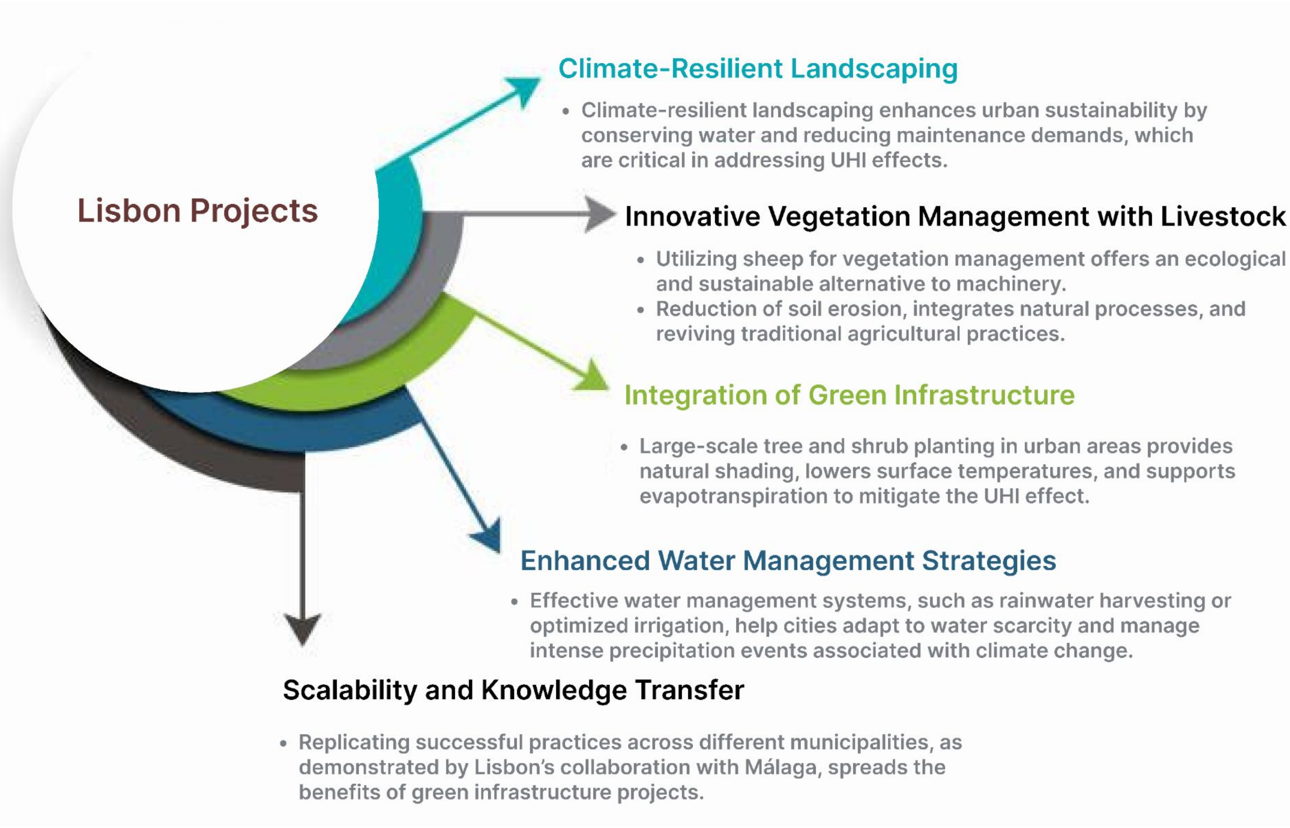




Lesson Learned

The initiative aims to mitigate urban heat island (UHI) effects through the implementation of sustainable solutions. Biodiversity Meadows serve as a climate-resilient solution to enhance natural cooling and diminish irrigation requirements in urban environments. Sheep grazing serves as an ecological land management technique, diminishing dependence on mechanical equipment and mitigating soil erosion. Effective water management solutions are employed to address extreme weather events and maintain the resilience of green spaces against heat. Tree planting is essential for reducing urban heat islands by offering shade, reducing surface and air temperatures, and enhancing urban microclimates. Extensive tree planting initiatives are crucial for Urban Heat Island (UHI) planning. The project's emphasis on duplicating effective green infrastructure strategies throughout municipalities illustrates the scalability of UHI solutions. The exchange of knowledge and collaboration across cities guarantees the widespread use of optimal practices, hence enhancing urban resilience. A comprehensive strategy that integrates tree planting, biodiversity meadows, and ecological land management can yield substantial cooling effects, enhance biodiversity, and promote community involvement in urban heat island solutions.

Figure 43: Summary of Lisbon’s project. Source: Personal elaboration.



CHAPTER 8

CASE STUDY: BERLIN

- ❖ Territorial and climate overlook description
- ❖ Climate action plan
- ❖ From lesson to project
- ❖ lesson learned

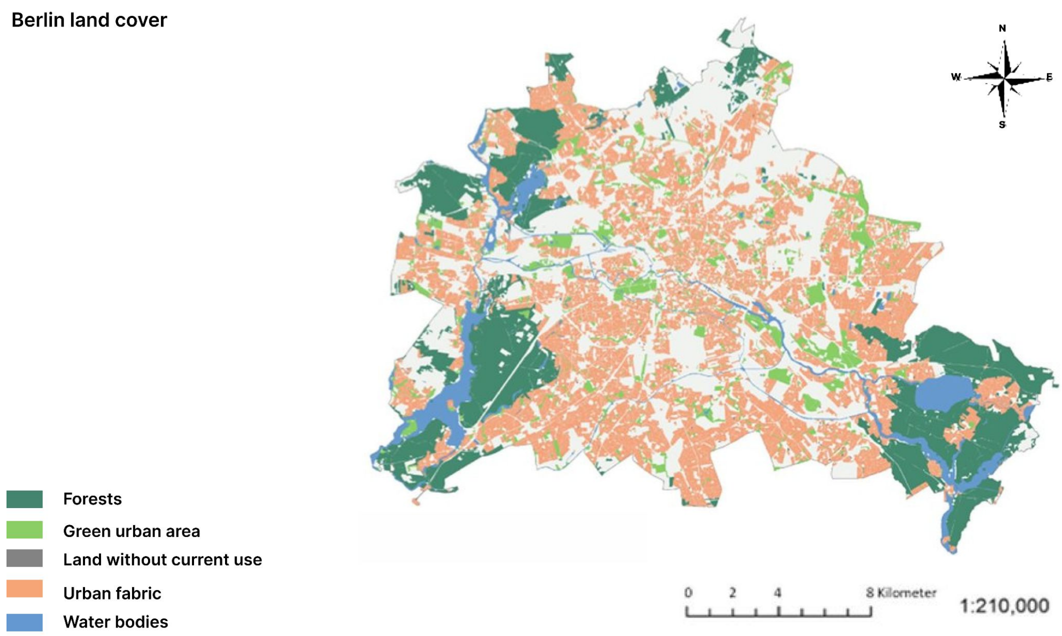
Territorial and climate overlook description

Territorial climate overlook description

Berlin, Germany's capital, is located in the northeastern European Plain, connected by rivers like the Spree and Havel. The city is divided into 12 administrative districts, each with its own local government and administrative responsibilities. The following map represents Berlin’s municipali boundaries.

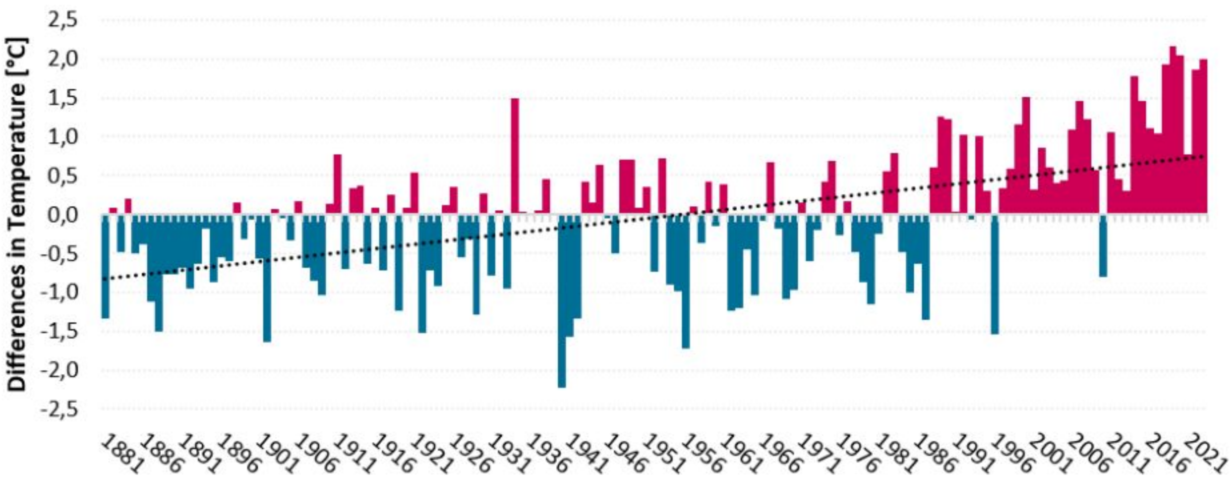
Map 42: Berlin Municipal districts. Source: Berlin.de Das offizielle Hauptstadtportal.

Map 43: Berlin Land cover . Source: elaborated by Kühn et al., 2017.



With an average daily maximum temperature of 1.2°C and a distant increase of 3.2°C, Berlin's climate is anticipated to see a notable rise in temperatures in not too far future. Autumn and winter will especially help one to observe this rise. Berlin's summers will also get warmer; mid-century temperatures will reach 1°C and end-century temperatures will run about 3°C.
With August showing the strongest warming trend, Figure 27 addresses the temperature anomalies from 1881 to 2023 showing a significant linear increase in temperatures across all months. This produces, in all seasons, much higher average temperatures than in the beginning of records.

Figure 44: Berlin - Temperature Anomaly 1881 -2023. Source: dibek. Berlin.

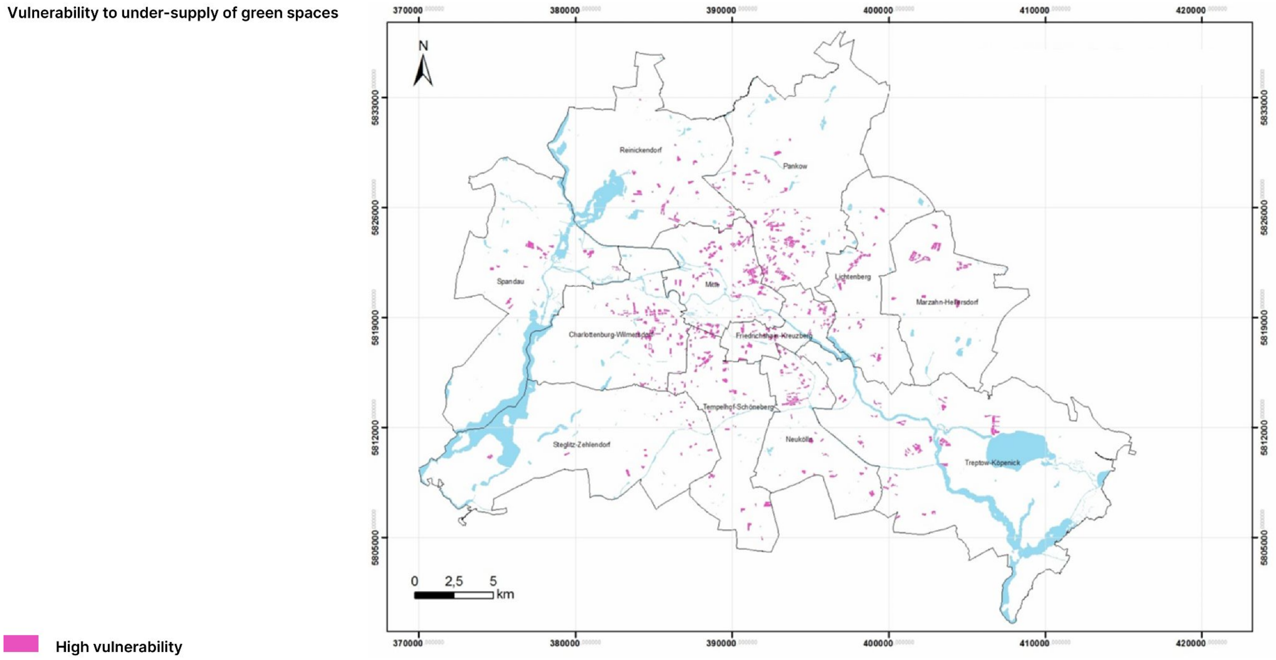


Berlin confronts urban heat island issues caused by rapid urbanization, high building coverage, and insufficient vegetation in some urban areas. Urban Heat Island phenomenon in Berlin gives rise to elevated temperatures in urban centers which affects vulnerable groups who are at risk such as the elderly and individuals with chronic health conditions, hence, it increases public health issues.
Temperature difference in Berlin also range from 4 to 10 °C. Furthermore, building and heating sectors account for more than 40% of CO2 emissions, with fossil fuels, for instance, oil, gas and coal which contributing more than 90% of the city's heat. (The official capital portal).
In addition, Berlin is disproportionately affected by climate change owing to its high local warming and urban heat island impact. the city has experienced changes in private transportation sector, land use and land sealing. In order to tackle with these issues, Berlin is actively collaborating with other cities and international city networks like C40 Cities, the EU Covenant of

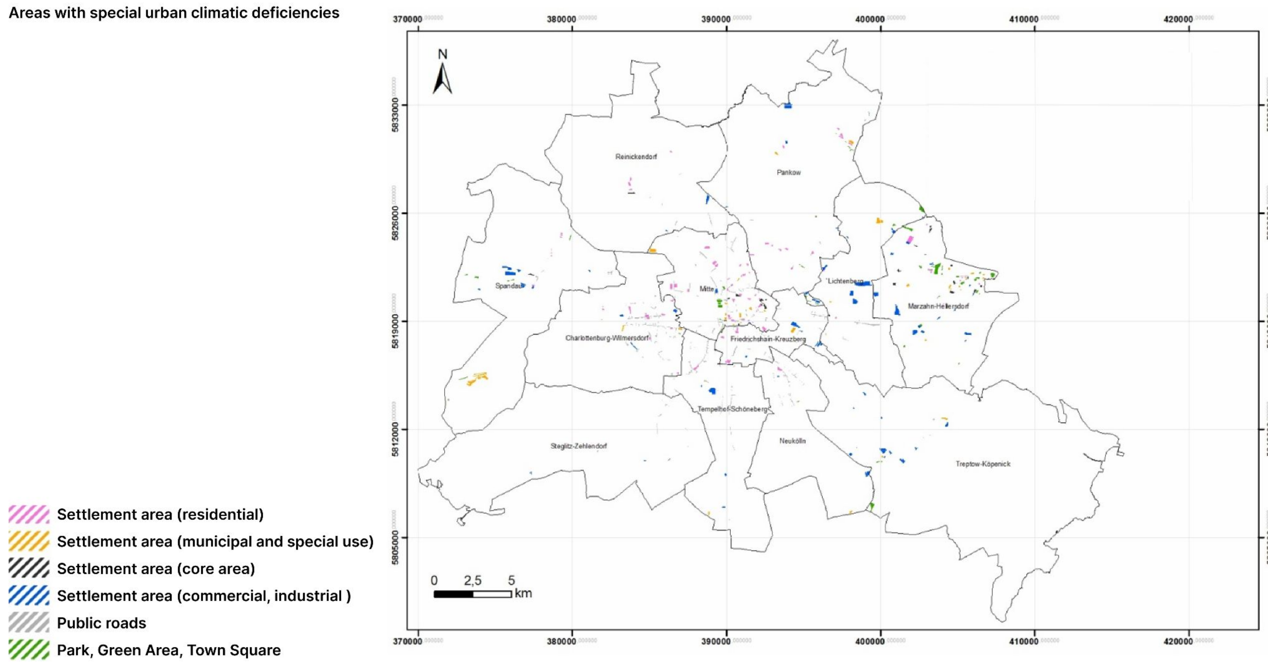
Mayors, and the Climate Alliance to provide a united voice for climate protection.

Map 38 illustrates spatial representation of areas with a particular vulnerability to the urban climate due to a shortage of green spaces in Berlin.

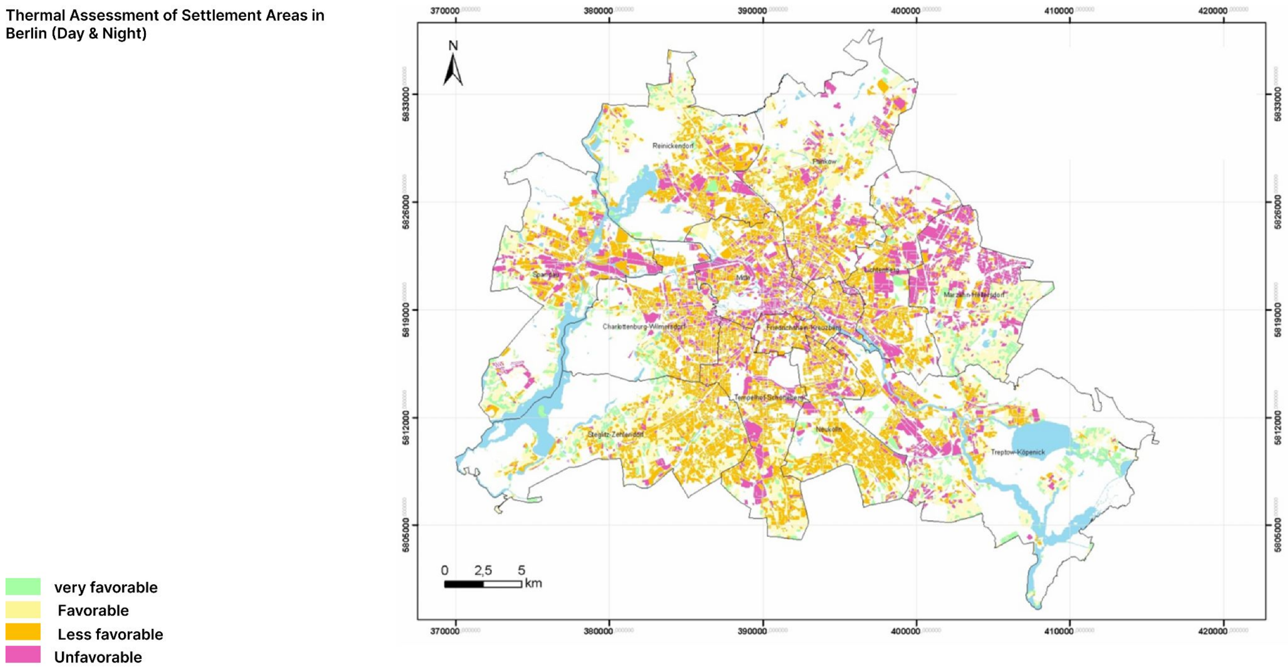
Map 44: Vulnerable area to urban climate change impact. Source: (Urban Development Berlin - Environmental Atlas).



Map 45: Areas with special urban climatic deficiencies in Berlin. Source: (Urban Development Berlin - Environmental Atlas).



Map 46: Spatial distribution of the assessment classes for the overall thermal situation in the settlement areas (linking of day and night situation). Source: (Urban Development Berlin - Environmental Atlas).



Climate Action Plans

The BEK 2030

The BEK 2030 is a citywide effort in Berlin focused on climate protection and mitigation to become climate-neutral by 2050. It encompasses strategies to mitigate CO2 emissions, including energy use in buildings. The project promotes emission reductions, fosters collaborations with commercial partners, and endorses climate protection initiatives in educational institutions. Initiatives encompass roof greening and the Berlin Rainwater Agency for the effective utilization of rainwater. So, the core objective of the BEK 2030 is an integrated strategy that responds to climate protection. and climate change mitigation.

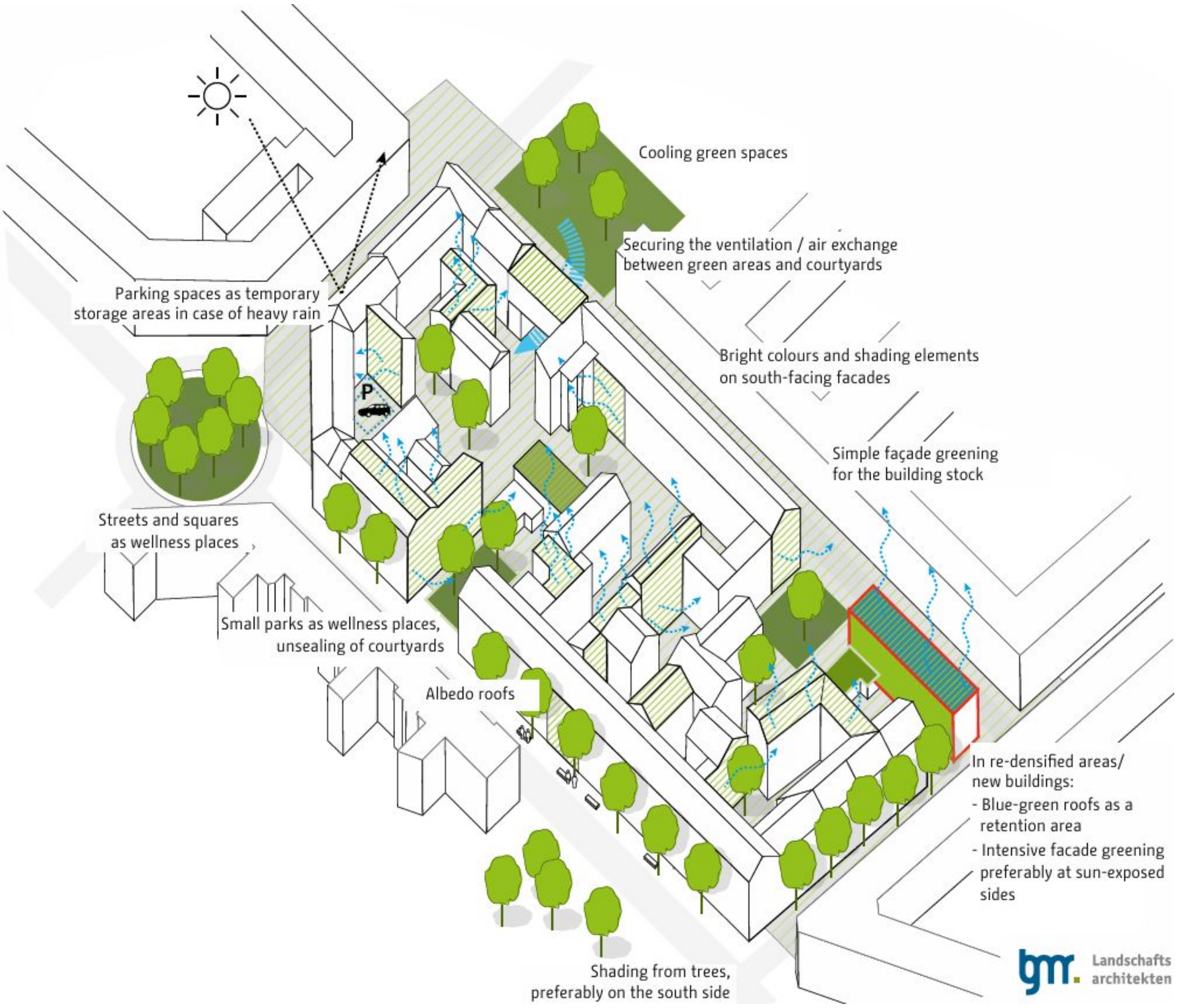
According to Berlin Energy and Climate Programme 2030 and Berlin Climate Action Plans, Berlin's long-term climate protection instruments also include the Berlin ImpulsE program, which promotes energy efficiency through educational programs for companies, public institutions, and households. Since 2015, BENE has funded initiatives focusing on energy efficiency, sustainable transportation, and green areas, resulting in the prevention of around 38,000 tons of CO2 emissions annually

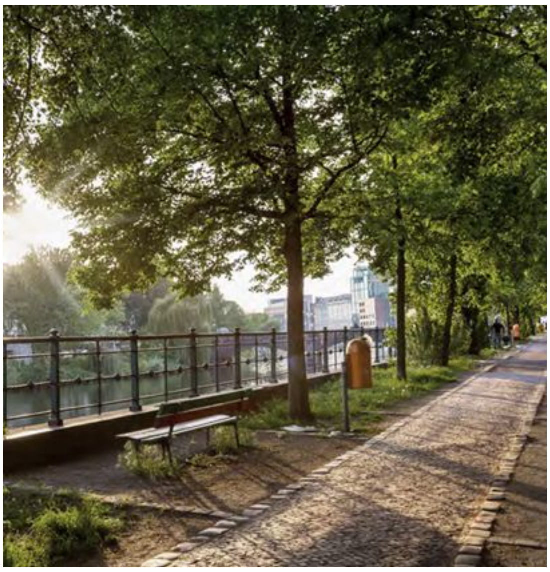
Adapting to Urban Heat Island impacts

The core urban areas of Berlin's S-Bahn Ring are 5°C warmer than the surrounding areas, despite being a compact city of short distances. So, adapting for UHI offers more advantages for climate protection, but also it requires more open urban fabric and de-densification for effective climate adaptation. Berlin can achieve both more housing and climate relief through effective planning. By considering the density and multiple functions of urban green surface area, Berlin’s green spaces can gain benefit from cooling and evaporation. the core objective of these initiatives is to reconstruct and strength urban landscape while preserving the quality of life throughout climate change. This can be accomplished by safeguarding vital green and open spaces, implementing systematic roof and facade greening, enhancing existing urban greenery and vegetation and also rendering impermeable surfaces permeable to rainfall,along with incorporating green comfort zones into urban districts. Moreover, a unique approach to water management in the city complements these tangible measures.this strategy enables Berlin to grow and develop in a climate-adapted way even without increasing its green areas.

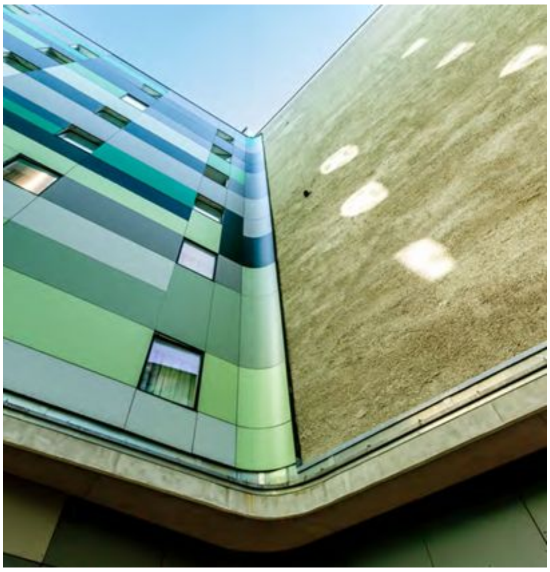
Figure 64 depicts adaptation potential in the compressed perimeter block development.

Figure 45: Adaptation potential in Berlin. Source: (Adapting to the Impacts of Climate Change in Berlin – AFOK, 2016).





Shadowed public spaces in the urban centre



Heat protection unoptimized facades

Heat Planning Act, WPG

Berlin's buildings ministry is implementing a heat protection strategy that concentrates on six main areas: shading heat-stressed areas, urban greening, building adaptation measures, natural cooling and sponge city model.These strategic solutions aim to cut back on heat in urban structure, provide instant relief from increasing temperatures and make hydration cooling more accessible to vulnerable populations. The approach also consists of unsealing asphalted surfaces for natural cooling, installing drinking water fountains and public showers. In addition to implementing the sponge city model, in order to manage flood hazards and enhance ecological infrastructure. These initiatives aim to mitigate the urban heat island impact and improve climate resilience in Berlin which are presented in the following figure (Leitfaden Wärmeplanung, 2024)

Figure 46: Berlin's urban heat strategies. Source: personal elaboration

Urban Development Plan for Climate Adaptation - Berlin 2016

The 2016 Urban Development Plan for Climate Adaptation in Berlin seeks to establish a water sensitive urban development and a heat resilient city which the main concentration is on social, ecological, and economic measures while neglecting to consider the impacts of climate change. The plan intends for developing tools and strategies for integrating adaptation measures into planning process, programs and initiatives and illustrating exemplary practices from local projects. It also supports STEP Klima Plan (2011).

The plan emphasizes nature-based solutions in green facades, roofs, courtyards, blue-green streets, tree planting, bioretention, rainwater gardens, urban wetlands, parks, and sustainable urban drainage systems (INTERPALACE HUB, 2023).

From Plans to Projects

Berlin has not implemented specific projects focusing on urban heat resilience at the ground level, despite its extensive research and analysis of available data. Also, aside from implementing urban greening and climate adaptation strategies like green roofs and the "sponge city" model, there is a lack of documented ground-level interventions specifically designed to mitigate the Urban Heat Island effect. This highlights a potential gap in Berlin's approach to urban heat management and the need for further exploration and documentation.

CHAPTER 9

CASE STUDY: MILAN

- Territorial and climate overlook description
- Climate action plan
- From lesson to project
- lesson learned

Territorial and climate overlook description

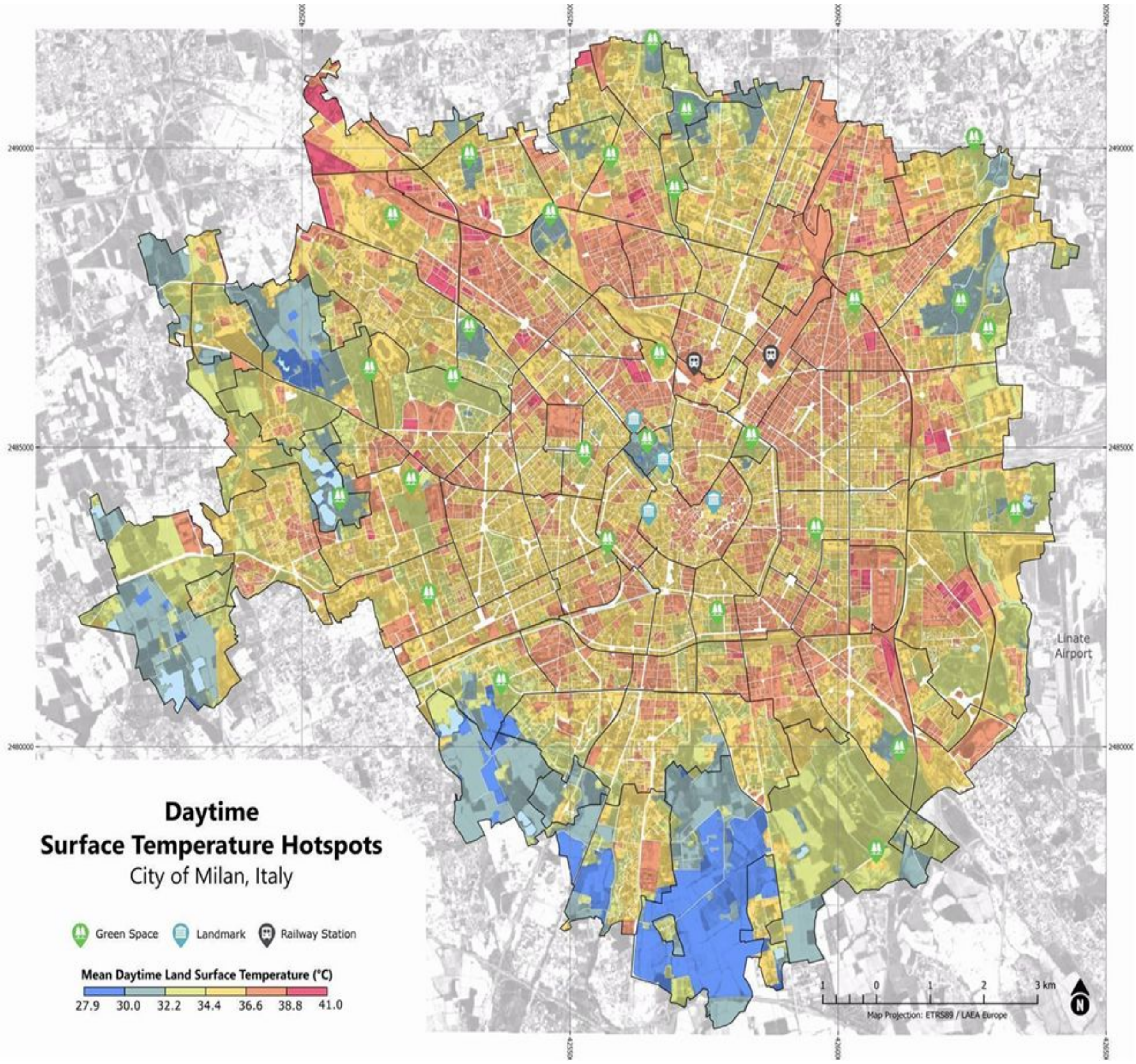
Territorial climate overlook description

Milan is situated in the northern region of the Po River plain in northern Italy. This is the foreland basin of the Alpine collisional belt, including up to 800 meters of marine-fan deposits, which are overlain by Fluvio-glacial unconsolidated deposits and the progradation of large alluvial plain deposits from the Alps. According to Köppen-Geiger Classification, Milan features a oceanic climate (Cfb). Temperatures typically range between 4 °C (39 °F) and 25 °C (77 °F) through the year, but rarely can drop to -5 °C (22 °F) or can rise to as high as 39 °C (102 °F) (Peel et al., 2007). Besides, the city experiences a mean annual precipitation of 1000mm and average annual air temperatures of 14.3°C in the city center and 16.0°C outside, with daily mean variations ranging from -5.4 to +31.0°C (Previati et al., 2022). Milan is divided into nine urban districts. Map 40 shows Milan's municipal borders.

Map 47: Milan's Municipal districts

As regards surface temperatures, the average daytime surface temperatures measured during the summer season of 4 consecutive years (2014-2017, June-July-August), highlighting the differences in temperature between the different types of urban fabric. The results of this analysis were represented in a map, showing the distribution of the recorded temperature classes in the city This map is the result of a satellite survey (Landsat-8), and consequently does not specifically take into account the parameters like albedo, solar radiation and presence of evapotranspiration surfaces, but detects their effects in aggregate and synthetic form. It can be seen that surface temperatures drop significantly near large urban green areas and peri-urban agricultural areas, while they reach maximum values in particularly dense and with a low permeability index.

Map 48: Average surface temperatures during the day in Milan (Bloomberg Associates and National Observatory of Athens-NOA)



Graphs 30 and 31 shows that temperatures in Milan have consistently increased over the years, leading to a positive translation of the normal curve of annual temperatures. This has resulted in a decrease in extreme cold events and an increase in extreme heat events. This has caused shocks and stress for the urban system, which was developed with a climate characterized by lower temperatures. Nearly 50%25 of Milan's building stock was built between the second post-war period and the 70s, making them energy-intensive during summer.

Figure 47: Projection of the minimum summer temperature -milan 1971-2000 is 2021-20250. Source: (Comune di Milano, 2024).

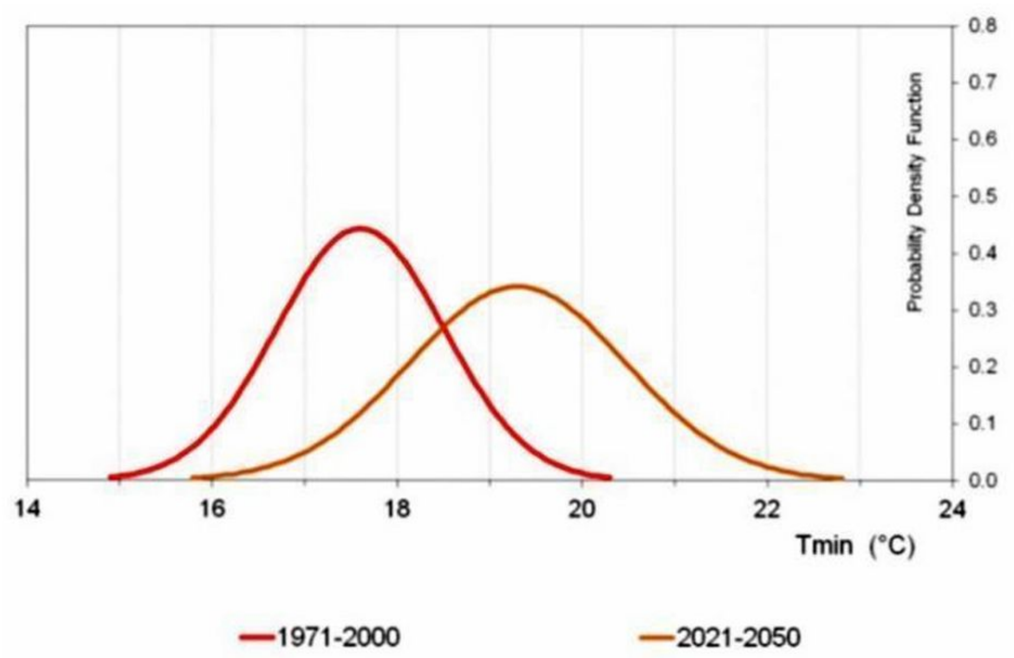
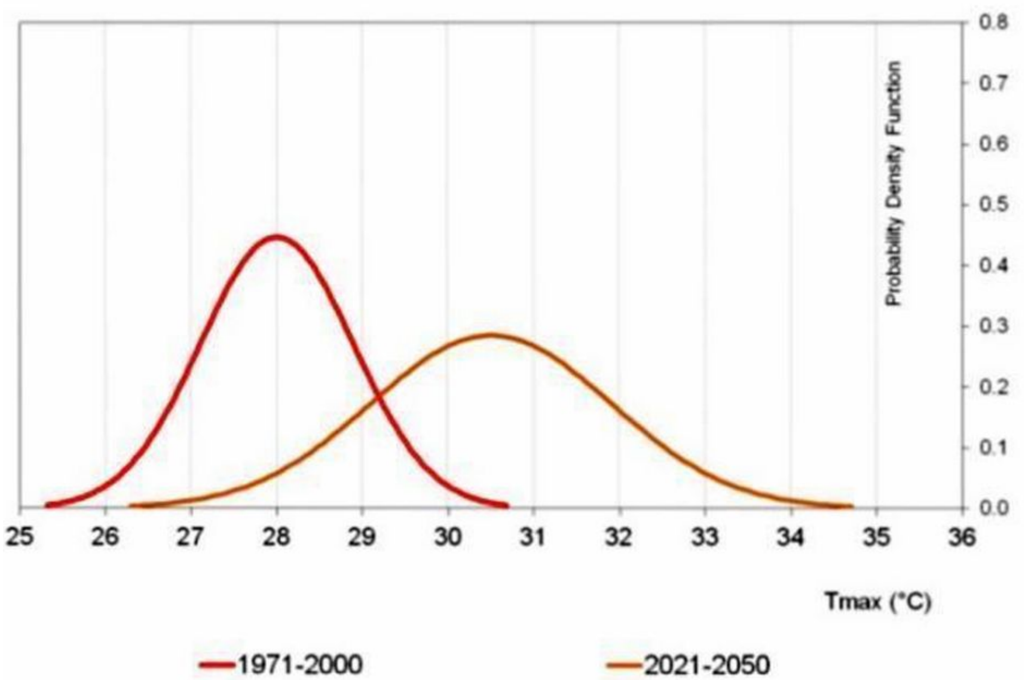


Figure 48: Projection of the Maximum summer temperature -milan 1971-2000 is 2021-20250. Source: (Comune di Milano, 2024).



Map 43 evaluates urban quality, focusing on degraded buildings and urban green space per inhabitant. Milan's high population density reduces green space per capita and potential expansion due to physical limitations. Therefore, green roof and vertical interventions are crucial elements for improving urban quality.

Map 49: Milan urban quality. Source: (Comune di Milano, 2024).

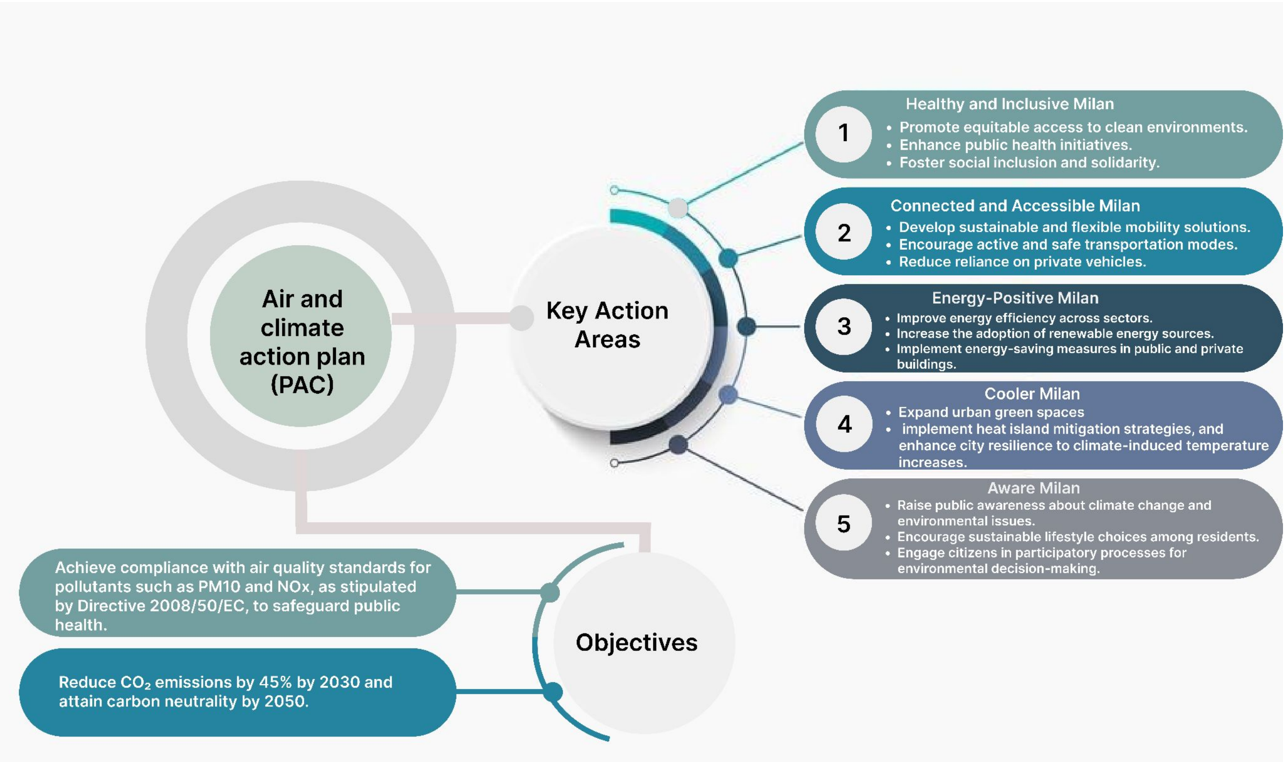
Climate Action Plans

Milan has made significant commitments to environmental issues, joining international networks and initiatives like the C40 Cities Climate network and the Urban Agenda Partnership on Air Quality. The city has committed to addressing air pollution, which does not meet EU and WHO guidelines. Milan has also committed to becoming a Carbon Neutral city by 2050, eliminating fossil fuels, in line with the 2015 Paris Agreement. The city's urban system adaptation measures aim to improve the city's quality of life and raise awareness about climate change vulnerability. These efforts are part of a larger effort to combat air pollution and contribute to a more sustainable future.

Air and climate plan

The Plan aims to reduce air pollution and combat climate change through adaptation mitigation policies. It adheres to health, equity, and justice principles, prioritizing social inclusion and protecting weaker populations. The plan aims to transition to a "zero-emission" city, integrating environmental and social justice. It transforms air quality and climate actions into systemic investments for a sustainable society and urban economy. The Plan is a strategic tool for planning and programming tools, focusing on reducing greenhouse gas emissions, improving air quality, adapting to climate change, social equity, and health protection (Comune di Milano, 2023).

Figure 49: Main features of air and climate plan. Source: personal elaboration.



Sustainable Energy and Climate Action Plan (SECAP)

The SECAP outlines strategies across five major themes: building energy retrofitting, renewable energy integration, sustainable mobility, energy production, green spaces expansion, sustainable urban design, public awareness and engagement, energy audits, incentive programs, public transport enhancement, cycling infrastructure development, urban greenery projects, and community workshops.

Considering 2005 as a reference year, the SECAP's preliminary goals are to cut back on CO2 emissions by at least 20% by 2020. To do so, key measures and actions encompass energy retrofitting in both public and private buildings, promoting integration of renewable energy sources into building infrastructures, enhancing public transportation systems, improving sustainable mobility, funding and investing in renewable energy initiatives, as well as implementing energy efficiency programs into place.

The strategies stated in Milan's SECAP serve to reduce the urban heat island impact by increasing green space, promoting building energy efficiency and more importantly increasing public awareness. By applying these measures, Milan's SECAP seeks to create more resilient and sustainable urban environment which effectively is dealing with climate change challenges, specifically like urban heat island effect. (Sustainable Energy and Climate Action Plan Municipality of Milan, 2009).

Guidelines for Adaptation to Climate Change in the City of Milan

The Guidelines for Adaptation to Climate Change in Milan is a strategic plan aimed at strengthening the city's resilience to climate change effects and enhance the quality of life for its inhabitants. The predominant objective of the plan is developing a Robust Urban Framework which indicated to modifying the city's infrastructure and policies to address climatic problems, guaranteeing sustainable and habitable circumstances.

In addition, the guideline specifically refers to some measures to address Urban Heat Island impacts. Figure 32 illustrates the actions that are able to tackle with UHI. Of course it is important to take into consideration that the actions correspond with Milan's Air and Climate Plan (PAC), ratified in February 2022, which defines 22 objectives and 49 actions across five major areas, including the "Cooler Milan" project (Comune di Milano, 2024).

Figure 50: Actions to combat with UHI based on Guideline for Adaptation to climate change in Milan . Source: personal elaboration.

Milan is working to mitigate the impacts of urban heat island by expanding the availability of green spaces, enhancing surfaces that reflect heat, as well as managing water resources more efficiently.Due to the fact that a more climate-resilient urban environment can be achieved through these measures which also can lower summer temperatures and enhance thermal comfort.

The 2030 Territorial Government Plan

The related objective to tackle with UHI is to cool the urban system by implementing green roofs and walls, even in areas where ground planting is not feasible. This widespread construction can create a sustainable urban regeneration system, contributing to the city's livability, providing new spaces for socialization and recreation, and encouraging job creation and income for green supply chain operators. Green roofs offer opportunities for creating new green spaces, gardens, and vegetable gardens, as well as installing renewable energy systems. Multifunctional green areas on public or private rooftops can make new spaces for sociality accessible and available to all. Despite the reduction in land consumption index from 74 to 70%, Milan remains a dense and waterproofed city with an overall permeability index of 56.37%. This is due to the high level of urbanization, urban morphology, widespread presence of underground services, and high density of the city (Commune di Milano, 2022).

Milan's green roofs and walls can considerably alleviate the impacts of urban heat island by incorporating vegetation into urban areas. Moreover, to functioning as microclimate regulators, these structures reduce surface temperatures and create a thermal buffer. Additionally, they make densely urbanised areas more livable by integrating nature to these areas. This action also gives rise to improving thermal comfort and air quality as well. Other advantages of green infrastructure are the reduction of impervious surfaces, creating more job opportunities in construction, maintenance and renewable energy sectors. Along with improving building energy efficiency and contributing in stormwater management, these actions also promote sustainable design by reducing heat absorption on impermeable surfaces.

From Plans to Projects

Project 1: Parco Biblioteca degli Alberi (Library of Trees Park)

Location of the project: Porta Nuova, Milan, Italy

Client: Municipality of Milan, INGRE

Technical design of the fences: Carve, Amsterdam

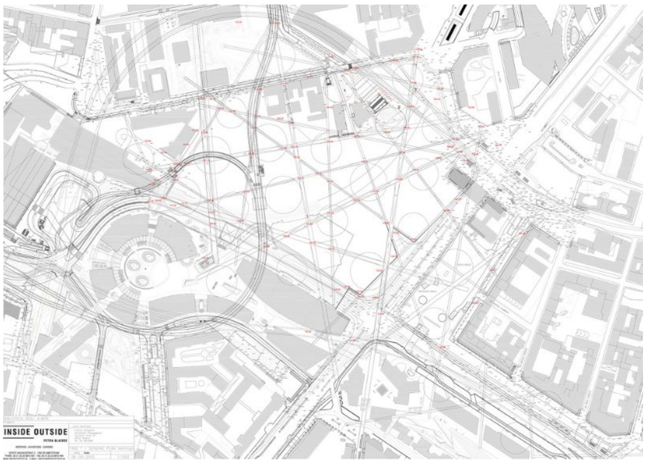
Project date: 2008 - 2018

Size: 10 ha

Figure 51: Location of the Project. Source: Google Earth

The Biblioteca degli Alberi (Library of Trees) is a newly constructed public park in Milan, Intended to integrate the urban landscape with different areas. The creation of intersection and overlapping pathways from commercial, residential and governmental areas is the core objective and focus of the project. Also the species that are used in park's design have been carefully chosen. Also each plot provides a unique growth type and program. Circular forests are spread throughout the site which offering diverse colours and structures canopies of vegetation. The park and its borders are also linked to a variety of commercial, cultural, social and educational buildings that attracts attention and brings about income for the area while enabling a comprehensive maintenance program. In 2010, the park was revived, assessed, and adjusted to the changing context. The park will serve as a hub between the municipality, commercial offices, fashion and culture-related buildings, public transport, busy streets, and quiet residential areas. The park's primary goals were to create an entirely novel type of urban park in Milan, a modern version of Botanic garden and cultural campus, an environmental friendly place for recreation, beauty, sport and learning as well as a link to all local communities which are surrounded around the park (INSIDE OUTSIDE, 2021).

Figure 52: Construction phase of the Parco Biblioteca degli Alberi project



Catalogue of the project

The Biblioteca degli Alberi functions as a multifunctional urban space that boosts aesthetic and recreational value while immediately mitigating urban heat island (UHI) effects and cooling the city.

Project 2: Vertical Forest Milan

Location of the project: Porta Nouva, Milan, Italy

Client: Coima Sgr (ex HINES Italaia s.r.l)

Project date: 2007 - 2014

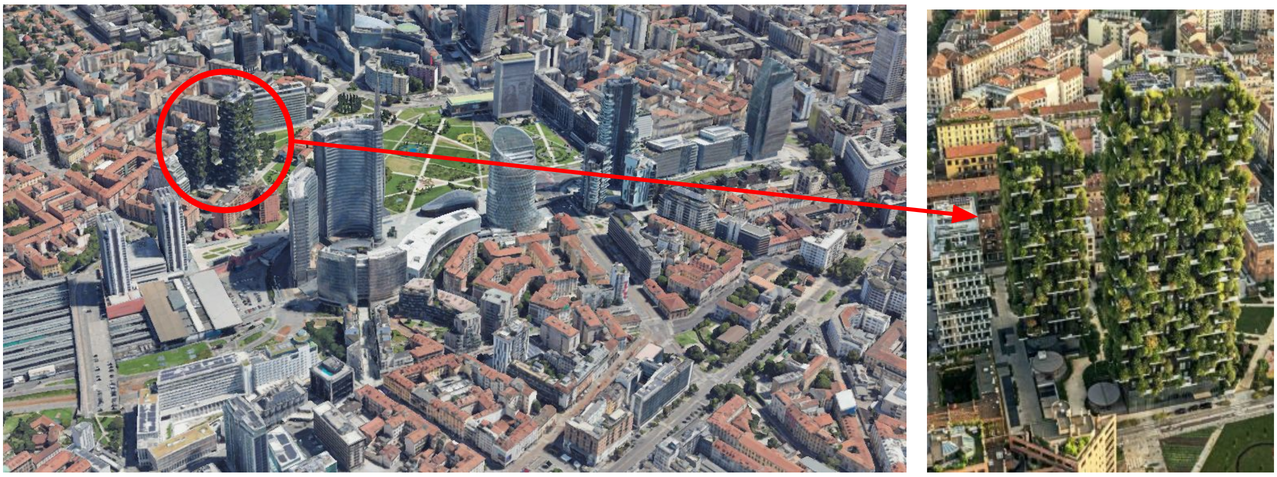
Size: 2300 mq, GFA: 18,200 sqm; H: 112 and 82 m

The Vertical Forest is an innovative architectural endeavor in Milan designed to incorporate biodiversity into urban life, with two towers that accommodate 800 trees, 15,000 perennials, 5,000 shrubs, and more vegetation. The towers encompass an area of 30,000 square meters of forest within merely 3,000 square meters of urban land, fostering a symbiotic link between humanity and environment. The project includes expansive, staggered balconies covered with porcelain stoneware facades that recreate tree bark, so boosting the building's aesthetic appealing and fostering a natural, welcoming environment.

The plants mitigate pollution by concealing CO2, moisture, and particulate matter, controlling the microclimate, screening solar radiation, and offering natural shade, so diminishing the urban heat island effect. The project incorporates centralized irrigation and water management technologies that utilize filtered effluent from the towers.

The Vertical Forest employs strategies such as utilizing plants for cooling, promoting biodiversity, implementing sustainable water management, and ensuring continuous maintenance and adaptability. The project mitigates the urban Heat Island effect by expanding vegetation in urban areas and facilitating natural cooling through shading and evapotranspiration. (Vertical Forest, Boeri Studio, 2007 - 2014)

Figure 53: Location of the Vertical Forest Milan Project. Source: Google Earth



Project 3: Milan Innovation District (MND 2032**)**

Location of the project: The former Expo site northwest of Milan's CBD

Project date: In progress

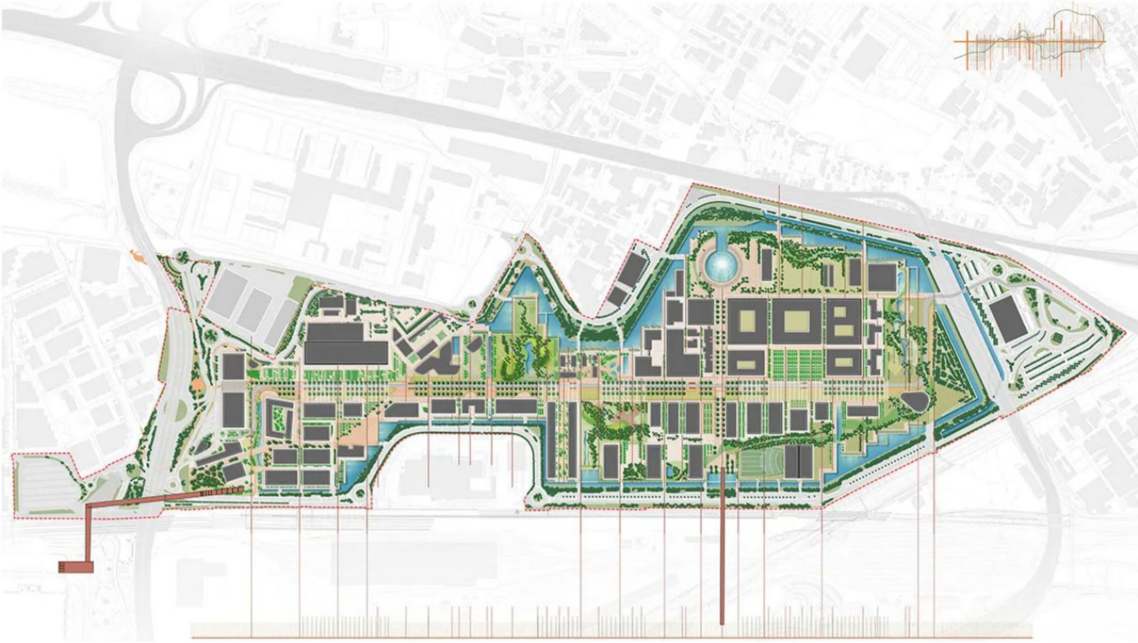
Size: 100 hectare mixed use redevelopment

The Milan Innovation District (MIND) is an broad, mixed-use redevelopment project that is located on the former Expo site to the northwest of Milan's core business district. The district include office buildings, residential areas, stores, labs, a university, and public spaces. It benefits outstanding transportation infrastructure, establishing it as a center for connectivity and innovation. The project encompasses 8,000 sqm of initial office space in the MIND Village, with prospective expansion to 356,000 sqm of office space, 1,083 rental apartments, and 35,000 sqm of retail space. The campus will include a hospital, university, and human technopole, creating a complex environment for living, working, and learning.

The MIND initiative has its main objectives which are promoting community integration, sustainability, and health. providing outdoor workspaces, training facilities. and recreational areas approximately 300,000 square meters of green and blue spaces that will support health and well-being. A comprehensive mobility strategy seeks to attain entirely electric transportation on-site and decrease vehicular journeys within the precinct by 50%, thereby encouraging pedestrian and cycling pathways. The project prioritizes sustainability, aiming for high energy efficiency, water conservation, and the incorporation of solar power to achieve a fully decarbonized system. With an aim of LEED Gold certification for sustainability, the project also intends to meet energy performance standards by 20%, reduce embodied carbon by 50%, and divert 95% of building waste from landfills.

The MIND project effectively mitigates the urban heat island (UHI) effect by integrating substantial green and blue spaces. Such features improve natural cooling by means of aquatic and floral elements, therefore helping to control temperature. Pedestrian zones and outdoor areas decrease heat-absorbing hardscapes, while energy-efficient structures and sustainable materials further minimize heat absorption. The decarbonized energy system and incorporation of solar power contribute in diminishing total urban heat generation. MIND promotes a cooler and more habitable urban environment by promoting green infrastructure and sustainable actions in accordance with Milan's universal climate resilience objectives (landlease,Milan Innovation District) .

Figure 54: Master plan of the MND project. Source: (MAC, n.d.).



The project features a mixed-use design integrating diverse functions to create a vibrant urban environment. Key components include public anchor projects like the Parco del Cibo della Salute, the Sports and Entertainment Park, and the new Rho-Arese Park. The development combines office spaces, laboratories, and light industrial facilities with built-to-rent residential units, student housing, and care homes. Compact, flexible workspaces are complemented by tall, slender residential buildings, interconnected through shared terraces and common areas that foster community interaction and collaboration.

Figure 55: Common ground and shared spaces in MND project. Source: (MAC, n.d.).

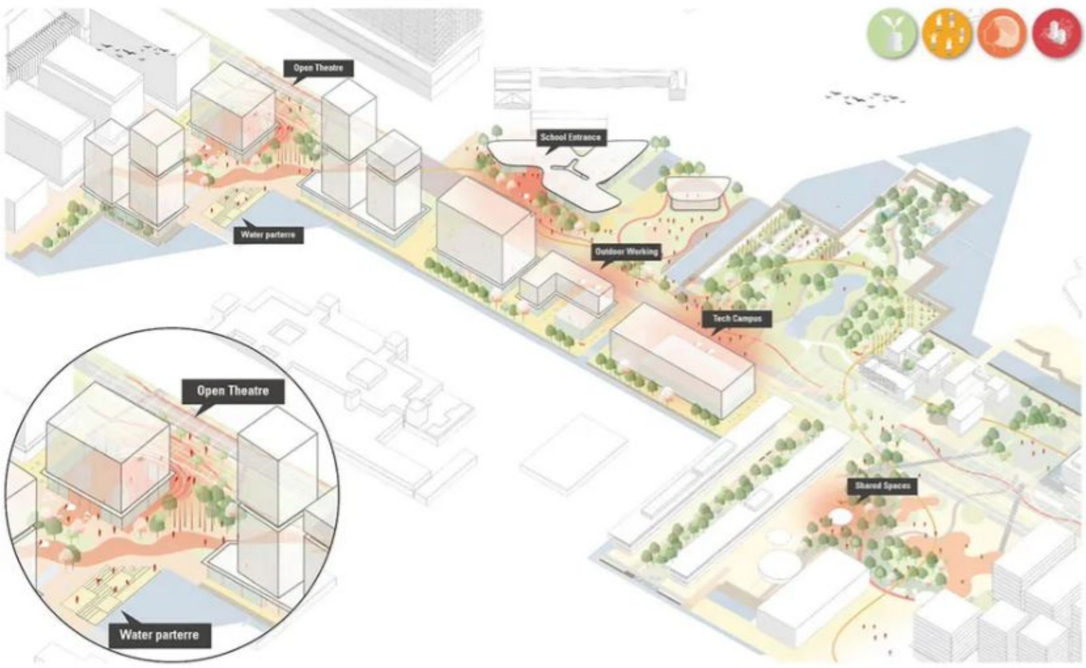
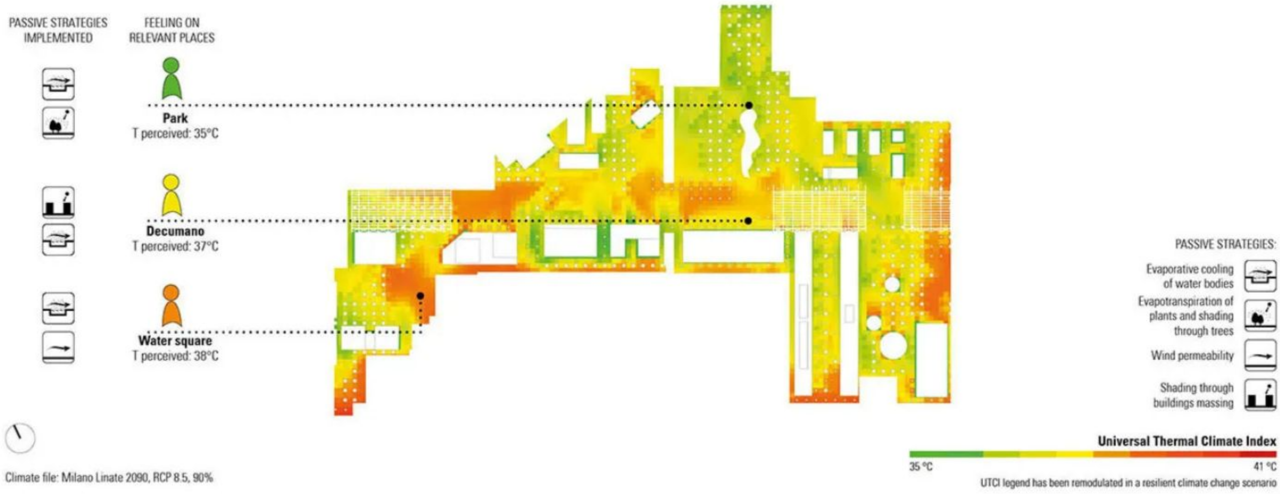


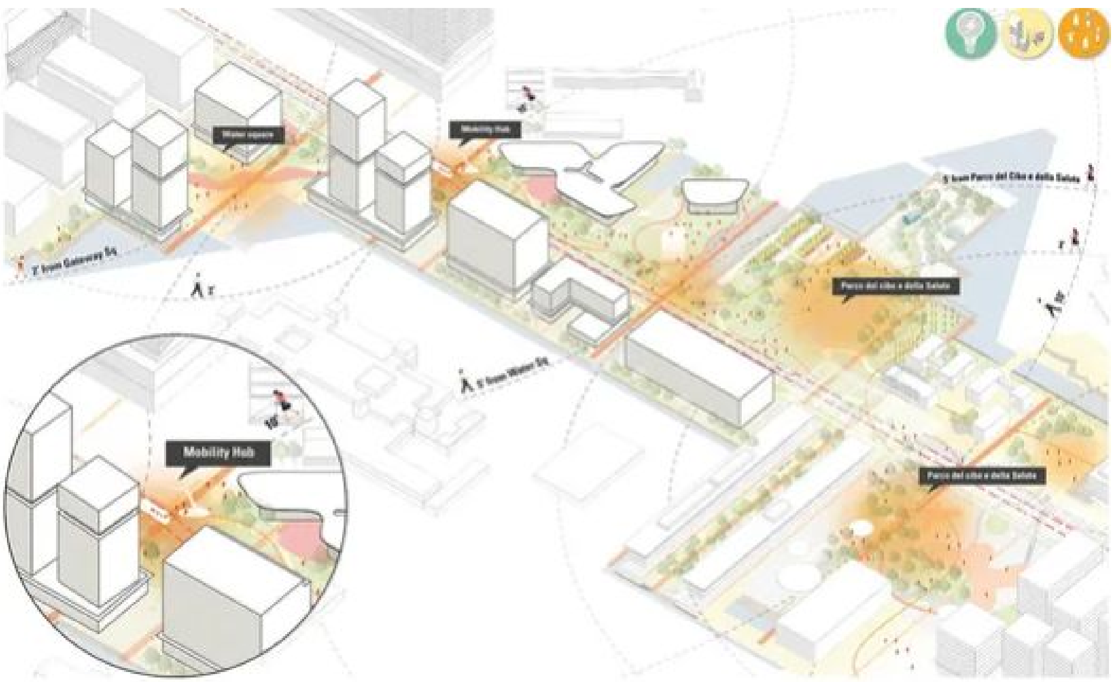
Figure 56: Universal Thermal Climate Index (UTCI). Source: (MAC, n.d.).



The new district is predominantly car-free, representing a novel urban paradigm that prioritizes pedestrians, bicycles, and slowly movement, while constantly attempting to eliminate the boundary between indoor and outdoor environments.

The MIND project is distinguished by its extremely high standard sustainability standards: it will obtain LEED certification for Cities and Communities, and the buildings will adhere to Design for Manufacture and Assembly (DfMA) principles from the initial stages of master planning, facilitating ongoing monitoring and evaluation of carbon and CO2 emissions throughout their lifetime. Furthermore, all the structures will possess LEED BD+C and WELL AP certifications.

Figure 57: Public transport and high walkability. Source: (MAC, n.d.).



Project 4: Piazze Aperte (open Squares) project for Milan

Piazze Aperte is a program in Milan, developed by AMAT, Bloomberg Associates, and the Global Designing Cities Initiative, focusing on urban regeneration and sustainable mobility. The program aims to enhance public spaces, promote sustainable mobility, and extend pedestrian areas. Public squares are reclaimed by Piazze Aperte as community gathering venues using a "tactical urbanism" technique.Collaboration agreements allow the City of Milan and its residents to actively cooperate in designing, developing, and implementing public spaces. The program has implemented over 35 tactical interventions and continues to plan new ones (Piazze Aperte, n.d.).

The Piazze Aperte Initiative directly facilitates urban heat mitigation through its innovative urban design strategy.The incorporation of greenery in these areas improves natural cooling processes including shading and evapotranspiration, hence reducing heat absorption. The effort indirectly encourages pedestrian activity and social engagement, minimizes dependence on vehicles, and thereby reduces heat emissions from traffic. The enhanced visual attractiveness of areas promotes outdoor activities in more thermally pleasant settings. Collectively, these measures establish cooler microclimates and facilitate a more extensive reduction of urban heat stress.

Piazza Dergano, 2018

Piazza Dergano, a small square in the neighborhood, has been redesigned to create a colorful pedestrian space for events and festivities. The area has been extended, redesigned, and streamlined to reduce vehicle speeds and ensure safe use. The new pedestrian area benefits residents and businesses.

Year of completion (tactical): 2018

Year of completion (final): 2021

Total area: 700 m2

New pedestrian area: 620 m2

Furniture:

- 12 benches
- 2 picnic tables
- 2 ping-pong tables
- 25 planters
- 3 bike racks
- 1 BikeMI point

Piazza Angilberto II, 2018

Piazza Angilberto II, an overbuilt intersection, has been redesigned to create a new pedestrian area. The sidewalks have been widened to accommodate new seating, ping-pong tables, plants, and bike share and parking. Small commercial businesses are now more accessible. A new contraflow cycle track has been added to Via Comacchio, connecting to Piazza Ferrara. The cycle lane, created between sidewalk curb and parking spaces, protects cyclists from moving vehicles. The new lane has increased the number of cyclists by 47% and pedestrians by 30%.

Location: Piazza Angilberto II

Year of completion (tactical):
2018

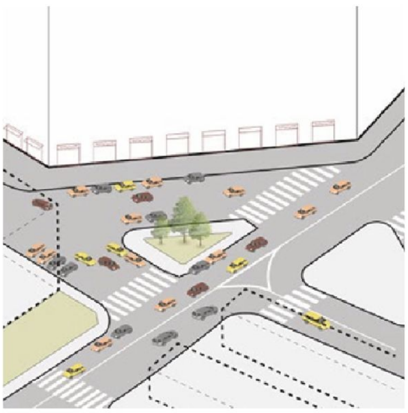
Year of completion (final):
2022

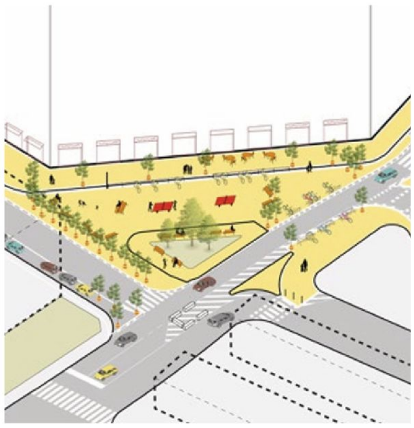
Total area: 1100 m2

New Pedestrian Area: 900 m2

Furniture:

- 16 benches
- 2 ping-pong tables
- 45 planters
- 5 bike racks
- 1 BikeMI point





Piazza San Luigi, 2018

From May 10 to 13, 2018, Milan experienced the first trials of "TréntaMi: Zone 30," a collaboration between Genitori Antismog, FIAB Milano Ciclobby, Matteo Dondé, Confesercenti Milano, "Social Streets" of the Corvetto neighborhood, and the City of Milan. The pilot involved narrowing Via Scrivia with angled parking, widening the side walk along Via Tagliamento, and improving the livability of Piazza San Luigi by creating a central pedestrian area and reducing crosswalk length.

Location: Piazza San Luigi

Year of completion (tactical): 2018

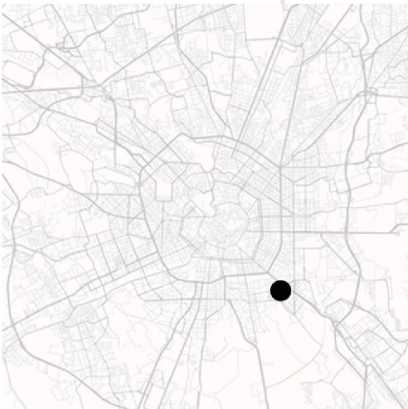
Year of completion (final): 2021

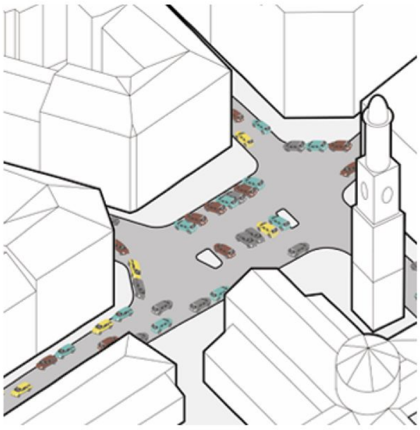
Total area: 1600 m2

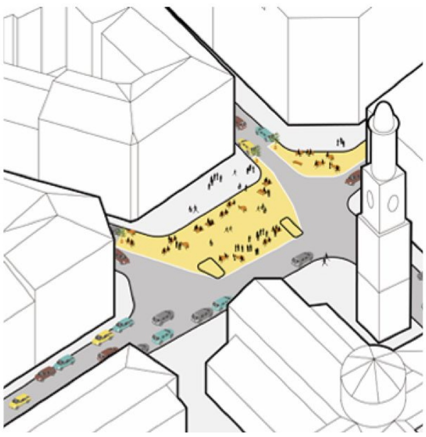
New Pedestrian Area: 900 m2

TréntaMI IN VERDE is an initiative by: Genitori Antismog FIAB Ciclobby Onlus

Temporary design Arch: . Matteo Dondé







Piazzale Stazione Genova, 2019

The pedestrian areas of the square near the historic train station have expanded from 1,200 to 4,000 m2, offering improved circulation and benches, bike racks, and planters. The route from the green M2 metro stop to the BikiMi walkway has been colored with white and blue stripes, indicating directions to nearby places of interest. Private vehicles have been prevented from accessing the square from Via Vigevano, Corso Colombo, and Via Valenza, and taxi stalls have been moved outside. In 2020, 30 new flower pots were added and the pavement was repainted.

Location: Piazza Stazione Genova

Year of completion (tactical): 2019

Total area: 4000 m2

New Pedestrian Area: 3000 m2

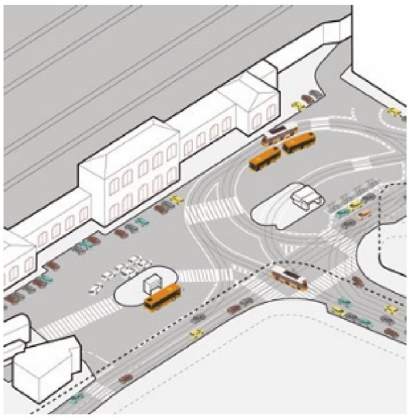
Furniture:

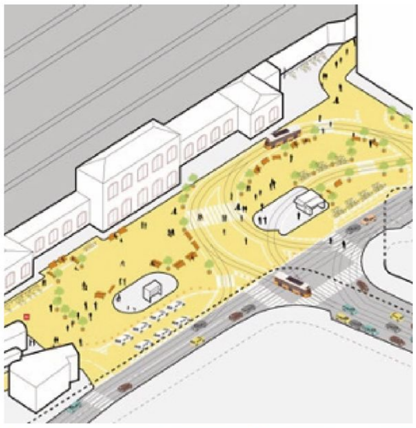
- 30 benches
- 10 mobile tables
- 62 planters
- 13 bike racks

Community partners 2019:

Retake Milano CBRE GWS

Colorificio Sammarinese





Via Spoleto / via Venini, 2019

The transformation of the Spoleto/Venini/Martiri Oscuri intersection was significantly influenced by its distinctive configuration: Excessively wide to qualify as a mere intersection, yet lacking a genuine pedestrian zone to be deemed a square. The makeover now offers Ciresola Elementary School a genuine public area for the school, parents, and children to cultivate community connections. The new roadway system seeks to divert through traffic from the residential area, thereby facilitating more convenient and enjoyable pedestrian movement. Furthermore, to enhance cycling mobility, the initiatives implemented in Spoleto are integral to the cycling route extending from Parco Trotter to the tunnel on Via Spoleto leading towards Via Gioia. A new parking-protected bike track has been established along Via Venini to finalize the new cycle network.

Location: via Spelto- via Venini

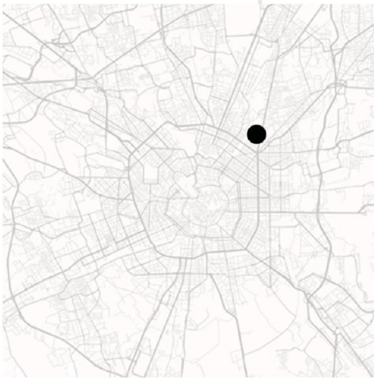
Year of completion (tactical): 2019

Total area: 2500 m2

New Pedestrian Area: 800m2

Furniture:

- 320 benches
- 2 tables
- 21 planters
- 9 bike racks



Piazza Belloveso, 2019

Piazza Belloveso, located near the center of Niguarda, includes a green space with a play area, functioning as a communal hub for children attending Vittorio Locchi Elementary School, the Church of San Martino churchyard, and the adjacent neighborhood library. The Piazza Aperte project integrates these regions with a vibrant and well-equipped pedestrian zone, previously occupied by car traffic and unregulated parking. Children and neighbors can now use the seats for rest, study at the tables, engage in ping-pong inside the green space, arrange events, and experience a genuine community area that serves as the neighborhood's focal point. The project is set to undergo a permanent alteration that has been presented to the community and is currently under construction.

Location: Via Bauer, Piazza Belloveso

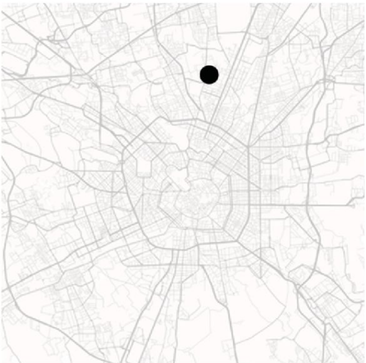
Year of completion (tactical): 2019

Total area: 3400 m2

New Pedestrian Area:1200 m2

Furniture:

- 13 benches
- 4 picnic tables
- 2 ping-pong tables
- 4 bike racks



Piazzale Lavater, 2019

Piazzale Lavater, in close proximity to Corso Buenos Aires and Porta Venezia, displays three oval-shaped Tree-lined green spaces, integral to the green zone linking Via Morgagni and the A. Stoppani K-14 school. Regrettably, the prospective public area was obscured by unregulated parking and hazardous pedestrian crosswalks. The Piazze Aperte project was designed to provide citizens with an area furnished with benches and bike racks, enabling children to utilize the space in front of the elementary school and safely access the school building via a newly established crosswalk at the intersection with Via Ramazzini.

Location: Piazzale Lavater

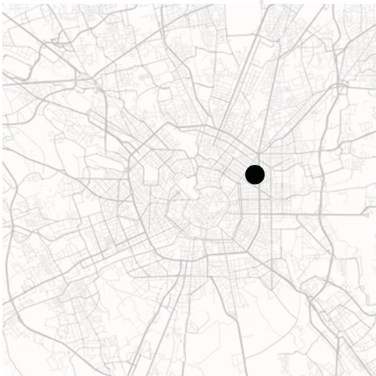
Year of completion (tactical): 2019

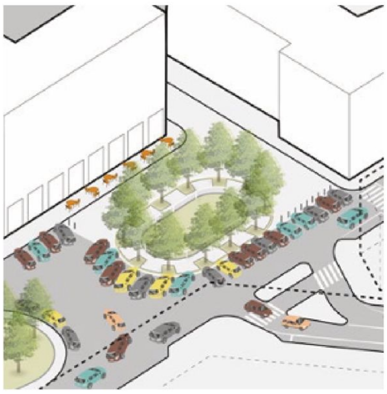
Total area: 1300 m2

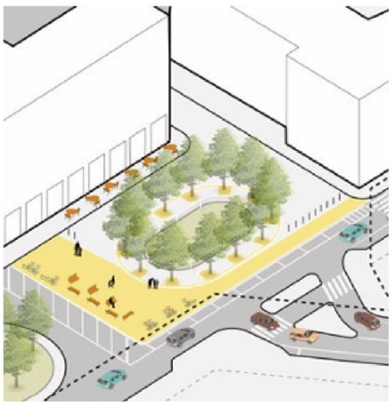
New Pedestrian Area: 350 m2

Furniture:

- 9 benches
- 5 bike racks







Via Rovereto / via Giacosa, 2019

TréntaMI in Verde is a 30km/h zone trial in collaboration with Milan, aiming to enhance the safety and experience of Via Rovereto and the crosswalk towards Parco Trotter. This tactical urbanism measure aims to improve the street's experience for all users, including car drivers, pedestrians, and cyclists. Capital construction has started on the project, with new plants, furniture, and a resurfaced roadway due for completion in 2022. The street aims to create a connection between the park and the neighborhood.

Location: Piazzale Lavater

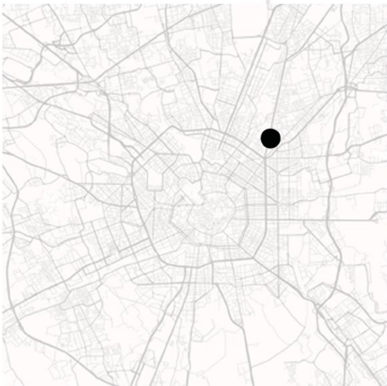
Year of completion (tactical): 2019

Total area: 1300 m2

New Pedestrian Area: 350 m2

Furniture:

9 benches
5 bike racks



Piazza Angilberto II, 2019

The space opposite the Shrine of St. Rita of Cascia, located at the intersection of Santa Rita da Cascia and Walter Tobagi, was previously used as a parking lot, obstructing residents' and worshipers' access and affecting the church's facade. To create a public space, the parking lot was scaled back, replaced with plants and benches, and the pavements decorated with children's games and colors. The space now hosts various events, including non-religious ones, and features new bike racks to promote active mobility.

Location: Via S.Rita da Cascia

Year of completion: 2019

Total area: 1200 m2

New pedestrian area: 500 m2

Furniture:

14 benches,

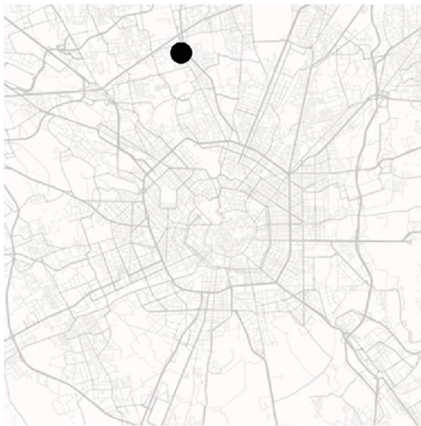
3 planters

4 bike racks

Pavement design: Arch. Sylvia Colombin

Piazza Gasparri, 2019

Piazza Gasparri was originally a plaza between two residential buildings with a portico on the ground floor. For a long time, despite it being close to the local elementary school, multiple businesses and various neighborhood associations, the square was used only as a space for unregulated parking. Thanks to the "Vicini in Piazza" ("Neighbors in the Square") program, the community has reclaimed the space, installing new furniture, as well as a cycle lane designed for training children to ride a bike around the edge of the plaza. The project succeeded not only in rejuvenating the central space of the pedestrian area and the two porticoes, but also in making the area where children enter and leave the school safer.



Location: Piazza Gasparri

Year of completion: 2019

Total area: 3500 m2

New pedestrian area: 2500 m2

Furniture: 10 benches, 2 new tree planting, 2 ping pong table, 1 petanque field

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Via Guido Reni, 2019

In 2018, the City of Milan closed to vehicular traffic a part of Via Guido Reni outside of the elementary school, to provide an outdoor public space for children and families to use after lessons and after school hours. The City, together with community organizations and the school, decided to enhance the space and make it more welcoming for children. The pavement has been colored with a design based on simple shapes and bold colors, creating three clear main children's play areas. The choice of games to include within the design was made through workshops held with the true users of the space - the children - by recreating the design in a classroom environment and letting the children play, observing their reactions and taking note of their preferences.

Location: Piazza Gasparri

Year of completion: 2019

Total area: 3500 m2

New pedestrian area: 2500 m2

Furniture: 10 benches, 2 new tree planting, 2 ping pong table, 1 petanque field

CARIMATI S.r.l PPg Italia Sales & Services

Piazzale della Cooperazione

With boxes for vegetable gardens, tables, ping-pong tables, benches, a Free book library and colored flooring, Piazzale della Cooperazione officially opened for Milan Green Week, has been renovated thanks to a tactical urbanism intervention that has brought back vitality and color to an area previously devoid of an identity. The program was chosen as part of a national competition promoted by the Consorzio Cooperative Lavoratori, open to designers, illustrators, graphic designers, and artists. The program has regenerated the plaza, which today features a weekly market, with the aim of enhancing the existing social housing project, and encouraging livability and social inclusion in an active neighborhood. The associations and local businesses will also benefit from the space through expanded community activities.

Location: Piazzale della Cooperazione

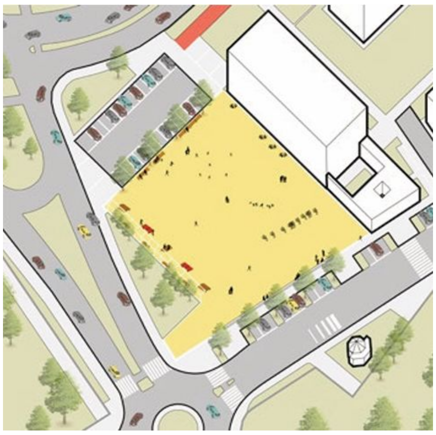
Year of completion: 2019

Total area: 2500 m2

New pedestrian area: 2500 m2

Furniture: 4 benches, 2 ping pong table, 1 vegetable box

Pavement design: SdArch



Piazza Sicilia, 2020

Piazza Sicilia is a new social space in front of IC Umberto Eco school, designed to cater to the needs of local children. The program involved a complete renovation of the area, pedestrianizing it, and installing benches, trees, and picnic tables. A new, block-long pedestrian route was created between the school entrances on Via Sacco and Via Seprio, reducing crosswalks and widening pedestrian space for parents. The new "open" Piazza Sicilia connects the school, library, and park, previously cut off by traffic.

Location: Via Sacco, Piazza Sicilia - MIlano

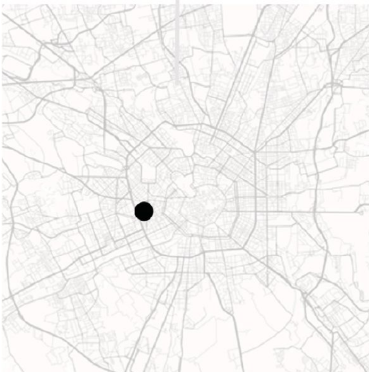
Year of completion: 2020

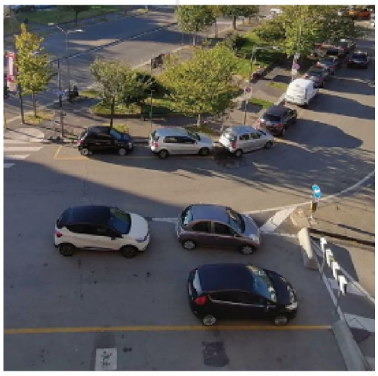
Total area: 2500 m2

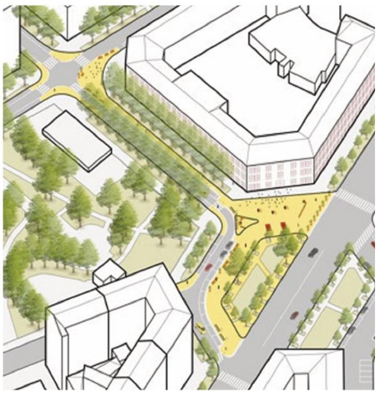
New Pedestrian Area: 1500 m2

Furniture:

- 21 benches
- 3 picnic tables
- 2 ping-pong tables
- 15 planters
- 6 bike racks







Piazza Minniti, 2020

Piazza Minniti has been transformed into a new social space in the heart of Isola. The project has redesigned the plaza, moving the parking area to the edge and creating a new central pedestrian area. A cycle lane has also been added along Via Garigliano to improve connections with Piazzale Lagosta. Because area hosts the weekly market, most street furniture was prohibited, but the new benches under the trees bring a sense of harmony and liveliness to the central open space that can accommodate formal and informal activities. The project also improved the safety of the intersections bordering the plaza, reducing distances and increasing visibility for pedestrians.

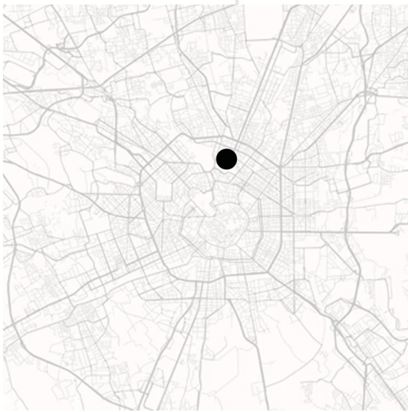
Location: Via Giambellino, Largo Balestra

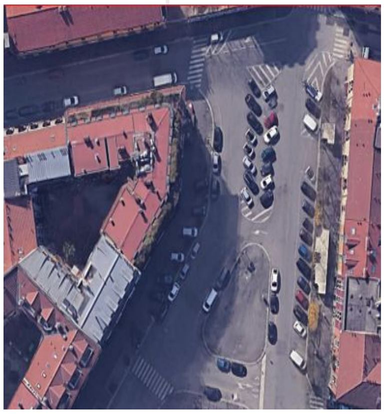
Year of completion: 2020

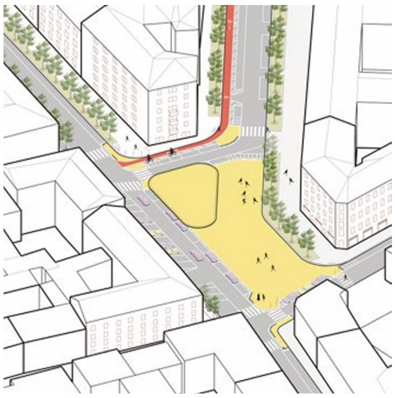
Total area: 580 m2

Furniture:

- Modello Milano benches
- 2 ping-pong tables
- planters







Largo Balestra, 2020

Largo Balestra, a pedestrian area with potential, is connected to a green space. The Fate Largo association uses it for initiatives, creating Piazza Aperta. The entrance to Via Giambellino features potted tree, ping-pong tables, and benches for spectators and local associations. The new urban living room invites people to enjoy events and events organized by local associations. A capital project is currently underway to further transform the plaza, showcasing the area's beauty and potential..

Location: Piazza Minniti, Via Garigliano

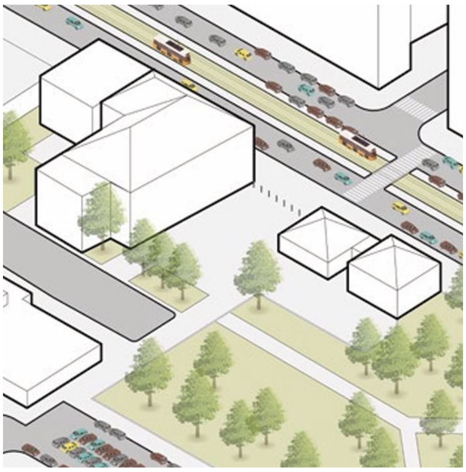
Year of completion: 2020

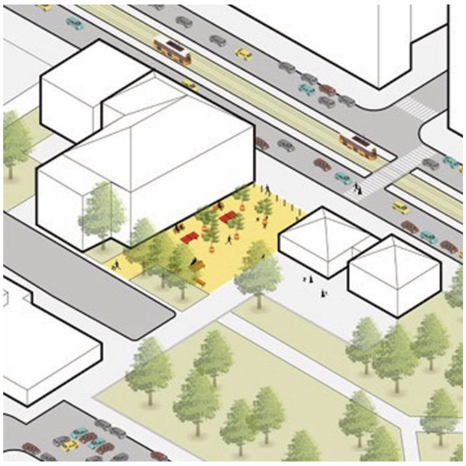
Total area: 1500 m2

New Pedestrian Area: 1200 m2

Furniture:

- 6 benches





Piazzale Tripoli, 2020

Piazzale Tripoli is a large and well equipped green space bisected by city streets. Previously, one of these streets hosted neighborhood children with inflatable attractions and games for a few months a year, but for the remaining months it was used for street level parking. Now, the area is has been resurfaced and completely pedestrianized, with a new artwork, dedicated to Gianni Rodari, that adds color, and gives life to the space. There are also new benches that allow residents to enjoy this vibrant street mural while surrounded by greenery, as well as picnic tables by the adjacent flower beds, offering pedestrians an opportunity to rest under the trees and truly take in the experience of the square. Since its transformation, the whole community has been enjoying the space, which is inviting and fun all year round.

Location: Piazzale Tripoli

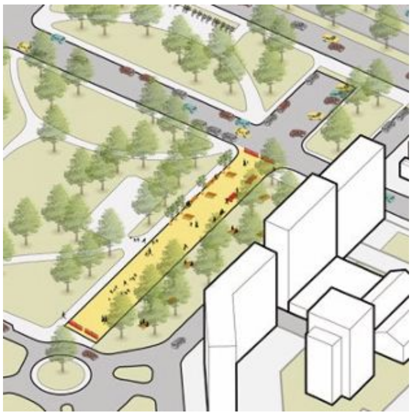
Year of completion: 2020

Total area: 1400 m2

New Pedestrian Area: 1400 m2

Furniture:

- 12 benches
- 4 picnic tables
- 6 planters
- 7 garden boxes



Via Val Lagarina, 2020

The measures put in place along Via Val Lagarina is part of a series of Piazze Aperte initiatives involving schools and nearby public spaces. In this case, a parking lot near the school entrance on Via Val Lagarina has been transformed into a new green plaza with 5 potted plants and 8 garden boxes. The project design combines play and education, visually dividing up the 600 m2 area into a square grid, like the graph paper in workbooks. This grid has been decorated with primary colors and geometric shapes, like the ones children learn and draw at school in their workbooks. The project also included the streamlining and creation of new parking spots on nearby streets to retain critical access to the school.

Location: Via Val Lagarina

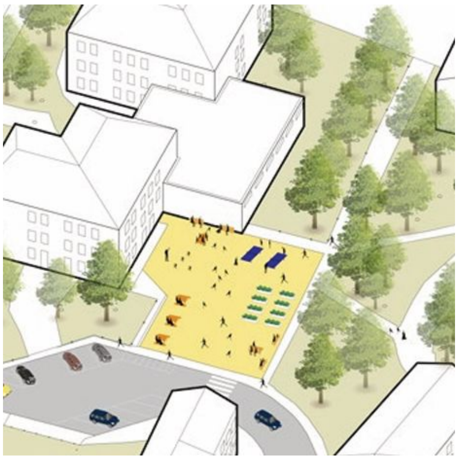
Year of completion: 2020

Total area: 800 m2

New Pedestrian Area: 650m2

Furniture:

- 8 garden boxed
- 5 planters



Via Luigi Capuana, 2020

Piazzetta Capuana, a renovated pedestrian area in Quarto Oggiaro, features improved green spaces and new asphalt. Local residents have expressed interest in activating the space with social events and have requested the addition of new furniture and potted plants. The central area is now lined with greenery, enhancing the environment, while neighborhood notice boards promote activities in the square.

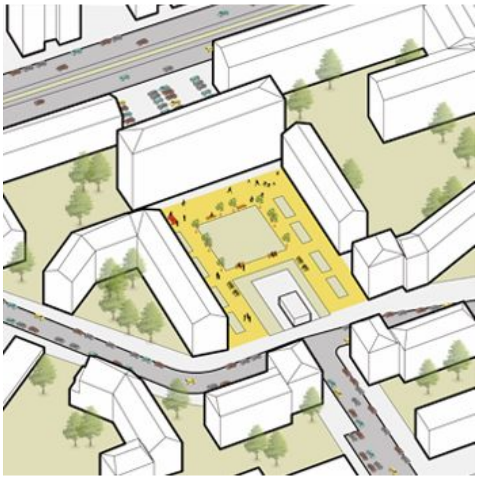
Location: Via Luigi Capuana

Year of completion: 2020

Total area: 2500 m2

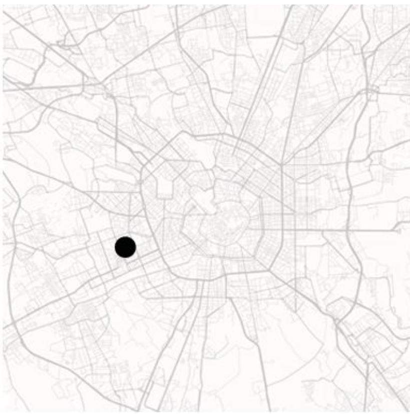
Furniture:

- 1 ping-pong table
- 2 neighborhood notice boards
- 10 planters
- 2 bike racks



Piazzetta Santi Patroni d’Italia, 2020

Piazzale Santi Patroni d’Italia is located in Arzaga, a western district of Milan, and has been used for many years as a parking lot. With the new configuration, the western sidewalk has been extended from the churchyard, creating a new pedestrian space. Vehicle travel towards Via Rosa Vergani Marelli has been retained, while the parking has been incorporated into the new design. Finally, the public space has been equipped with seats, tables, racks and sports equipment. Great care has been given to the positioning of potted plants, to ensure adequate shading of the seats in the summer months. This intervention brings a public space back to its neighborhood, for the benefit of the visitors and citizens who live there



Location: **Piazzetta Santi Patroni d’Italia**

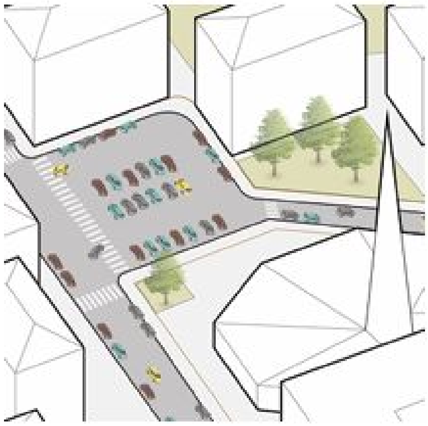
Year of completion: 2021

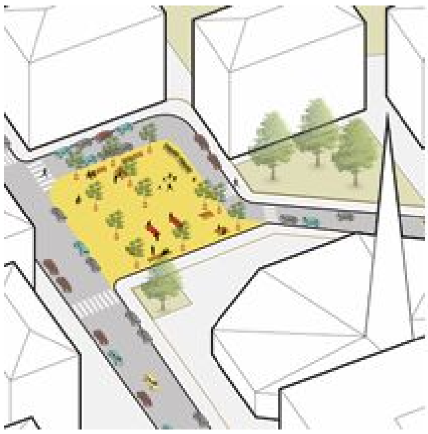
Total area: 1000 m2

New pedestrian area: 550 m2

Furniture:

- 9 benches
- 2 picnic table
- 12 planters



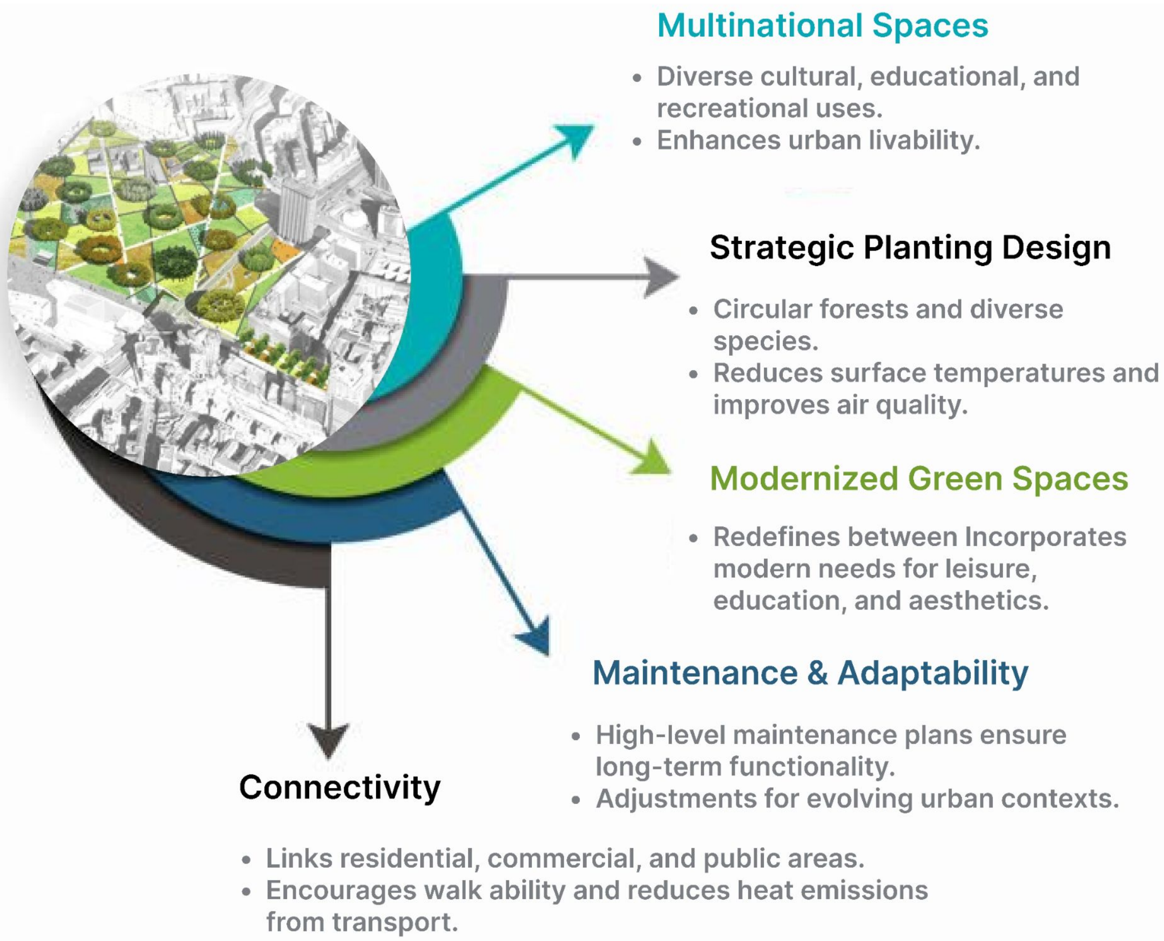


Lesson Learned

Parco Biblioteca degli Alberi

The Library of Trees Park demonstrates the importance of multifunctional urban green spaces in addressing ecological and social challenges. It combines social, cultural, educational, and commercial factors to produce a synergy between urban connectivity, improvement of biodiversity, and community involvement. The planting design of the park reduces urban heat island effects by including circular forests with a range of species and foliage roofs acting as natural coolers. The park's design also emphasizes connectivity as a climate strategy by linking public, commercial, residential, and governmental areas, therefore reducing dependency on vehicle transportation and supporting sustainable mobility.The park's design also emphasizes connectivity as a climate strategy, linking residential, commercial, governmental, and public spaces, reducing dependence on vehicular transport and encouraging sustainable mobility. High-level maintenance and adaptive management are essential for the longevity and relevance of urban green space projects. The park also demonstrates the potential of adapting traditional green spaces to contemporary urban needs, demonstrating the importance of innovative thinking in designing urban parks.

Figure 58: Summary of the lesson learned from Parco Biblioteca degli Alberi project. Source: Personal elaboration.



Vertical Forest Milan

The Vertical Forest is a groundbreaking urban design that incorporates biodiversity into urban structures, demonstrating how vertical spaces can compensate for the limited availability of horizontal green spaces. The project demonstrates how urban planning can benefit from vertical greening to optimize land use and improve biodiversity in dense urban settings. It also effectively mitigates the Urban Heat Island effect by creating a microclimate that lowers temperatures around the building, reducing energy consumption and climate mitigation goals. With centralized irrigation systems and the "Flying Gardeners" conceptual for plant care, the project also highlights the need of sustainable water and maintenance systems. The Vertical Forest also offers aesthetic and social benefits, fostering community pride and global recognition. It serves as a replicable prototype for urban planners, emphasizing adaptability in design and maintenance.

Figure 59: Summary of the lesson learned from Vertical Forest Milan project. Source: Personal elaboration.

The Milan Innovation District

The Milan Innovation District (MIND) aims to achieve a fully decarbonized energy grid, surpassing energy performance standards, and reducing embodied carbon in construction and it focuses on three main objectives: health and well-being, sustainability and connectivity and mobility. It aims to promote healthier lifestyles for residents and workers by prioritizing public spaces for leisure, recreation, and outdoor work. The project also

MIND's approach to mitigating Urban Heat Island (UHI) involves large green and blue spaces, reducing hardscapes, using energy-efficient and sustainable buildings, integrating green infrastructure into the design, and focusing on non-motorized transport and reduced vehicular traffic.

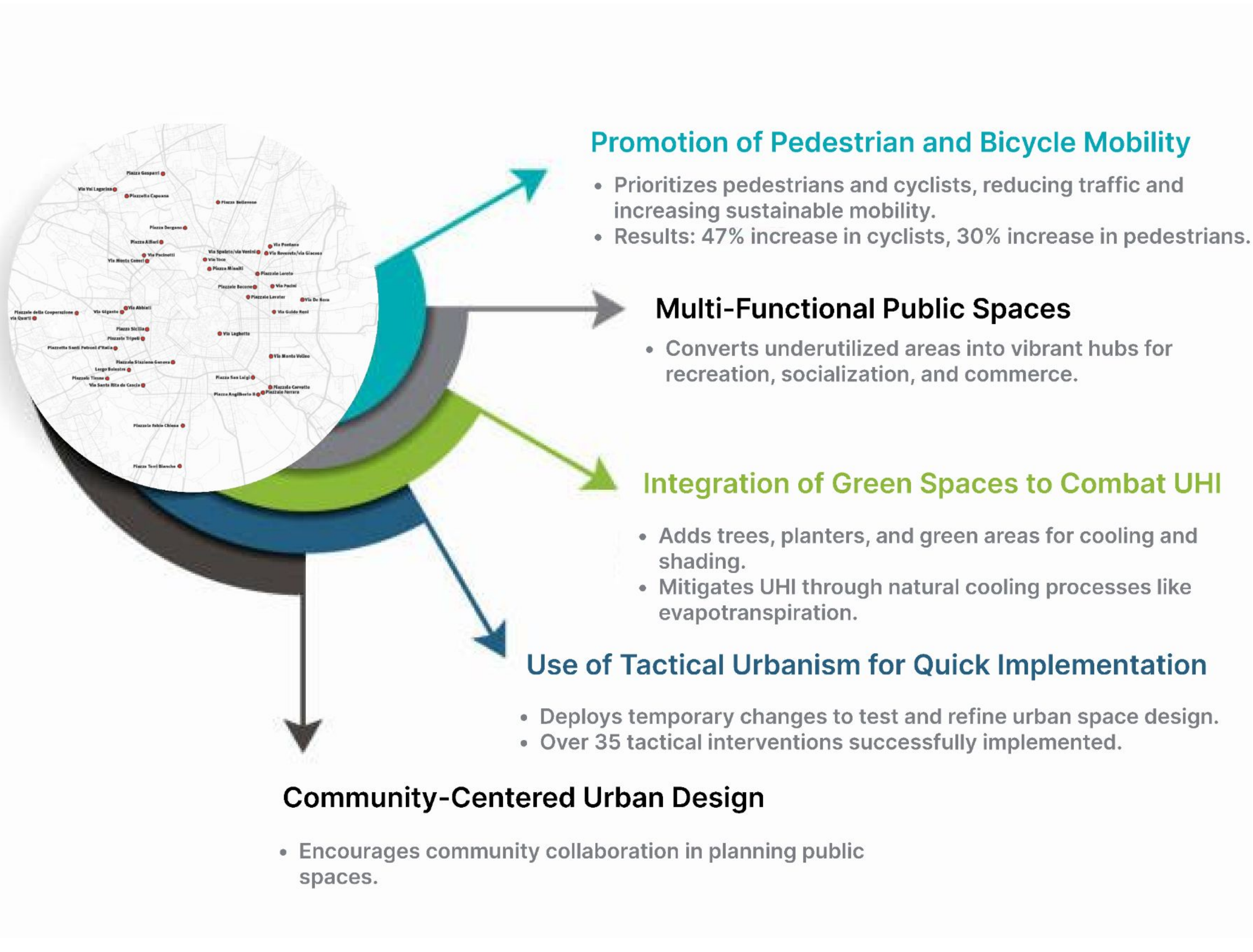
The MIND project offers valuable lessons for urban planning, such as integrating green and blue spaces, sustainable building practices, car-free urban design, and climate resilience. By incorporating sustainability, green infrastructure, and reducing reliance on motorized transport, the MIND project offers valuable lessons in combating UHI and enhancing the quality of life for urban dwellers.

Figure 60: Summary of the lesson learned from Vertical Forest Milan project. Source: Personal elaboration.

The Piazze Aperte Program

The Piazze Aperte Program in Milan has significantly advanced pedestrian and bicycle mobility through the remodeling of public squares and roadways. This has resulted in a substantial rise in pedestrian and bike activity, with a 47% increase in cyclists and a 30% increase in pedestrians. The program additionally incorporated green spaces to mitigate the urban heat island (UHI) effect, offering natural cooling and shade. This, when combined with evapotranspiration, can lower temperatures and enhance air quality. The Open Squares initiative engaged local communities in urban planning to develop public spaces that address social and cultural requirements. Tactical urbanism tactics, including temporary interventions, have been effectively executed, facilitating rapid transformation and evaluation of public places. Multi-functional public spaces, designed to address many community requirements, have been established, enhancing the value of areas and fostering social interaction. These initiatives have fostered a more sustainable and dynamic urban environment.

Figure 61: Summary of the lesson learned from Piazze Aperte Program project. Source: Personal elaboration.



PART III

Conclusion

CHAPTER 10

Comparative Analysis

Urban Heat Island Mitigation actions and SDGs Alignment

Rising urbanism and climate change made the consequences of urban heat islands a worldwide issue. Therefore, sustainable design techniques, nature-based solutions and integrated urban planning are absolutely essential for mitigating these effects. This chapter reviews the climate actions implemented in seven European cities to mitigate the impacts of urban heat island, emphasizing their alignment with the UN Sustainable Development Goals, as well.

It also provides case studies that outline particular actions to mitigate Urban Heat Island effects, categorized into nature-based solutions, urban design innovations, and community-driven initiatives. Every action supports relevant Sustainable Development Goals to underline its overall contribution to sustainable urban development. This systematic method clarifies the function of each activity in alleviating UHI impacts while supporting global sustainability objectives.

Furthermore, the research examines urban heat reduction measures in seven case studies. Essential measures encompass nature-based solutions such as afforestation, circular forestry practices, vertical forest and the establishment of green corridors, which mitigate urban heat and promote biodiversity. Urban design strategies such as reflecting surfaces and shade structures can diminish heat absorption and enhance pedestrian comfort. Community-engaged revitalization initiatives and multifunctional public areas promote social interaction and mitigate urban heat issues. These initiatives correspond with the Sustainable Development Goals (SDGs) and tackle urban resilience, environmental sustainability, and social fairness. A streamlined table summarizes essential efforts across seven cities, emphasizing the interrelatedness of these practices, which frequently produce co-benefits such as enhanced air quality, better water management, and increased community resilience.

According to this analysis, UHI reduction measures are widely adopted owing to their efficacy and adaptability. Tree planting is the most widely adopted strategy, targeting shading, evapotranspiration, and carbon sequestration, while improving air quality and biodiversity. Cities such as Vienna, Paris, Madrid, Athens, Lisbon, and Milan exemplify its adaptability in reducing urban heat islands and promoting resilience. Other strategies encompass converting agricultural land into parks, enhancing streets with greenery, and employing permeable pavements. These measures highlight nature-based solutions and sustainable urban development.

The concept of this chapter is provided in table form which is presented in the following pages. And it is also important to note that due to lack of project documentation for Berlin, in current analysis, no analysis is provided for this case study.

City	Main Urban Heat Mitigation Actions	Category	Impact on UH Resilient	SDGs Addressed
Vienna	Establishment of Open Space Networks (e.g., linking urban areas to surrounding regions)	Urban Planning & Nature Based Solutions	Improved urban airflow, enhanced recreational value, boosted biodiversity, and reduction of meso- and microclimates.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
		Nature Based Solutions	Expansion of open green spaces, Water absorption improvement, delaying surface water discharge to enhance climate-resilient.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Implementation of reflective & permeable surfaces	Urban design	Reduction of heat absorption, increased evaporation cooling, pedestrian comfort enhancing.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Greening streets and Façade	Urban design	Reducing temperatures in the atmosphere, providing more shading, enhanced building thermal efficiency, and increasing socio-spatial aesthetics.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Tree Planting (urban streets, parks, courtyards)	Nature Based Solutions	Decreased temperature via evaporative cooling, enhanced air quality, improved biodiversity, and strengthened urban resilience.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Expansion of forested areas and sustainable forest management	Nature Based Solutions	Heatwaves reduction, moisture preservation, biodiversity enhancement, establishment of recreational area.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Application of Sponge City principles for rainwater management	Nature Based Solution, urban design	Enhanced rainwater infiltration, extended tree lifespan, diminished urban flooding, and controlled heat absorption.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION

City	Main Urban Heat Mitigation Actions	Category	Impact on UH Resilient	SDGs Addressed
Vienna	Re-naturalization of rural green infrastructures and offshore areas	Nature Based Solution, urban design	Improved fresh air corridors, ecosystem services, and urban climatic equilibrium while maintaining biotope networks.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Vienna Nature Conservation Act and Building Code enforcement	Policy & nature conservation	Conservation of agricultural and green areas, enhanced protecting of biodiversity, and sustainable land-use practices.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
Paris	Development of School yard's Oasis project	Urban design, education and nature based solutions	Conversion of asphalt areas into verdant, open spaces that encourage social interaction, provide cooling effects, and facilitate environmental education.	4 QUALITY EDUCATION; 11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Tree planting	Nature Based Solution, urban design	Increased shade, cooling via evapotranspiration, enhanced air quality, and biodiversity improvement.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Establishment of new water areas	Nature Based Solutions	Cooling enhancement via evaporation, adding more recreational spaces, micro-climate regulation improvement.	6 CLEAN WATER AND SANITATION; 11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Implementation of rooftop gardens and green walls	Urban design and nature based solutions	Cooling enhancement via evaporation, adding more recreational spaces, micro-climate regulation improvement.	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Soil unsealing	Urban design and nature based solutions	Improved water infiltration, less surface runoff, better soil quality, and elevated evapotranspiration cooling.	6 CLEAN WATER AND SANITATION; 11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Integrating of greenery with grey infrastructure	Urban design and nature based solutions	Decreased heat retention, improved air quality, and enhancement of urban biodiversity.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION

City	Main Urban Heat Mitigation Actions	Category	Impact on UH Resilient	SDGs Addressed
Madrid	Replacement of impermeable surfaces with vegetated areas	Urban design and nature based solutions	Heat absorption reduction, natural cooling enhancement through vegetation, and flood resilient improvement.	11 Sustainable Cities and Communities; 15 Life on Land; 13 Climate Action
	Construction of water-permeable surfaces	Urban design	Enhanced water infiltration, reduced surface runoff, and diminished heat retention.	6 Clean Water and Sanitation; 11 Sustainable Cities and Communities; 13 Climate Action
	Planting trees and shaded pedestrians	Nature Based Solutions	Improved shading, cooling through evapotranspiration, and optimized pedestrian comfort during heatwaves.	11 Sustainable Cities and Communities; 15 Life on Land
	Utilization of reflective construction materials	Urban design	Decreased heat absorption and cooling of urban surfaces, reducing urban heat island impacts.	11 Sustainable Cities and Communities; 9 Industry, Innovation and Infrastructure
	Río Project: park creation	Nature Based Solution and Community Engagement	Improved connectivity between northern and southern natural regions, urban cooling, biodiversity, and recreational spaces.	11 Sustainable Cities and Communities; 15 Life on Land; 13 Climate Action
	Restoration of Manzanares River banks	Nature Based Solutions	Enhanced ecological continuity, a boost in biodiversity, and the building of an environmental corridor.	6 Clean Water and Sanitation; 15 Life on Land
	Building of Salón de Pinos	Urban design and nature based solutions	Urban cooling via shaded areas, enhanced air quality, and aesthetic improvement of urban environments.	11 Sustainable Cities and Communities; 15 Life on Land
	Renovation of historical bridges and fostering new spatial relationships with monuments	Urban design and cultural heritage	Merging of historical and cultural components with green spaces to generate an equilibrium urban environment.	11 Sustainable Cities and Communities; 15 Life on Land

City	Main Urban Heat Mitigation Actions	Category	Impact on UH Resilient	SDGs Addressed
Athens	Rethink Athens Project	Holistic Urban Cooling Strategies	Lower temperatures and surfaces, enhanced pedestrian comfort, decreased reliance on air conditioning, and energy conservation via natural components and reflective surfaces.	7 AFFORDABLE AND CLEAN ENERGY; 11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Planting of native species with low resource consumption	Sustainable Landscape Practices	Improved climate resilience, diminished water and energy consumption, and enhanced local biodiversity.	12 RESPONSIBLE CONSUMPTION AND PRODUCTION; 15 LIFE ON LAND
	Creation of artificial trees for bioclimatic activities	Bioclimatic Innovations	Optimized cooling with creative designs that take on natural shading and climate adaptability strategies.	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 13 CLIMATE ACTION
	Preservation of existing trees and addition of new trees	Urban greening	Improvements in shading, cooling, and carbon sequestration, while promoting biodiversity.	15 LIFE ON LAND; 13 CLIMATE ACTION
	Use of sustainable agricultural practices with organic fertilizers and efficient irrigation	Sustainable landscape practices	Enhanced resource efficiency, less water usage, and improved soil quality for maintained urban cooling.	12 RESPONSIBLE CONSUMPTION AND PRODUCTION; 15 LIFE ON LAND
Lisbon	Planting trees and shrubs	Nature Based Solution and green infrastructure	Shade-induced cooling, decreased surface temperatures, and improved air quality.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Biodiversity meadows	Nature Based Solutions	Adaptation to seasonal variations, less irrigation requirements, assistance for pollinators, and enhanced climate resilience.	13 CLIMATE ACTION; 15 LIFE ON LAND
	Reduction of vehicular traffic to promote pedestrian mobility	Urban design	Decreasing anthropocentric heat and air pollution, improving urban cooling and livability.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION

City	Main Urban Heat Mitigation Actions	Category	Impact on UH Resilient	SDGs Addressed
Lisbon	Usage of lighter-colored pavement materials	Urban design	Minimizing heat absorption on surface, lowering overall temperature in cities	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION
	Green corridor	Urban Green Infrastructure	Diminishing carbon footprint, Improving urban cooling, biodiversity, and livability.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
	Expansion of pedestrian spaces	Urban design	Optimized cooling with creative designs that take on natural shading and climate adaptability strategies.	11 SUSTAINABLE CITIES AND COMMUNITIES
	Utilization of sheep for vegetation management through grazing	Nature Based Solutions	Soil preservation, and environmental integration	15 LIFE ON LAND
Milan	Circular forestry and planting design utilizing selected species	Nature Based Solutions	Reduces Urban Heat Island effects via shading and evapotranspiration, while providing ecological and recreational advantages.	15 LIFE ON LAND; 13 CLIMATE ACTION
	Vertical Forest	Innovative Architecture	Maintaining micro-climate, diminishing CO2 levels, and enhancing biodiversity.	11 SUSTAINABLE CITIES AND COMMUNITIES; 15 LIFE ON LAND; 13 CLIMATE ACTION
		Sustainable Water Management	Efficient water utilization for urban greenery improves plant vitality and facilitates natural cooling.	6 CLEAN WATER AND SANITATION; 13 CLIMATE ACTION
	Green Space Reclamation	Urban design	Restores public areas, combines vegetation, diminishes traffic heat emissions, and promotes cooler microclimates.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION

Figure 62: Comparative analysis of UHI mitigation actions across seven case studies. Source: Personal elaboration

Main UHI Mitigation Actions	Vienna	Paris	Madrid	Lisbon	Athens	Milan	Berlin
Tree Planting	✓	✓	✓	✓	✓	✓	n/a
Transformation of agricultural lands into parks	✓	✗	✗	✓	✗	✗	n/a
Circular forestry & planting design	✗	✗	✗	✗	✗	✓	n/a
Building green corridors	✓	✓	✓	✓	✓	✓	n/a
Green streets & Facades	✓	✗	✓	✓	✗	✓	n/a
Utilization of sheep for vegetation management	✗	✗	✗	✓	✗	✗	n/a
Soil unsealing	✗	✓	✓	✗	✗	✗	n/a
Sponge city design principle	✓	✗	✗	✗	✗	✗	n/a
Building water features	✗	✓	✗	✗	✓	✗	n/a
Building permeable surfaces	✗	✓	✓	✓	✗	✗	n/a
Implementation of reflective/lighter-colored surfaces	✗	✗	✗	✓	✓	✗	n/a
Using shading structures	✗	✓	✗	✓	✓	✓	n/a
Expanding pedestrainspaces	✗	✓	✗	✓	✗	✓	n/a
Converting green infrastructure with grey ones	✗	✓	✗	✗	✗	✗	n/a
Vertical forest	✗	✗	✗	✗	✗	✓	n/a
Energy-efficient, low-carbon building practices	✗	✗	✗	✗	✓	✓	n/a
Community-engaged urban Regeneration	✗	✓	✓	✗	✗	✓	n/a
Multi-use public spaces construction	✗	✗	✗	✓	✗	✓	n/a

CHAPTER 11

Recommendations and considerations

SDG-aligned proposals: enhancing Urban Heat Resilience in case studies

In line with specific Sustainable Development Goals and objectives, these recommendations aim to mitigate Urban heat islands by rectifying gaps in green spaces in order to increase urban heat resilience. Another characteristic of these recommendations is scalability which can be used in other cities successfully.

- **Making green network between schools, parks and community areas**

  In order to improve cooling and promote social interaction, the plan suggests creating urban green corridors that connect parks, communal areas, and schools. The benefits which can gain by these corridors are providing constant cooling zones by incorporating vegetation, green walls, and tree-lined streets. This plan also improves air quality, fosters biodiversity and cut back on urban heat islands impacts. Additionally, connecting green spaces guarantees equitable access to cooling zones through the city, as well as mitigating temperature disparity between neighborhoods. Moreover, this proposal align with SDBs 3, 11, and 15.

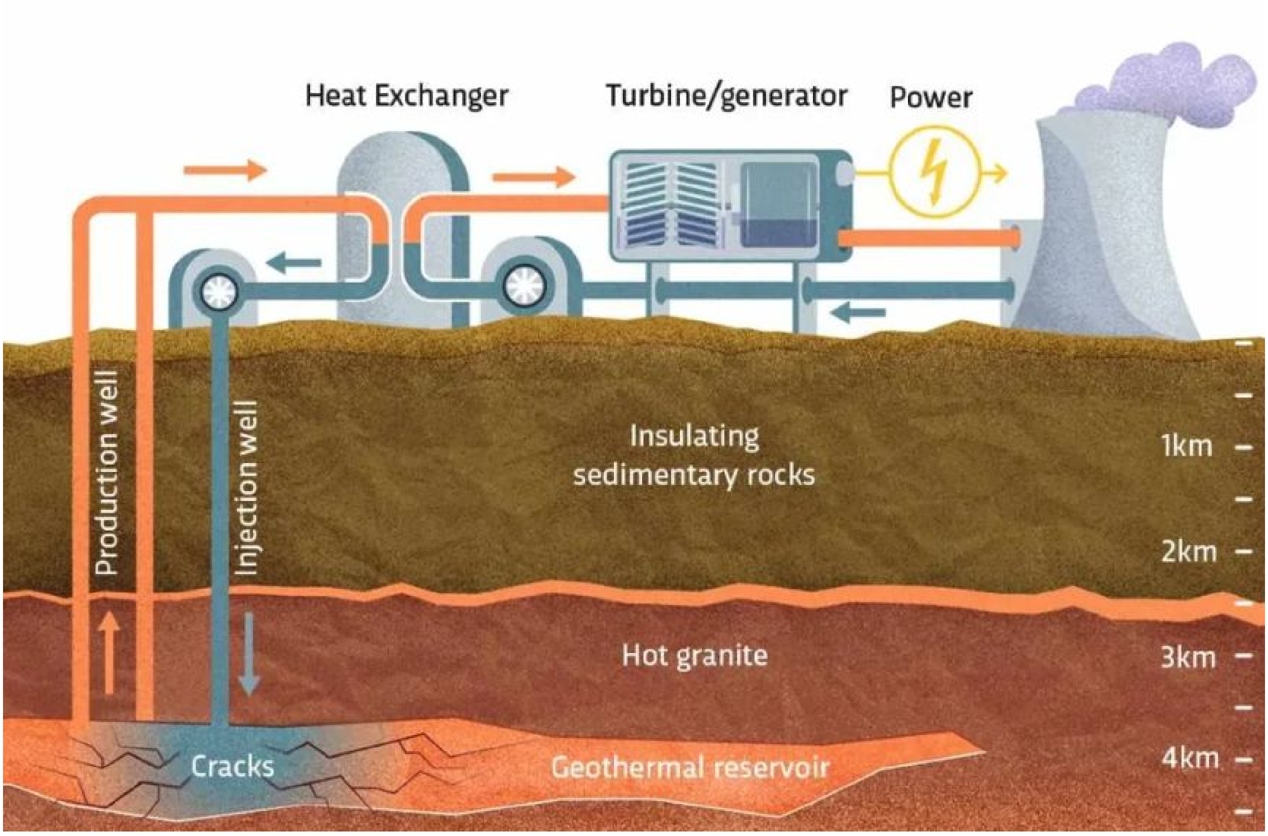
- **Installation of solar powered evaporative cooling system in public areas**

  Installing solar-powered evaporative cooling systems in public spaces like parks, plazas, and green corridors are able to substantially decrease heat due to taking advantage of renewable energy for cooling that reduces the need for energy-intensive air conditioning and lower overall energy consumption, whereas simultaneously reducing the effects of urban heat islands. Moreover, these systems can make use of water features that increase cooling by means of evaporation, which lowers the surrounding temperature and consequently improve comfort. So, the main function of solar-powered evaporative cooler is to enhance cooling during the period of extreme heat events, which bring about decreasing energy consumption and fostering the renewable energy usage. This proposal aligns with SDG 7, SDG 11, and SDG 13.

- **Implementation of Under Ground Thermal System**

  Underground Thermal Storage systems (UTSS) capture and release extra heat during periods of high and low temperatures, offering a sustainable method to mitigate the effects of urban heat islands. Technically, by reducing surface heat retention and energy consumption. They can be integrated to water systems in order to enhance thermal regulation and improve urban resilience. Moreover, UTSS is a carbon-free renewable energy source that contributes to the objectives of carbon peak and carbon neutrality by producing consistent and dependable output. UTSS is also algin with SDG 6, SDG 7, SDG 9, SDG 11, and SDG 13.

Figure 63:Comprehensive analysis of underground thermal storage. Source: (Aurora Li, n.d.).



- **Replacing current pavements to cool pavement structure**

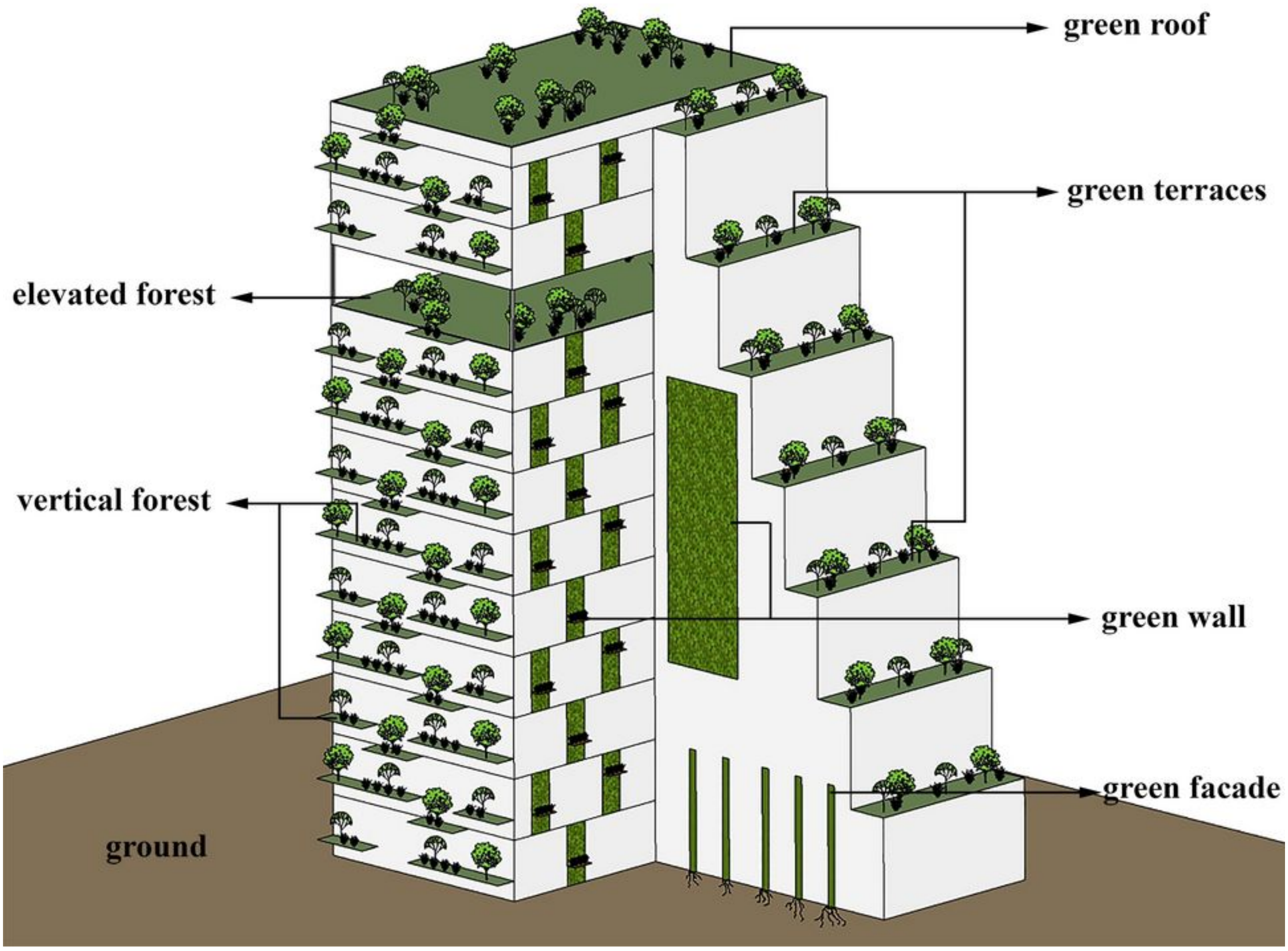
  Using cooling pavements in pedestrian areas and replacing asphalt with materials reflect solar radiation and absorb less heat, it also aligns with SDG 9 and SDG 11, which improves pedestrian comfort.

- **Vertical greenery expansion on high-density built-up area**

  Vertical forests and green façades in areas of high density mitigate surface temperatures, decrease heat absorption, and enhance air quality, in accordance with SDG 11 and SDG 13.

  This proposal is applicable for the case studies like **Vienna** and **Madrid** due to the lack of existing reported project with a similar aim of addressing climate change mitigation and more specifically regarding UHI mitigation.

Figure 64: Concept of vertical greenery design.



- **Building Green roofs and Walls clusters in high density urban areas**
  The proposal encourages for the installation of green roof and wall clusters on existing constructions in densely populated urban regions to enhance vegetation coverage, diminish heat absorption, improve air quality, and establish cooling microclimates, in accordance with SDG 11, SDG 13, and SDG 15.

Figure 65: Green roof and walls in built environment. Source: (Calheiros & Stefanakis, 2021)

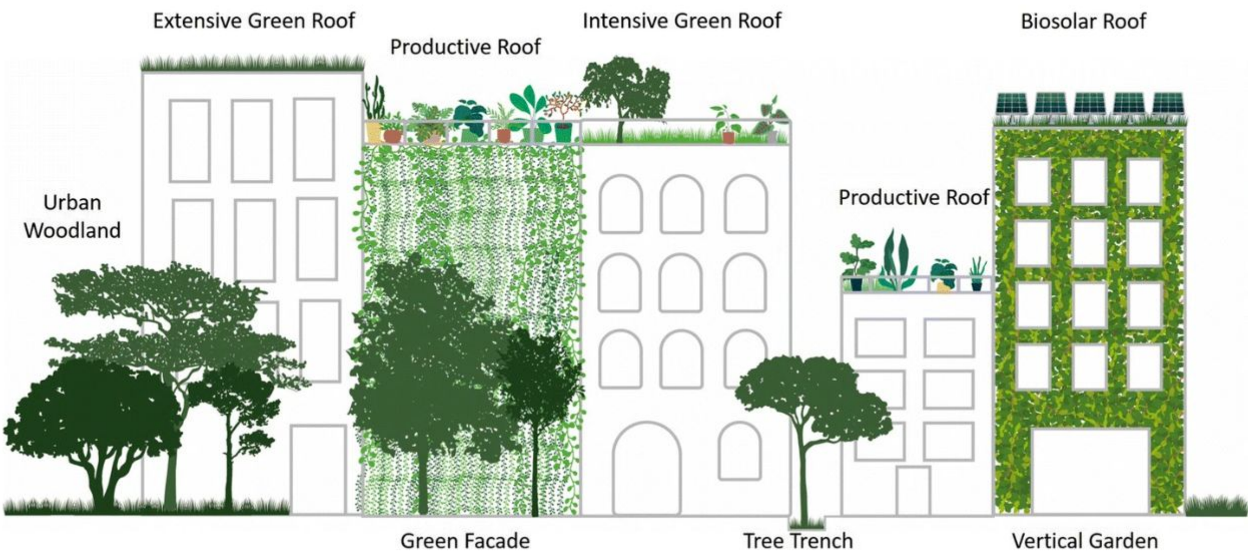
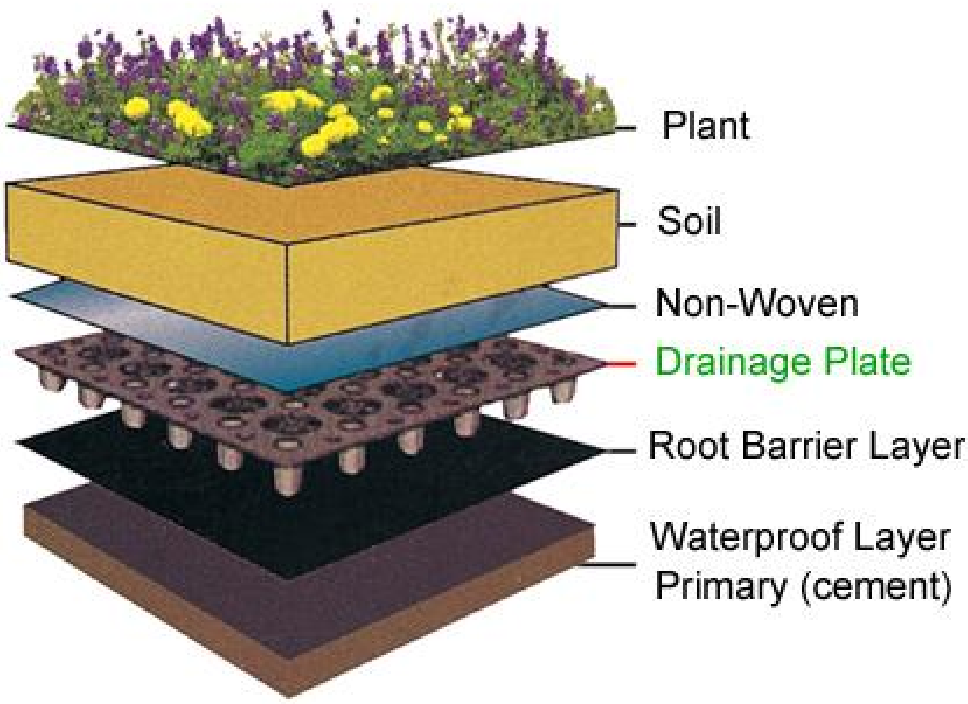
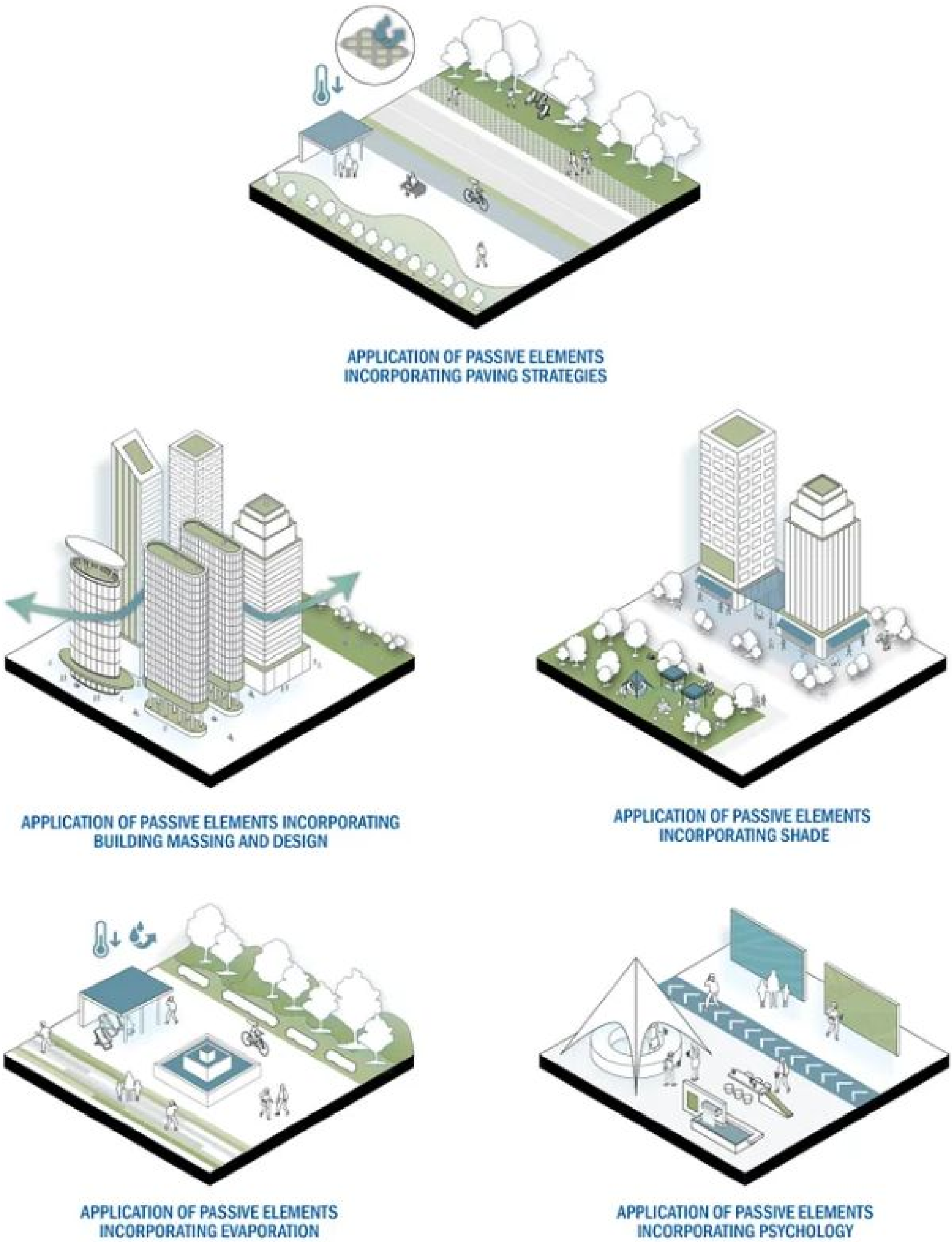


Figure 66: How to construct a green roof. Source: Greening Solutions. 2014



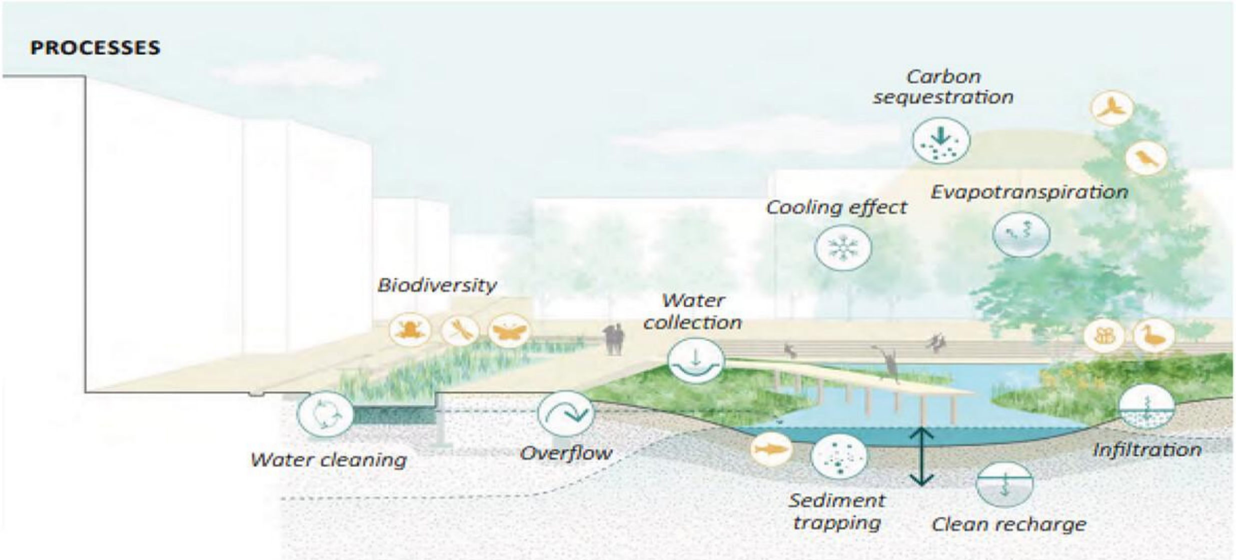
- **Building passive cooling area with community-centric approach**
  creation of cooling zones proposes the creation of shaded public spaces with water features, particularly in areas with inadequate cooling zones, to improve social interaction and reduce heat, aligning with SDG 3 and SDG 11, thereby ensuring equal access to cooling for vulnerable populations.

Figure 67:Passive cooling area design. Source: (Eastman, P., 2020).



- **Establishing artificial urban wetlands in vacant spaces**
  Urban wetlands in underutilized parts of the city transform vacant lots into small-scale wetlands for stormwater management, biodiversity enhancements, in accordance with SDG 6 and SDG 15. They develop natural cooling mechanisms, enhance water retention, and increase habitat diversity.

Figure 68: Benefits from Artificial urban wetlands scheme. source: (Matter & Gado, 2024))



Conclusion

This research thesis studies and examines the Urban Heat Island phenomenon in the context of European cities which is rooted in rapid growing urbanization, with concentrating on a comparative analysis among European cities: Athens, Milan, Berlin, Paris, Lisbon, Madrid and Vienna with respect to their mitigation and adaptation action plans and subsequently the projects that are implemented to cope with this phenomenon. This research presents a comprehensive and analysis of climate action plans, project-level initiatives, and best practices, revealing different strategies in each case study and providing substantial insights to improve urban resilience which can severe the city during heat events. Besides, at the end the relationship between each action and the Sustainable Development Goals in comparative analysis part has been identified, illustrating how each action contributes to achieving one of SDGs. On the whole, all the implemented actions in case studies were align with SDGs 4, 6, 7, 9, 11, 12, 13, and 15.

The research findings have highlighted the necessity of taking advantage of sustainable urban planning strategies to bring down Urban Heat Island impacts. As it has detrimental impacts on environment, like increased temperature, poor air quality, loss of biodiversity and increased water pollution, another deterious effects are related to economic elements like high energy consumption, infrastructure damages, and reduced work productivity. And lastly, social and health impacts. Although the main focus of the present research is on urban planning perspective and city design, it is important to take into consideration that UHI has influences on increasing the risk of illnesses and mortality among vulnerable population. Moreover, from social perspective, it can cause increased cost for energy consumption for residents; that is, low-income communities are likely to struggle with rising expenses. So, it can also strengthen inequality. Besides, some underserved neighborhoods often with less tree cover and insufficient number of green spaces suffer from UHIs impacts.

Cities like Vienna and Paris has shown unique solutions and alternatives that adaptly tackle environmental, social, and spatial challenges. Vienna's wide-ranging green space initiative, which technically encompases biotope networks, air corridors, as well as green transportation infrastructure, illustrate a holistic approach to urban cooling and biodiversity improvement. It is analogous to what Oasis Schoolyard Initiative in Paris has done, highlighting the necessity of adaptable greening approaches which prioritize biodiversity, equity, and community engagement. It also provides easily frameworks which can be used for other urban areas as well.

In Vienna, the "Sponge City" dual infiltration rainwater management model at Lakeside Crescent Quarter in Seestadt is implemented which improves tree conditions and control rainwater runoff, nourishing trees and providing shade that at the end these outcomes alleviate Urban Heat island effects.

In case studies like the Río Project in Madrid and the bioclimatic initiatives in Athens provide good examples of how nature-based solutions may have a transformative impact in urban settings. As a matter of fact the implementation of green infrastructure, creation of ecological corridors, building shaded pedestrians, and utilizing permeable materials in urban design are the key priorities in Madrid and Athens. These cities serve as outstanding instances of the advantages of combining environmental restoration with urban development. Consequently, putting these techniques and designs into practice improves social cohesion and ensures that everyone has equal access to cooling areas.

In Athens, specifically, the main concentration is on connecting green spaces together and incorporating specific native species into urban cooling corridors which these actions bring out the importance of sustainable urban landscapes in reducing urban heat islands as well as supporting and preserving biodiversity.

Innovative projects like MID and vertical forests in Milan were also recognised by the research. The projects render the considerable potential of sustainable architecture design, vertical greening techniques, as well as integration of green and blue infrastructure in reducing Urban Heat Island impacts. Furthermore, these techniques provide flexibility, versatility and community engagement, a guidance for urban microclimates enhancement while they promote mobility and sustainable resilience in the city.

Additionally, Lisbon actions in tactical urbanism and collaborative urban planning emphasizes that how crucial it is to use strategies which give rise to community engagement in planning and building multifunctional public spaces which at the end will meet social, cultural and environmental needs. Hence, sustainable solutions that lisbon generally implemented with the aim of enhancing natural cooling, irrigation reduction, and soil erosion mitigation are tree planting, biodiversity meadows, sheep grazing, and water management.

But regarding, Berlin, although it has achieved remarkable progress in urban greening and research on urban heat island mitigation plans, there is lack of documented ground-level projects which causes obstacle in order to have detailed analysis and find out more on this case study at ground level. This underlines the need and necessity for using proactive approach which is align with Berlin's current action plans .

The present research enhances urban planning by offering an in-depth framework for comprehending and assessing UHI mitigation strategies. By presenting a catalogue of best practices and lessons learned through the projects, it also provides practical insights for cities aiming to reproduce or modify these techniques to their specific settings. The results points out the necessity for context-specific solutions that reconcile environmental sustainability with social and economic imperatives.

To sum up, Urban Heat Island mitigation requires a comprehensive strategies and plans which must contain green infrastructure, innovative urban design, collaborative governance, inclusive planning process, adaptive management and more importantly citizen centric approach that encourage the city residents to engage with plans and benefit from the final design. Plans and projects which can keep up with the rapid pace of urbanization and the exacerbation of climate change to guarantee scalability of urban heat island solutions and sustainability at the end. These insights offer a vital framework for developing cooler, more habitable, and resilient communities globally.

In other words, urban heat resilient planning and city design aimed at creating a sustainable and resilient city against extreme heat events should enhance both quality of the city and at the same time promote social equity at an urban level. European cities that are studied in this research have shown that mitigation actions cut back on urban temperature successfully, improve air quality, public health and more importantly community engagement. This research provides a comprehensive framework for building more resilient, cool and livable community which can be applied in different cities to tackle with UHI effects.

Finally, Future studies should focus on long-term UHI mitigation outcomes, examining synergies between climate action strategies and urban sustainability goals, and highlighting the need for customized plans.

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